

ASP.NET Core 3 and Angular 9

Third Edition

Full stack web development with .NET Core 3.1 and Angular 9



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Valerio De Sanctis

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and Angular 9

Valerio De Sanctis



BIRMINGHAM - MUMBAI

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Preface

ASP.NET Core is a free and open source modular web framework developed by Microsoft that runs on top of the full .NET Framework (Windows) or .NET Core (cross-platform). It has been made specifically for building efficient HTTP services that can be reached and consumed by a massive range of clients, including web browsers, mobile devices, smart TVs, web-based home automation tools, and more.

Angular is the successor of AngularJS, a world-renowned development framework born with the aim of providing the coder with the toolbox that is needed to build reactive and cross-platform web-based apps that are optimized for desktop and mobile. It features a structure-rich template approach based upon a natural, easy-to-write, and readable syntax.

Technically, these two frameworks have little or nothing in common: ASP.NET Core is mostly focused on the **server-side** part of the web development stack, while Angular is dedicated to covering all the **client-side** aspects of web applications, such as the **User Interface (UI)** and **User Experience (UX)**. However, both of them came into being because of a common vision shared by their respective creators: *the HTTP protocol is not limited to serving web pages; it can also be used as a viable platform upon which to build web-based APIs to effectively send and receive data*. This is the notion that slowly made its way through the first 20 years of the World Wide Web's life and is now an undeniable, widely acknowledged statement and also a fundamental pillar of almost every modern web development approach.

As for the reasons behind this perspective switch, there are plenty of good ones, the most important of them being related to the intrinsic characteristics of the HTTP protocol: it's rather simple to use, and flexible enough to match most of the development needs of the ever-changing environment that the World Wide Web happens to be in. This is not to mention how universal it has become nowadays: almost any platform that we can think of has an HTTP library, so HTTP services can reach a broad range of clients, including desktop and mobile browsers, IoT devices, desktop applications, video games, and so on.

The main purpose of this book is to bring together the latest versions of ASP.NET Core and Angular within a single development stack to demonstrate how they can be used to create high-performance web applications and services that can be used seamlessly by any clients.

Who this book is for

This book is for experienced ASP.NET developers who already know about ASP.NET Core and Angular and are looking to learn more about them and understand how to use them together to create a production-ready **Single-Page Application (SPA)** or **Progressive Web Application (PWA)**. However, the fully documented code samples (also available on GitHub) and the step-by-step implementation tutorials make this book easy to understand even for beginners and developers who are just getting started.

What this book covers

Chapter 1, *Getting Ready*, introduces some of the basic concepts of the frameworks that we are going to use throughout the book, as well as the various kinds of web applications that can be created (SPAs, PWAs, native web apps, and more).

Chapter 2, *Looking Around*, is a detailed overview of the various back-end and front-end elements provided by the .NET Core and Angular template shipped with Visual Studio 2019, backed up with some high-level explanations about how they can work together in a typical HTTP request-response cycle.

Chapter 3, *Front-end and Back-end Interactions*, provides a comprehensive tutorial for building a sample ASP.NET Core and Angular app that provides diagnostic info to the end user by querying health check middleware using a Bootstrap-based Angular client.

Chapter 4, *Data Model with Entity Framework Core*, constitutes a journey through Entity Framework Core and its capabilities as an **Object-Relational Mapping (ORM)** framework, from SQL database deployment (cloud-based and/or local instance) to data model design, including various techniques to read and write data from back-end controllers.

Chapter 5, *Fetching and Displaying Data*, covers how to expose Entity Framework Core data using the ASP.NET Core back-end web API, consume that data with Angular, and then show it to end users using the front-end UI.

Chapter 6, *Forms and Data Validation*, details how to implement the HTTP PUT and POST methods in back-end web APIs in order to perform insert and update operations with Angular, along with server-side and client-side data validation.

Chapter 7, *Code Tweaks and Data Services*, explores some useful refactoring and improvements to strengthen your app's source code and includes an in-depth analysis of Angular's data services to understand why and how to use them.

Chapter 8, *Back-end and Front-end Debugging* looks at how to properly debug the back-end and front-end stacks of a typical web application using the various debugging tools provided by Visual Studio to their full extent.

Chapter 9, *ASP.NET Core and Angular Unit Testing*, comprises a detailed review of the **Test-Driven Development (TDD)** and **Behavior-Driven Development (BDD)** development practices and goes into how to define, implement, and perform back-end and front-end unit tests using xUnit, Jasmine, and Karma.

Chapter 10, *Authentication and Authorization*, gives you a high-level introduction to the concepts of authentication and authorization and presents a narrow lineup of some of the various techniques, methodologies, and approaches to properly implementing proprietary or third-party user identity systems. A practical example of a working ASP.NET Core and Angular authentication mechanism based upon ASP.NET Identity and IdentityServer4 is included.

Chapter 11, *Progressive Web Apps*, delves into how to convert an existing SPA into a PWA using service workers, manifest files, and offline caching features.

Chapter 12, *Windows and Linux Deployment*, teaches you how to deploy the ASP.NET and Angular apps created in the previous chapters and publish them in a cloud-based environment using either a Windows Server 2019 or Linux CentOS virtual machine.

To get the most out of this book

These are the software packages (and relevant version numbers) used to write this book and test the source code:

- Visual Studio 2019 Community Edition 16.4.3
- Microsoft .NET Core SDK 3.1.1
- TypeScript 3.7.5
- NuGet Package Manager 5.1.0
- Node.js 13.7.0 (we strongly suggest installing it using the **Node Version Manager**, also known as NVM)
- Angular 9.0.0 final

For deployment on **Windows**:

- ASP.NET Core 3.1 Runtime for Linux (YUM package manager)
- .NET Core 3.1 CLR for Linux (YUM package manager)
- Nginx HTTP Server (YUM package manager)

For deployment on **Linux**:

- ASP.NET Core 3.1 Runtime for Linux (YUM package manager)
- .NET Core 3.1 CLR for Linux (YUM package manager)
- Nginx HTTP Server (YUM package manager)



If you're on Windows, I strongly suggest installing Node.js using NVM for Windows—a neat Node.js version manager for the Windows system. You can download it from the following URL:

<https://github.com/coreybutler/nvm-windows/releases>.

We strongly suggest using the same version used within this book—or newer, but at your own risk! Jokes aside, if you prefer to use a different version, that's perfectly fine, as long as you are aware that, in that case, *you may need to make some manual changes and adjustments to the source code*.

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Once the file is downloaded, please make sure that you unzip or extract the folder using the latest version of:

- WinRAR/7-Zip for Windows
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The code bundle for the book is also hosted on GitHub at <https://github.com/PacktPublishing/ASP.NET-Core-3-and-Angular-9-Third-Edition>. In case there's an update to the code, it will be updated on the existing GitHub repository.

We also have other code bundles from our rich catalog of books and videos available at <https://github.com/PacktPublishing/>. Check them out!

Download the color images

We also provide a PDF file that has color images of the screenshots/diagrams used in this book. You can download it here: https://static.packt-cdn.com/downloads/9781789612165_ColorImages.pdf.

Conventions used

There are a number of text conventions used throughout this book.

CodeInText: Indicates code words in the text, database table names, folder names, filenames, file extensions, pathnames, dummy URLs, user input, and Twitter handles. Here is an example: "Navigate to the /ClientApp/src/app/cities folder."

A block of code is set as follows:

```
<mat-form-field [hidden]="!cities">
  <input matInput (keyup)="loadData($event.target.value)"
        placeholder="Filter by name (or part of it)...">
</mat-form-field>
```

When we wish to draw your attention to a particular part of a code block, the relevant lines or items are set in bold:

```
import { FormGroup, FormControl } from '@angular/forms';

class ModelFormComponent implements OnInit {
  form: FormGroup;

  ngOnInit() {
    this.form = new FormGroup({
      title: new FormControl()
    });
  }
}
```

Any command-line input or output is written as follows:

```
> dotnet new angular -o HealthCheck
```

Bold: Indicates a new term, an important word, or words that you see onscreen. For example, words in menus or dialog boxes appear in the text like this. Here is an example: "A simple **Add a new City** button will fix both these issues at once."

Warnings or important notes appear like this.



Tips and tricks appear like this.



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1

Getting Ready

In this chapter, we'll build the basics of our ASP.NET and Angular journey by mixing a theoretical coverage of their most relevant features and using a more practical approach. More specifically, in the upcoming part of this chapter, we'll briefly review the recent history of ASP.NET Core and Angular frameworks, while in the latter part, we'll learn how to configure our local development environment so we can assemble, build, and test a sample web application boilerplate.

By the end of this chapter, you'll have gained knowledge of the path taken by ASP.NET Core and Angular to improve web development in the last few years, and learned how to properly set up an ASP.NET and Angular web application.

Here are the main topics that we are going to cover:

- **The ASP.NET Core revolution:** A brief history of ASP.NET Core and Angular's most recent achievements.
- **A full-stack approach:** The importance of being able to learn how to design, assemble, and deliver a complete product.
- **Single-Page Applications (SPAs), Native Web Applications (NWAs), and Progressive Web Applications (PWAs):** Key features and the most important differences between the various types of web applications, as well as how well ASP.NET Core and Angular could relate to each one of them.
- **A sample SPA project:** What we're going to do throughout this book.
- **Preparing the workspace:** How to set up our workstation to achieve our first goal – implementing a simple Hello World boilerplate that will be further extended within the following chapters.

Technical requirements

These are the software packages (and relevant version numbers) used to write this book and test the source code:

- Visual Studio 2019 Community Edition 16.4.3
- Microsoft .NET Core SDK 3.1.1
- TypeScript 3.7.5
- NuGet Package Manager 5.1.0
- Node.js 13.7.0 (we strongly suggest installing it using the **Node Version Manager**, also known as **NVM**)
- Angular 9.0.0 final



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<https://github.com/coreybutler/nvm-windows/releases>.

We strongly suggest using the same version used within this book—or newer, but at your own risk! Jokes aside, if you prefer to use a different version, that's perfectly fine, as long as you are aware that, in that case, *you may need to make some manual changes and adjustments to the source code*.

Two players, one goal

From the perspective of a fully functional web-based application, we can say that the Web API interface provided with the ASP.NET Core framework is a programmatic set of server-side handlers used by the server to expose a number of hooks and/or endpoints to a defined request-response message system. This is typically expressed in structured markup languages (XML), language-independent data formats (JSON), or query languages for APIs (GraphQL). As we've already said, this is achieved by exposing **application programming interfaces (APIs)** through HTTP and/or HTTPS protocols via a publicly available web server such as IIS, Node.js, Apache, Nginx, and so on.

Similarly, Angular can be described as a modern, feature-rich, client-side framework that pushes the HTML and ECMAScript's most advanced features, along with the modern browser's capabilities, to their full extent by binding the input and/or output parts of an HTML web page into a flexible, reusable and easily testable model.

Can we combine the *back-end* strengths of ASP.NET Core and the *front-end* capabilities of Angular in order to build a modern, feature-rich, and highly versatile web application?

The answer, in short, is yes. In the following chapters, we'll see how we can do that by analyzing all the fundamental aspects of a well-written, properly designed, web-based product, and how the latest versions of ASP.NET Core and/or Angular can be used to handle each one of them. However, before doing all that, it can be very useful to backtrack a bit and spend some valuable time recollecting what's happened in the last 3 years in the development history of the two frameworks we're going to use. It will be very useful to understand the main reasons why we're still giving them full credit, despite the valuable efforts of their ever-growing competitors.

The ASP.NET Core revolution

To summarize what happened in the ASP.NET world within the last 4 years is not an easy task; in short, we can say that we've undoubtedly witnessed the most important series of changes in .NET Framework since the year it came to life. This was a revolution that changed the whole Microsoft approach to software development in almost every way. To properly understand what happened through these years, it can be useful to identify some distinctive key frames within a slow, yet constant, journey that allowed a company known (and somewhat loathed) for its proprietary software, licenses, and patents to become a driving force for open source development worldwide.

The first relevant step, at least in my humble opinion, was taken on April 3, 2014 at the annual Microsoft Build Conference, which took place at the Moscone Center (West) in San Francisco. It was there, during a memorable keynote speech, that Anders Hejlsberg – father of Delphi and lead architect of C# – publicly released the first version of the .NET Compiler Platform, known as Roslyn, as an open source project. It was also there that Scott Guthrie, executive vice president of the Microsoft Cloud and AI group, announced the official launch of the .NET Foundation, a non-profit organization aimed at improving open source software development and collaborative work within the .NET ecosystem.

From that pivotal day, the .NET development team published a constant flow of Microsoft open source projects on the GitHub platform, including: Entity Framework Core (May 2014), TypeScript (October 2014), .NET Core (October 2014), CoreFX (November 2014), CoreCLR and RyuJIT (January 2015), MSBuild (March 2015), .NET Core CLI (October 2015), Visual Studio Code (November 2015), .NET Standard (September 2016), and so on.

ASP.NET Core 1.x

The most important achievement brought by these efforts towards open source development was the public release of ASP.NET Core 1.0, which came out in Q3 2016. It was a complete reimplementations of the ASP.NET Framework that we knew since January 2002 and that had evolved, without significant changes in its core architecture, up to version 4.6.2 (August 2016). The brand new framework united all the previous web application technologies, such as MVC, Web API, and web pages, into a single programming module, formerly known as MVC6. The new framework introduced a fully featured, cross-platform Component, also known as .NET Core, shipped with the whole set of open source tools mentioned previously, namely, a compiler platform (Roslyn), a cross-platform runtime (CoreCLR), and an improved x64 Just-In-Time compiler (RyuJIT).

Some of you may be wondering what happened to ASP.NET 5 and Web API 2, as these used to be quite popular names until mid-2016.

ASP.NET 5 was no less than the original name of ASP.NET Core before the developers chose to rename it to emphasize the fact that it is a complete rewrite. The reasons for that, along with the Microsoft vision about the new product, are further explained in the following Scott Hanselman blog post that anticipated the changes on Jan 16, 2016:

<http://www.hanselman.com/blog/ASPNET5IsDeadIntroducingASPNETCore10AndNETCore10.aspx>.



For those who don't know, Scott Hanselman is the outreach and community manager for .NET/ASP.NET/IIS/Azure and Visual Studio since 2007. Additional information regarding the perspective switch is also available in the following article by Jeffrey T. Fritz, program manager for Microsoft and a NuGet team leader:
<https://blogs.msdn.microsoft.com/webdev/2016/02/01/an-update-on-asp-net-core-and-net-core/>.



As for Web API 2, it was a dedicated framework for building HTTP services that returned pure JSON or XML data instead of web pages. Initially born as an alternative to the MVC platform, it has been merged with the latter into the new, general-purpose web application framework known as MVC6, which is now shipped as a separate module of ASP.NET Core.

The 1.0 final release was shortly followed by ASP.NET Core 1.1 (Q4 2016), which brought some new features and performance enhancements, and also addressed many bugs and compatibility issues affecting the earlier release. These new features include the ability to configure middleware as filters (by adding them to the MVC pipeline rather than the HTTP request pipeline), a built-in, host-independent URL rewrite module, made available through the dedicated `Microsoft.AspNetCore.Rewrite` NuGet package, View Components as tag helpers, View compilation at runtime instead of on demand, .NET native Compression and Caching middleware modules, and so on.

For a detailed list of all the new features, improvements, and bug fixes of ASP.NET Core 1.1, check out the following links:



Release notes: <https://github.com/aspnet/AspNetCore/releases/1.1.0>.

Commits list: <https://github.com/dotnet/core/blob/master/release-notes/1.1/1.1-commits.md>.

ASP.NET Core 2.x

Another major step was taken with ASP.NET Core 2.0, which came out in Q2 2017 as a preview and then in Q3 2017 for the final release. The new version featured a wide number of significant interface improvements, mostly aimed at standardizing the shared APIs among .NET Framework, .NET Core, and .NET Standard to make them backward-compatible with .NET Framework. Thanks to these efforts, moving existing .NET Framework projects to .NET Core and/or .NET Standard became a lot easier than before, giving many traditional developers the chance to try and adapt to the new paradigm without losing their existing know-how.

Again, the major version was shortly followed by an improved and refined one: ASP.NET Core 2.1. This was officially released on May 30, 2018 and introduced a series of additional security and performance improvements, as well as a bunch of new features, including SignalR, an open source library that simplifies adding real-time web functionality to .NET Core apps; Razor class libraries; a significant improvement in Razor SDK that allows developers to build views and pages into reusable class libraries, and/or library projects that could be shipped as NuGet packages; Identity UI library and scaffolding, to add identity to any app and customize it to meet your needs, HTTPS support enabled by default; built-in **General Data Protection Regulation (GDPR)** support using privacy-oriented APIs and templates that give users control over their personal data and cookie consent; updated SPA templates for Angular and ReactJS client-side frameworks; and much more.

For a detailed list of all the new features, improvements, and bug fixes of ASP.NET Core 2.1, check out the following links:



Release notes: <https://docs.microsoft.com/en-US/aspnet/core/release-notes/aspnetcore-2.1>.

Commits list: <https://github.com/dotnet/core/blob/master/release-notes/2.1/2.1.0-commit.md>.

Wait a minute: did we just say Angular? Yeah, that's right. As a matter of fact, since its initial release, ASP.NET Core has been specifically designed to seamlessly integrate with popular client-side frameworks such as ReactJS and Angular. It is precisely for this reason that books such as this do actually exist. The major difference introduced in ASP.NET Core 2.1 is that the default Angular and ReactJS templates have been updated to use the standard project structures and build systems for each framework (Angular CLI and NPX's `create-react-app` command) instead of relying on task runners such as Grunt or Gulp, module builders such as webpack, or toolchains such as Babel, which were widely used in the past although were quite difficult to install and configure.



Being able to eliminate the need for these tools was a major achievement, which played a decisive role in revamping the .NET Core usage and growth rate among the developer communities since 2017. If you take a look at the two previous installments of this book – *ASP.NET Core and Angular 2*, published in mid-2016, and *ASP.NET Core 2 and Angular 5*, out in late 2017 – and compare their first chapter with this one, you will see the huge difference between having to manually use Gulp, Grunt, or webpack and relying on the integrated framework-native tools. This is a substantial reduction in complexity that would greatly benefit any developer, especially those less accustomed to working with those tools.

After 6 months from the release of the 2.1 version, the .NET Foundation came out with a further improvement: ASP.NET Core 2.2 was released on December 4, 2018 with several fixes and new features, such as an improved endpoint routing system for better dispatching of requests, updated templates featuring Bootstrap 4 and Angular 6 support, a new health checks service to monitor the status of deployment environments and their underlying infrastructures, including container orchestration systems such as Kubernetes, built-in HTTP/2 support in Kestrel, a new SignalR Java client to ease the usage of SignalR within Android apps, and so on.

For a detailed list of all the new features, improvements, and bug fixes of ASP.NET Core 2.2, check out the following links:



Release notes: <https://docs.microsoft.com/en-US/aspnet/core/release-notes/aspnetcore-2.2>.

Commits list: <https://github.com/dotnet/core/blob/master/release-notes/2.2/2.2.0/2.2.0-commits.md>.

ASP.NET Core 3.x

ASP.NET Core 3 was released in September 2019 and came with another bunch of performance and security improvements and new features, such as Windows desktop applications support (Windows only) with advanced importing capabilities for Windows Forms and **Windows Presentation Foundation (WPF)** applications, C# 8 support, .NET Platform-Dependent Intrinsic access through a new set of built-in APIs that could bring significant performance improvements in certain scenarios, single-file executables support via the `dotnet publish` command using the `<PublishSingleFile>` XML element in project configuration or through the `/p:PublishSingleFile` command-line parameter, a new built-in JSON support featuring high performance and low allocation that's arguably 2x-3x faster than the JSON.NET third-party library (which became a de facto standard in most ASP.NET web projects), TLS 1.3 and OpenSSL 1.1.1 support in Linux, some important security improvements in the `System.Security.Cryptography` namespace, including AES-GCM and AES-CCM ciphers support, and so on.

A lot of work has also been done to improve the performance and reliability of the framework when used in a containerized environment. The ASP.NET Core development team put a lot of effort into improving the .NET Core Docker experience on .NET Core 3.0. More specifically, this is the first release featuring substantive runtime changes to make CoreCLR more efficient, honor Docker resource limits better (such as memory and CPU) by default, and offer more configuration tweaks. Among the various improvements, we could mention improved memory and GC heap usage by default, and PowerShell Core, a cross-platform version of the famous automation and configuration tool, which is now shipped with the .NET Core SDK Docker container images.

.NET Core Framework 3 also introduced Blazor, a free and open source web framework that enables developers to create web apps using C# and HTML.

Last but not least, it's worth noting that the new .NET Core SDK is much smaller than the previous installments, mostly thanks to the fact that the development team removed a huge set of unnecessary artifacts included in the various NuGet packages that were used to assemble the previous SDKs (including ASP.NET Core 2.2) from the final build, thus wasting a lot of space. The size improvements are huge for Linux and macOS versions, while less noticeable on Windows because that SDK also contains the new WPF and Windows Forms set of platform-specific libraries.

For a detailed list of all the new features, improvements, and bug fixes of ASP.NET Core 3.0, check out the following links:



Release notes: <https://docs.microsoft.com/en-us/dotnet/core/whats-new/dotnet-core-3-0>.

ASP.NET Core 3.0 releases page: <https://github.com/dotnet/core/tree/master/release-notes/3.0>.

ASP.NET Core 3.1, which is the most recent stable version at the time of writing, was released on December 3, 2019. The changes in the latest version are mostly focused on Windows desktop development, with the definitive removal of a number of legacy Windows Forms controls (*DataGrid*, *ToolBar*, *ContextMenu*, *Menu*, *MainMenu*, and *MenuItem*) and added support for creating C++/CLI Components (on Windows only).

Most of the ASP.NET Core updates were fixes related to Blazor, such as preventing default actions for events and stopping event propagation in Blazor apps, partial class support for Razor Components, additional *Tag Helper Component* features, and so on; however, much like the other .1 releases, the primary goal of .NET Core 3.1 was to refine and improve the features already delivered in the previous version, with more than 150 performance and stability issues fixed.



A detailed list of the new features, improvements, and bug fixes introduced with ASP.NET Core 3.1 is available at the following URL:

Release notes: <https://docs.microsoft.com/en-us/dotnet/core/whats-new/dotnet-core-3-1>.

This concludes our journey through the recent history of ASP.NET Core. In the next section, we'll move our focus to the Angular ecosystem, which experienced a rather similar turn of events.

What's new in Angular?

If following in the footsteps of Microsoft and the .NET Foundation in recent years has not been an easy task, things were not going to get any better when we turned our eyes to the client-side web framework known as Angular. In order to understand what happened there, we have to go back 10 years when JavaScript libraries such as jQuery and MooTools were dominating the client-side scenes, the first client-side frameworks such as Dojo, Backbone.js, and Knockout.js were struggling to gain popularity and reach wide adoption, and stuff such as React and Vue.js didn't even exist.



Truth be told, jQuery is still dominating the scene to a huge extent, at least according to Libscore (<http://libscore.com/#libs>) and w3Techs (https://w3techs.com/technologies/overview/javascript_library/all). However, despite being used by 74.1% of all websites, it's definitely a less chosen option for web developers than it was 10 years ago.

GetAngular

The story of AngularJS started in 2009 when Miško Hevery (now senior computer scientist and Agile coach at Google) and Adam Abrons (now director of engineering at Grand Rounds) were working on their side project, an **end-to-end (E2E)** web development tool that would have offered an online JSON storage service and also a client-side library to build web applications depending on it. To publish their project, they took the `GetAngular.com` hostname.

During that time, Hevery, who was already working at Google, was assigned to the Google Feedback project with two other developers. Together, they wrote more than 17,000 lines of code in 6 months, slowly sinking into a frustrating scenario of code bloat and testing issues. Given the situation, Hevery asked his manager to rewrite the application using GetAngular (the side project mentioned previously), betting that he could do that alone within 2 weeks. His manager accepted and Hevery lost the bet shortly thereafter, as the whole thing took him 3 weeks instead of two; however, the new application had only 1,500 lines of code instead of 17,000. This was more than enough to get Google's interest for the new framework, which was given the name of AngularJS shortly thereafter.



To listen to the full story, take a look at the following Miško Hevery keynote speech at ng-conf 2014:

<https://www.youtube.com/watch?v=r1A1VR0ibIQ>.

AngularJS

The first stable release of AngularJS (version 0.9.0, also known as dragon-breath) was released on GitHub in October 2010 under an MIT license; when AngularJS 1.0.0 (also known as temporal domination) came out on June 2012, the framework had already achieved huge popularity within the web development communities worldwide.

The reasons for such extraordinary success can hardly be summarized in a few words, but I'll try to do that nonetheless by emphasizing some fundamental key selling points:

- **Dependency injection:** AngularJS was the first client-side framework to implement it. This was undeniably a huge advantage over the competitors, including DOM-manipulating libraries such as jQuery. With AngularJS, developers could write loosely coupled and easily testable Components, leaving the framework with the task of creating them, resolving their dependencies, and passing them to other Components when requested.
- **Directives:** These can be described as markers on specific DOM items such as elements, attributes, styles, and so on: a powerful feature that could be used to specify custom and reusable HTML-like elements and attributes that define data bindings and/or other specific behaviors of presentation Components.
- **Two-way data binding:** The automatic synchronization of data between model and view Components. When data in a model changes, the view reflects the change; when data in the view changes, the model is updated as well. This happens immediately and automatically, which makes sure that the model and the view are updated at all times.
- **Single-page approach:** AngularJS was the first framework to completely remove the need for page reloads. This provided great benefits at both server-side (fewer and smaller network requests) and client-side level (smoother transitions, more responsive experience), and paved the way for the Single-Page Application pattern that would be also adopted by React, Vue.js, and the other runner-up frameworks later on.

- **Cache-friendly:** All the AngularJS magic was meant to happen on the client-side, without any server-side effort to generate the UI/UX parts. For this very reason, all AngularJS websites could be cached anywhere and/or made available through a CDN.



For a detailed list of AngularJS features, improvements, and bug fixes from 0.9.0 through 1.7.8, check out the following link:

Angularjs 1.x Changelog: <https://github.com/angular/angular.js/blob/master/CHANGELOG.md>.

Angular 2

The new release of AngularJS, released on September 14, 2016 and known as Angular 2, was a complete rewrite of the previous one, entirely based upon the new ECMAScript version 6 (officially ECMAScript 2015) specifications. Just like the ASP.NET Core rewrite, the revolution brought such a number of breaking changes at architectural level, HTTP pipeline handling, app life cycle, and state management that porting the old code to the new one was nearly impossible. Despite keeping its former name, the new Angular version was a brand new framework with little or nothing in common with the previous one.

The choice of not making Angular 2 backward-compatible with AngularJS clearly demonstrated the intention of the author's team to adopt a completely new approach: not only in the code syntax, but also in their way of thinking and designing the client app. The new Angular was highly modular, Component-based, came with a new and improved dependency injection model, and a whole lot of programming patterns its older cousin had never heard of.

Here's a brief list of the most important improvements introduced with Angular 2:

- **Semantic versioning:** Angular 2 is the first release to use semantic versioning, also known as SemVer: a universal way of versioning the various software releases to help developers track down what's going on without having to dig into the changelog details. SemVer is based on three numbers – X.Y.Z – where X stands for a *major* version, Y stands for a *minor* version, and Z stands for a *patch* release. More specifically, the X number, representing the *major* version, gets incremented when incompatible API changes are made to stable APIs, the Y number, representing the *minor* version, gets incremented when backward-compatible functionality is added, and the Z number, representing a *patch* release, gets incremented when a backward-compatible bug is fixed. Such improvements can be easily underestimated, yet it's a must-have for most modern software development scenarios where **Continuous Delivery (CDE)** is paramount and new versions are released with great frequency.
- **TypeScript:** If you're a seasoned web developer, you probably already know what TypeScript is. In case you don't, no worries, you'll get way more on that later on since we're going to use it a lot during the Angular-related chapters of this book. For now, let's just say that TypeScript is a Microsoft-made superset of JavaScript that allows the use of all ES2015 features (such as Default-Rest-Spread Parameters, Template Literals, Arrow Functions, Promises, and more) and adds powerful type-checking and object-oriented features during development (such as class and type declarations). The TypeScript source code can be transpiled into standard JavaScript code that all browsers can understand.
- **Server-side rendering (SSR):** Angular 2 comes with Angular Universal, an open source technology that allows a *back-end* server to run Angular applications and serve only the resulting static HTML files to the client. In a nutshell, the server will render a first pass of the page for faster delivery to the client, then immediately refresh it with client code. SSR has its caveats, such as requiring Node.js to be installed on the host machine to execute the necessary pre-rendering steps, as well as having the whole `node_modules` folder there, but can greatly increase the app's response time for a typical internet browser, thus mitigating a known AngularJS performance issue.
- **Angular Mobile Toolkit (AMT):** A set of tools specifically designed for building high-performance mobile apps.
- **Command-line interface (CLI):** The new CLI introduced with Angular 2 could be used by developers to generate Components, routes, services, and pipes via console/Terminal commands, together with simple test shells.

- **Components.** These are the main building blocks of Angular 2, entirely replacing the Controllers and scopes of AngularJS, and also lifting most of the tasks previously covered by the former directives. Application data, business logic, templating, and the styling of an Angular 2 app can all be made using Components.



I did my best to explore most of these features in my first book, *ASP.NET Core and Angular 2*, which was published in October 2016, right after the final release of the two frameworks:

<https://www.packtpub.com/application-development/aspnet-core-and-angular-2>.

Angular 4

On March 23, 2017, Google released Angular 4: the number 3 version was skipped entirely in order to unify all the major versions of the many Angular Components that had been developed separately until that date, such as Angular Router, which already was at version 3.x at the time. Starting with Angular 4, the entire Angular framework was then unified into the same MAJOR.MINOR.PATCH SemVer pattern.

The new major version brought a limited number of breaking changes, such as a new and improved routing system, TypeScript 2.1+ support (and requirement), and some deprecated interfaces and tags. There was also a good amount of improvements, including:

- **Ahead-of-time (AOT) compilation:** Angular 4 compiles the templates during the build phase and generates JavaScript code accordingly. That's a huge architectural improvement over the JIT mode used by AngularJS and Angular 2 where the app was compiled at runtime. For example, when the application starts, not only is the app faster since the client doesn't have to compile anything, but it throws/breaks at build time instead of during runtime for most Component errors, thus leading to more secure and stable deployments.
- **Animations npm package:** All the existing UI animations and effects – as well as new ones – have been moved to the `@angular/animations` dedicated package instead of being part of `@angular/core`. This was a smart move to give non-animated apps the chance to drop that part of code, thus being much smaller and arguably faster.

Other notable improvements included: a new form validator to check for valid email addresses, a new paramMap interface for URL parameters in the HTTP routing module, better internalization support, and so on.

Angular 5

Released on November 1, 2017, Angular 5 featured TypeScript 2.3 support, another small set of breaking changes, many performance and stability improvements, and a couple of new features, such as the following:

- **New HTTP Client API:** Starting from Angular 4.3, the `@angular/http` module was put aside in favor of a new `@angular/common/http` package with better JSON support, interceptors and immutable request/response objects, and other stuff. The switch was completed in Angular 5 with the previous module being deprecated and the new one recommended for use in all apps.
- **State Transfer API:** A new feature that gives the developer the ability to transfer the state of the application between the server and the client.
- **A new set of router events for more granular control over the HTTP life cycle:** `ActivationStart`, `ActivationEnd`, `ChildActivationStart`, `ChildActivationEnd`, `GuardsCheckStart`, `GuardsCheckEnd`, `ResolveStart` and `ResolveEnd`.

November 2017 was also the release month of my *ASP.NET Core 2 and Angular 5* book, which covers most of the aforementioned improvements:



<https://www.packtpub.com/application-development/aspnet-core-2-and-angular-5>.

In June 2018, that book was made available as a video course:

<https://www.packtpub.com/web-development/asp-net-core-2-and-angular-5-video>.

Angular 6

Released on April 2018, Angular 6 was mostly a maintenance release, more focused on improving the overall consistency of the framework and its toolchain than adding new features. Therefore, there were no major breaking changes. RxJS 6 supports a new way to register providers, the new `providedIn` injectable decorator, improved Angular Material support (a Component specifically made to implement material design in the Angular client-side UI), more CLI commands/updates, and so on.

Another improvement worth mentioning was the new CLI `ng add` command, which uses the package manager to download new dependencies and invoke an installation script to update our project with configuration changes, add additional dependencies, and/or scaffold package-specific initialization code.

Last, but not least, the Angular team introduced Ivy, a next-generation Angular rendering engine that aims to increase the speed and decrease the size of the application.

Angular 7

Angular 7 came out in October 2018 and it definitely was a major update, as we can easily guess by reading the words written by Stephen Fluin, developer relations lead at Google and prominent Angular spokesman, on the official Angular development blog upon the official release:

"This is a major release spanning the entire platform, including the core framework, Angular Material, and the CLI with synchronized major versions. This release contains new features for our toolchain, and has enabled several major partner launches."

Here's a list of the new features:

- **Easy upgrade:** Thanks to the groundwork made with version 6, the Angular team was able to reduce the steps that need to be done to upgrade an existing Angular app from an older version to the most recent one. The detailed procedure can be viewed by visiting <https://update.angular.io>, an incredibly useful Angular upgrade interactive guide that can be used to quickly recover the required steps, such as CLI commands, package updates, and so on. This needs to be done to upgrade an existing Angular app from an older version of Angular to a most recent one.

- **CLI update:** A new command that attempts to automatically upgrade the Angular application and its dependencies by following the procedure mentioned previously.
- **CLI prompts:** The Angular command-line interface has been modified to prompt users when running common commands such as `ng new` or `ng add @angular/material` to help developers discover built-in features such as routing, SCSS support, and so on.
- **Angular Material and CDK:** Additional UI elements such as virtual scrolling, a Component that loads and unloads elements from the DOM based on the visible parts of a list, making it possible to build very fast experiences for users with very large scrollable lists, CDK-native drag-and-drop support, improved drop-down list elements, and more.
- **Partner launches:** Improved compatibility with a number of third-party community projects such as: Angular Console; a downloadable console for starting and running Angular projects on your local machine, `AngularFire`, the official Angular package for Firebase integration, Angular for NativeScript; an integration between Angular and NativeScript – a framework for building native iOS and Android apps using JavaScript and/or JS-based client frameworks, some interesting new Angular-specific features for StackBlitz; an online IDE that can be used to create Angular and React projects, such as a tabbed editor and an integration with the Angular Language Service, and so on.
- **Updated dependencies:** Added support for TypeScript 3.1, RxJS 6.3, and Node 10, although the previous versions can still be used for backward compatibility.



The Angular Language Service is a way to get completions, errors, hints, and navigation inside Angular templates: think about it as a virtuous mix between a syntax highlighter, IntelliSense, and a real-time syntax error checker. Before Angular 7, which added the support for StackBlitz, such a feature was only available for Visual Studio Code and WebStorm.

For additional information about the Angular Language Service, take a look at the following URL:

<https://angular.io/guide/language-service>

Angular 8

Angular 7 was quickly followed by Angular 8, which was released on May 29, 2018. The new release is mostly about Ivy, the long-awaited new compiler/runtime of Angular: although being an ongoing project since Angular 5, version 8 was the first one to officially offer a runtime switch to actually opt-in to using Ivy, which would become the default runtime starting from Angular 9.

In order to enable Ivy on Angular 8, the developers had to add an `"enableIvy": true` property to the `angularCompilerOptions` section within the app's `tsconfig.json` file.



Those who want to know more about Ivy are encouraged to give an extensive look at the following post by Cédric Exbrayat, co-founder and trainer at the Ninja-Squad website and now part of the Angular developer team:

<https://blog.ninja-squad.com/2019/05/07/what-is-angular-ivy/>.

Other notable improvements and new features include:

- **Bazel support:** Angular 8 was the first version to support Bazel, a free software tool developed and used by Google for the automation of building and testing software. It can be very useful for developers aiming to automate their delivery pipeline as it allows incremental build and tests, and even the possibility to configure remote builds (and cache) on a build farm.
- **Routing:** A new syntax was introduced to declare the lazy-loading routes using the `import()` syntax from TypeScript 2.4+ instead of relying on a string literal. The old syntax has been kept for backward compatibility, but will be arguably dropped soon.
- **Service workers:** A new registration strategy has been introduced to allow developers to choose when to register their workers instead of doing it automatically at the end of the app's startup life cycle. It's also possible to bypass a service worker for a specific HTTP request using the new `ngsw-bypass` header.
- **Workspace API:** A new and more convenient way to read and modify the Angular workspace configuration instead of manually modifying the `angular.json` file.



In client-side development, a service worker is a script that the browser runs in the background to do any kind of stuff that doesn't require either a user interface or any user interaction.

The new version also introduced some notable breaking changes – mostly due to Ivy – and removed some long-time deprecated packages such as `@angular/http`, which was replaced by `@angular/common/http` in Angular 4.3 and then officially deprecated in 5.0.



A comprehensive list of all the deprecated APIs can be found in the official Angular deprecations guide at the following URL:

<https://angular.io/guide/deprecations>.

Angular 9

Last, but not least, we come to Angular 9, which was released in February 2020 after a long streak of release candidates through 2019 Q4 and is currently the most recent version.

The new release brings the following new features:

- **JavaScript bundles and performance:** An attempt to fix the very large bundle files, one of the most cumbersome issues of the previous versions of Angular, has drastically increased the download time and brought down the overall performances.
- **Ivy compiler:** The new Angular build and render pipeline, shipped with Angular 8 as an opt-in preview, is now the default rendering engine.
- **Selector-less bindings:** A useful feature that was available to the previous rendering engine, but missing from the Angular 8 Ivy preview, is now available to Ivy as well.
- **Internationalization:** Another Ivy enhancement that makes use of the Angular CLI to generate most of the standard code necessary to create files for translators and to publish an Angular app in multiple languages, thanks to the new `i18n` attribute.



The new `i18n` attribute is a numeronym, which is often used as an alias of internationalization. The number 18 stands for the number of letters between the first i and the last n in the word internationalization. The term seems to have been coined by the **Digital Equipment Corporation (DEC)** around the 1970s or 1980s, together with `l10n` for localization, due to the excessive length of the two words.

The long-awaited Ivy compiler deserves a couple more words, being a very important feature for the future of Angular.

As you most likely already know, the rendering engine plays a major role in the overall performance of any *front-end* framework since it's the tool that translates the actions and intents performed by the presentation logic (in Angular, Components, and templates) into the instructions that will update the DOM. If the renderer is more efficient, it will arguably require less instructions, thus increasing the overall performance while decreasing the amount of required JavaScript code at the same time. Since the JavaScript bundles produced by Ivy are much smaller than the previous rendering engine, Angular 9's overall improvement is relevant in terms of both performance and size.

This concludes our brief review of the recent history of the ASP.NET Core and Angular ecosystems. In the next sections, we'll summarize the most important reasons that led us to actually choosing them in 2020.

Reasons for choosing .NET Core and Angular

As we have seen, both frameworks have gone through three intense years of changes. This led to a whole refoundation of their core and, right after that, a constant strain to get back on top – or at least not lose ground against most modern frameworks that came out after their now departed golden age. They are eager to dominate the development scene: Python, Go, and Rust for the server-side part and React, Vue.js, and Ember.js for the client-side part, not to mention the Node.js and Express ecosystem, and most of the old competitors from the 1990s and 2000s, such as Java, Ruby, and PHP, which are still alive and kicking.

That said, here's a list of good reasons for picking ASP.NET Core in 2019:

- **Performance:** The new .NET Core web stack is considerably fast, especially since version 3.x.
- **Integration:** It supports most, if not all, modern client-side frameworks, including Angular, React, and Vue.js.
- **Cross-platform approach:** .NET Core web applications can run on Windows, macOS, and Linux in an almost seamless way.
- **Hosting:** .NET Core web applications can be hosted almost anywhere: from a Windows machine with IIS to a Linux appliance with Apache or Nginx, from Docker containers to edge-case, self-hosting scenarios using the Kestrel and WebListener HTTP servers.
- **Dependency injection:** The framework supports a built-in dependency injection design pattern that provides a huge number of advantages during development, such as reduced dependencies, code reusability, readability, and testing.
- **Modular HTTP pipeline:** ASP.NET Core middleware grants developers granular control over the HTTP pipeline, which can be reduced to its core (for ultra-lightweight tasks) or enriched with powerful, highly configurable features such as internationalization, third-party authentication/authorization, caching, routing, and so on.
- **Open source:** The whole .NET Core stack has been released as open source and is entirely focused on strong community support, thus being reviewed and improved by thousands of developers every day.
- **Side-by-side execution:** It supports the simultaneous running of multiple versions of an application or Component on the same machine. This basically means that it's possible to have multiple versions of the common language runtime, and multiple versions of applications and Components that use a version of the runtime, on the same computer at the same time. This is great for most real-life development scenarios as it gives the development team more control over which versions of a Component an application binds to, and more control over which version of the runtime an application uses.

As for the Angular framework, the most important reason we're picking it over other excellent JS libraries such as React, Vue.js, and Ember.js is the fact that it already comes with a huge pack of features out of the box, making it the most suitable choice, although maybe not as simple to use as other framework/libraries. If we combine that with the consistency benefits brought by the TypeScript language, we can say that Angular, from its 2016 rebirth up to the present day, embraced the framework approach more convincingly than the others. This has been consistently confirmed over the course of the past 3 years where the project underwent six major versions and gained a lot in terms of stability, performance, and features, without losing much in terms of backward compatibility, best practices, and overall approach. All these reasons are solid enough to invest in it, hoping it will continue to keep up with these compelling premises.

Now that we have acknowledged the reasons to use these frameworks, let's ask ourselves the best way to find out more about them: the next sections should give us the answers we need.

A full-stack approach

Learning to use ASP.NET Core and Angular together would mean being able to work with both the *front-end* (client side) and *back-end* (server side) of a web application; to put it in other words, it means being able to design, assemble, and deliver a complete product.

Eventually, in order to do that, we'll need to dig through the following:

- *Back-end* programming
- *Front-end* programming
- UI styling and UX design
- Database design, modeling, configuration, and administration
- Web server configuration and administration
- Web application deployment

At first glance, it can seem that this kind of approach goes against common sense; a single developer should not be allowed to do everything by himself. Every developer knows that the *back-end* and the *front-end* require entirely different skills and experiences, so why in the world should we do that?

Before answering this question, we should understand what we really mean when we say *being able to*. We don't have to become experts on every single layer of the stack; no one expects us to. When we choose to embrace the full-stack approach, what we really need to do is raise our awareness level throughout the whole stack we're working on; this means that we need to know how the *back-end* works, and how it can and will be connected to the *front-end*. We need to know how the data will be stored, retrieved, and then served through the client. We need to acknowledge the interactions we will need to layer out between the various Components that our web application is made of, and we need to be aware of security concerns, authentication mechanisms, optimization strategies, load balancing techniques, and so on.

This doesn't necessarily mean that we have to have strong skills in all these areas; as a matter of fact, we hardly ever will. Nonetheless, if we want to pursue a full-stack approach, we need to understand the meaning, role, and scope of all of them. Furthermore, we should be able to work our way through any of these fields whenever we need to.

SPAs, NWAs, and PWAs

In order to demonstrate how ASP.NET Core and Angular can work together to their full extent, we couldn't think of anything better than building some small SPA projects with most, if not all, Native Web Application features. The reason for such a choice is quite obvious: there is no better approach to show some of the best features they have to offer nowadays. We'll have the chance to work with modern interfaces and patterns such as HTML5 pushState API, webhooks, data transport-based requests, dynamic web Components, UI data bindings, and a stateless, AJAX-driven architecture capable of flawlessly encompassing all of these. We'll also make good use of some distinctive NWA features such as service workers, web manifest files, and so on.

If you don't know the meaning of these definitions and acronyms, don't worry, we are going to explore these concepts in the next couple of sections, which are dedicated to enumerating the most relevant features of the following types of web applications: SPAs, NWAs, and PWAs. While we're there, we'll also try to figure out the most common product owner's expectations for a typical web-based project.

Single-page application

To put it briefly, an SPA is a web-based application that struggles to provide the same user experience as a desktop application. If we consider the fact that all SPAs are still served through a web server and thus accessed by web browsers just like any other standard website, we can easily understand how that desired outcome can only be achieved by changing some of the default patterns commonly used in web development, such as resource loading, DOM management, and UI navigation. In a good SPA, both contents and resources – HTML, JavaScript, CSS, and so on – are either retrieved within a single page load or are dynamically fetched when needed. This also means that the page doesn't reload or refresh, it just changes and adapts in response to user actions, performing the required server-side calls behind the scenes.

These are some of the key features provided by a competitive SPA nowadays:

- **No server-side round trips:** A competitive SPA can redraw any part of the client UI without requiring a full server-side round trip to retrieve a full HTML page. This is mostly achieved by implementing a **separation of concerns (SOC)** design principle, which means that the data source, the business logic, and the presentation layer will be separated.
- **Efficient routing:** A competitive SPA is able to keep track of the user's current state and location during its whole navigation experience using organized, JavaScript-based routers. We'll talk more about that in the upcoming chapters when we introduce the concepts of server-side and client-side routing.
- **Performance and flexibility:** A competitive SPA usually transfers all of its UI to the client, thanks to its JavaScript SDK of choice (Angular, JQuery, Bootstrap, and so on). This is often good for network performance as increasing client-side rendering and offline processing reduces the UI impact over the network. However, the real deal brought by this approach is the flexibility granted to the UI as the developer will be able to completely rewrite the application *front-end* with little or no impact on the server, aside from a few of the static resource files.

This list can easily grow, as these are only some of the major advantages of a properly designed, competitive SPA. These aspects play a major role nowadays, as many business websites and services are switching from their traditional **Multi-Page Application (MPA)** mindset to fully-committed or hybrid SPA-based approaches.

Native web application

Multi-page applications, which have been increasingly popular since 2015, are commonly called NWAs because they tend to implement a number of small-scale, single-page modules bound together upon a multipage skeleton rather than building a single, monolithic SPA.

A – not to mention the fact that there are also a lot of enterprise-level SPAs and NWAs flawlessly serving thousands of users every day. Want to name a few? WhatsApp Web and Teleport Web, Flickr, plus a wide range of Google web services, including Gmail, Contacts, Spreadsheet, Maps, and more. These services, along with their huge user base, are the ultimate proof that we're not talking about a silly trend that will fade away with time; conversely, we're witnessing the completion of a consolidated pattern that's definitely meant to stay.

Progressive web application

During 2015, another web development pattern pushed its way into light when Frances Berriman (a British freelance designer) and Alex Russel (a Google Chrome engineer) used the term PWAs for the first time to refer to those web applications that could take advantage of a couple of new important features supported by modern browsers: service workers and web manifest files. These two important improvements could be successfully used to deliver some functionalities usually only available on mobile apps – push notifications, offline mode, permission-based hardware access, and so on – using standard web-based development tools such as HTML, CSS, and JavaScript.

The rise of Progressive Web Apps began in March 19, 2018, when Apple implemented support for service workers in Safari 11.1. Starting from that date, PWAs have been widely adopted throughout the industry thanks to their undeniable advantages over MPAs, SPAs, and NWAs: faster load times, smaller application sizes, higher audience engagement, and so on.

Here are the main technical features of a Progressive Web App (according to Google):

- **Progressive:** Works for every user, regardless of browser choice, using progressive enhancement principles
- **Responsive:** Fits any form factor: desktop, mobile, tablet, or forms yet to emerge.
- Connectivity independent: Service workers allow offline uses, or on low-quality networks.
- **App-like:** Feels like an app to the user with app-style interactions and navigation.
- **Fresh:** Always up to date due to the service worker update process
- **Safe:** Served via HTTPS to prevent snooping and ensure content hasn't been tampered with
- **Discoverable:** Identifiable as an application by a web manifest (`manifest.json`) file, and a registered service worker, and discoverable by search engines
- **Re-engageable:** Ability to use push notifications to maintain engagement with the user
- **Installable:** Provides home screen icons without the use of an App Store
- **Linkable:** Can easily be shared via a URL and does not require complex installation

However, their technical baseline criteria can be restricted to the following subset:

- **HTTPS:** They must be served from a secure origin, which means over TLS with green padlock displays (no active mixed content).
- **Minimal offline mode:** They must be able to start, even if the device is not connected to the web, with limited functions or at least displaying a custom offline page.
- **Service workers:** They have to register a service worker with a fetch event handler (which is required for minimal offline support, as explained previously).
- **Web manifest file:** They need to reference a valid `manifest.json` file with at least four key properties (`name`, `short_name`, `start_url`, and `display`) and a minimum set of required icons.

For those interested in reading about this directly from the source, here's the original link from the Google Developers website:

[https://developers.google.com/web/progressive-web-apps/.](https://developers.google.com/web/progressive-web-apps/)

In addition, here are two follow-up posts from Alex Russell's *Infrequently Noted* blog:



<https://infrequently.org/2015/06/progressive-apps-escaping-tabs-without-losing-our-soul/>.

<https://infrequently.org/2016/09/what-exactly-makes-something-a-progressive-web-app/>.

For those who don't know, Alex Russell has worked as a senior staff software engineer at Google since December 2008.

Although having some similarities, PWAs and SPAs are two different concepts, have different requirements, and differ in many important aspects. As we can see, none of the PWA requirements mentioned previously are referring to Single-Page Applications or server-side round trips. A Progressive Web App *can* work within a single HTML page and AJAX-based requests (thus also being an SPA), but it *could* also request other server-rendered (or static) pages and/or perform standard HTTP GET or POST requests, much like an MPA. It's also the opposite: any SPA can implement any single PWA technical criteria, depending on the product owner's requirements (more on that later), the server-side and client-side frameworks adopted, and the developer's ultimate goal.

Since we're going to use Angular, which is all about developing Single-Page Applications, and also ships with a strong and steady service worker implementation since version 5, we are fully entitled to take advantage of the best of both worlds. For this very reason, we're going to use service workers – along with the benefits of increased reliability and performance they provide – whenever we need to, all while keeping a solid SPA approach. Furthermore, we're definitely going to implement some strategic HTTP round trips (and/or other redirect-based techniques) whenever we can profitably use a microservice to lift off some workload from our app, just like any good Native Web Application is meant to do.

Are all these features able to respond to modern market needs? Let's try to find it out.

Product owner expectations

One of the most interesting, yet underrated, concepts brought out by many modern Agile software development frameworks, such as Scrum, is the importance given to the meanings and definitions of roles. Among these, there's nothing as important as the product owner, also known as the customer in Extreme Programming methodology, or customer representative elsewhere. They're the ones who bring to the development table the expectations we'll struggle to satisfy. They will tell us what's most important to deliver and when they will prioritize our work based on its manifest business value rather than its underlying architectural value. They'll be entitled by management to make decisions and make tough calls, which is sometimes great, sometimes not; this will often have a big impact on our development schedule. To cut it short, they're the ones in charge of the project; that's why, in order to deliver a web application matching their expectancy, we'll need to understand their vision and feel it as if it were our own.

This is always true, even if the project's product owner is our dad, wife, or best friend: that's how it works.

Now that we have made that clear, let's take a look at some of the most common product owner's expectations for a typical web-based SPA project. We ought to see whether the choice of using ASP.NET Core and Angular will be good enough to fulfill each one of them, as follows:

- **Early release(s):** No matter what we're selling, the customer will always want to see what he's buying. For example, if we plan to use an Agile development framework such as Scrum, we'll have to release a potentially shippable product at the end of each sprint. If we are looking to adopt a Waterfall-based approach, we're going to have milestones, and so on. One thing is for sure, the best thing we can do in order to efficiently organize our development efforts will be to adopt an iterative and/or modular-oriented approach. ASP.NET Core and Angular, along with the strong separation of concerns granted by their underlying MVC- or MVVM-based patterns, will gracefully push us into the mindset needed to do just that.

- **GUI over back-end:** We'll often be asked to work on the GUI and *front-end* functionalities because that will be the only really viewable and measurable thing for the customer. This basically means that we'll have to mock the data model and start working on the *front-end* as soon as possible, delaying everything that relies under the hood, even if that means leaving it empty; we can say that the hood is what we need the most. Note that this kind of approach is not necessarily bad; by all means, we won't do that just to satisfy the product owner's expectations. On the contrary, the choice of using ASP.NET Core along with Angular will grant us the chance to easily decouple the presentation layer and the data layer, implementing the first and mocking the latter, which is a great thing to do. We'll be able to see where we're going before wasting valuable time or being forced to make potentially wrong decisions. ASP.NET Core's Web API interface will provide the proper tools to do that by allowing us to create a sample web application skeleton in a matter of seconds using the Controller templates available within Visual Studio and in-memory data contexts powered by Entity Framework Core, which we'll be able to access using Entity models and code first. As soon as we do that, we'll be able to switch to GUI design using the Angular presentation layer toolbox as much as we want until we reach the desired results. Once we're satisfied, we'll just need to properly implement the Web API Controller interfaces and hook up the actual data.
- **Fast completion:** None of the preceding things will work unless we also manage to get everything done in a reasonable time span. This is one of the key reasons to choose to adopt a server-side framework and a client-side framework working together with ease. ASP.NET Core and Angular are the tools of choice, not only because they're both built on a solid, consistent ground, but also because they're meant to do precisely that – get the job done on their respective sides and provide a usable interface to the other partner.
- **Adaptability:** As stated by the Agile manifesto, being able to respond to change requests is more important than following a plan. This is especially true in software development where we can even claim that anything that cannot handle change is a failed project. That's another great reason to embrace the separation of concerns enforced by our two frameworks of choice, as this grants the developer the ability to manage—and even welcome, to some extent—most of the layout or structural changes that will be expected during the development phase.

A few lines ago, we mentioned Scrum, which is one of the most popular Agile software development frameworks out there. Those who don't know it yet should definitely take a look at what it can offer to any results-driven team leader and/or project manager.

Here's a good place to start:



[https://en.wikipedia.org/wiki/Scrum_\(software_development\)](https://en.wikipedia.org/wiki/Scrum_(software_development)).

For those who are curious about the Waterfall model, here's a good place to learn more about it:

https://en.wikipedia.org/wiki/Waterfall_model.

That's about it. Note that we didn't cover everything here as it will be impossible without knowing an actual assignment. We just tried to give an extensive answer to the following general question: if we were to build an SPA and/or a PWA, would ASP.NET Core and Angular be an appropriate choice? The answer is undoubtedly yes, especially when used together.

Does this mean that we're done already? Not a chance, as we have no intention of taking this assumption for granted. Conversely, it's time for us to demonstrate this by ceasing to speak in general terms and start to put things in motion. That's precisely what we're going to do in the next section: prepare, build, and test a sample Single-Page Application project.

A sample SPA project

What we need now is to conceive a suitable test case scenario similar to the ones we will eventually have to deal with – a sample SPA project with all the core aspects we would expect from a potentially shippable product.

In order to do this, the first thing we need to do is to become our own customer for a minute and come up with an idea; a vision to share with our other self. We'll then be able to put our developer shoes back on and split our abstract plan into a list of items we'll need to implement; these will be the core requirements of our project. Finally, we'll set up our workstation by getting the required packages, adding the resource files, and configuring both the ASP.NET Core and Angular frameworks in the Visual Studio IDE.

Not your usual Hello World!

The code we're going to write within this book won't be just a shallow demonstration of full-stack development concepts; we won't throw some working code here and there and expect you to connect the dots. Our objective is to create solid, realistic web applications – with server-side web APIs and client-side UIs – using the frameworks we've chosen, and we're also going to do that following the current development best practices.

Each chapter will be dedicated to a single core aspect. If you feel like you already know your way there, feel free to skip to the next one. Conversely, if you're willing to follow us through the whole loop, you'll have a great journey through the most useful aspects of ASP.NET Core and Angular, as well as how they can work together to deliver the most common and useful web-development tasks, from the most trivial ones to the more complex beasts. It's an investment that will pay dividends as it will leave you with a maintainable, extensible, and well-structured project, plus the knowledge needed to build your own. The following chapters will guide us through such a journey. During that trip, we'll also learn how to take care of some important high-level aspects such as SEO, security, performance issues, best coding practices, and deployment, as they will become very important if/when our applications will be eventually published in a production environment.

To avoid making things too boring, we'll try to pick enjoyable themes and scenarios that will also have some usefulness in the real world: to better understand what we mean – no spoilers here – you'll just have to keep reading.

Preparing the workspace

The first thing we have to do is set up our workstation; it won't be difficult because we only need a small set of essential tools. These include Visual Studio 2019, an updated Node.js runtime, a development web server (such as the built-in IIS Express), and a decent source code control system such as Git, Mercurial, or Team Foundation. We will take the latter for granted as we most likely already have it up and running.



In the unlikely case you don't, you should really make amends before moving on! Stop reading, go to www.github.com, www.bitbucket.com or whichever online SCM service you like the most, create a free account, and spend some time learning how to effectively use these tools; you won't regret it, that's for sure.

During the next sections, we'll set up the web application project, install or upgrade the packages and libraries, and build and eventually test the result of our work. However, before doing that, we're going to spend a couple of minutes in order to understand a very important concept that is required to properly use this book without getting (emotionally) hurt – at least in my opinion.

Disclaimer – do (not) try this at home

There's something very important that we need to understand before proceeding. If you're a seasoned web developer, you will most likely know about it already; however, since this book is for (almost) everyone, I feel like it's very important to deal with this matter as soon as possible.

This book will make extensive use of a number of different programming tools, external Components, third-party libraries, and so on. Most of them, such as TypeScript, NPM, NuGet, most .NET Core frameworks/packages/runtimes, and so on, are shipped together with Visual Studio 2019, while others, such as Angular, its required JS dependencies and other third-party server-side and client-side packages will be fetched from their official repositories. These things are meant to work together in a 100% compatible fashion; however, they are all subject to changes and updates during the inevitable course of time. As time passes by, the chance that these updates might affect the way they interact with each other and the project's health will decrease.

The broken code myth

In an attempt to minimize the chances that this can occur, this book will always work with fixed versions/builds of any third-party Component that can be handled using the configuration files. However, some of them, such as Visual Studio and/or .NET Framework updates, might be out of that scope and might bring havoc to the project. The source code might cease to work, or Visual Studio could suddenly be unable to properly compile it.

When something like that happens, the less-experienced person will always be tempted to put the blame on the book itself. Some of them may even start thinking something like this:

There are a lot of compile errors, hence the source code must be broken!

Alternatively, they may think like this:

The code sample doesn't work: the author must have rushed things here and there, and forgot to test what he was writing.

It goes without saying that such hypotheses are rarely true, especially considering the amount of time that the authors, editors, and technical reviewers of these books spend in writing, testing, and refining the source code before building it up, making it available on GitHub, and often even publishing working instances of the resulting applications to worldwide public websites.

The GitHub repository for this book can be found here:

<https://github.com/PacktPublishing/ASP.NET-Core-3-and-Angular-9-Third-Edition>



It contains a Visual Studio solution file for each chapter (`Chapter_01.sln`, `Chapter_02.sln` and so on), as well as an additional solution file (`All_Chapters.sln`) containing the source code for all the chapters.

Any experienced developer will easily understand that most of these things couldn't even be done if there was some broken code somewhere; there's no way this book can even attempt to hit the shelves unless it comes with a 100% working source code, except for a few possible minor typos that will quickly be reported to the publisher and thus fixed within the GitHub repository in a short while. In the unlikely case that it looks like it doesn't, such as raising unexpected compile errors, the novice developer should spend a reasonable amount of time trying to understand the root cause.

Here's a list of questions they should try to answer before anything else:

- Am I using the same development framework, third-party libraries, versions, and builds adopted by the book?
- If I updated something because I felt like I needed to, am I aware of the changes that might affect the source code? Did I read the relevant changelogs? Have I spent a reasonable amount of time looking around for breaking changes and/or known issues that could have had an impact on the source code?
- Is the book's GitHub repository also affected by this issue? Did I try to compare it with my own code, possibly replacing mine?

If the answer to any of these questions is *No*, then there's a good chance that the problem is not ascribable to this book.

Stay hungry, stay foolish, yet be responsible as well

Don't get me wrong: whenever you want to use a newer version of Visual Studio, update your Typescript compiler or upgrade any third-party library, which you are encouraged to do. This is nothing less than the main scope of this book – making you fully aware of what you're doing and capable of, way beyond the given code samples.

However, if you feel you're ready to do that, you will also have to adapt the code accordingly; most of the time, we're talking about trivial stuff, especially these days when you can Google the issue and/or get the solution on StackOverflow. They changed the typings? Then you need to load the new typings. They moved the class somewhere else? Then you need to find the new namespace and change it accordingly, and so on.

That's about it – nothing more, nothing less. The code reflects the passage of time; the developer just needs to keep up with the flow, performing minimum changes to it when required. You can't possibly get lost and blame someone other than yourself if you update your environment and fail to acknowledge that you have to change a bunch of code lines to make it work again.

Am I implying that the author is not responsible for the source code of this book? It's the exact opposite; the author is always responsible. They're supposed to do their best to fix all the reported compatibility issues while keeping the GitHub repository updated. However, you should also have your own level of responsibility; more specifically, you should understand how things work for *any* development book and the inevitable impact of the passage of time on any given source code. No matter how hard the author can work to maintain it, the patches will never be fast or comprehensive enough to make these lines of code always work on any given scenario. That's why the most important thing you need to understand – even before the book topics – is the most valuable concept in modern software development: being able to efficiently deal with the inevitable changes that *will* always occur.

Whoever refuses to understand that is doomed; there's no way around it.

Setting up the project

Assuming that we have already installed Visual Studio 2019 and Node.js, here's what we need to do:

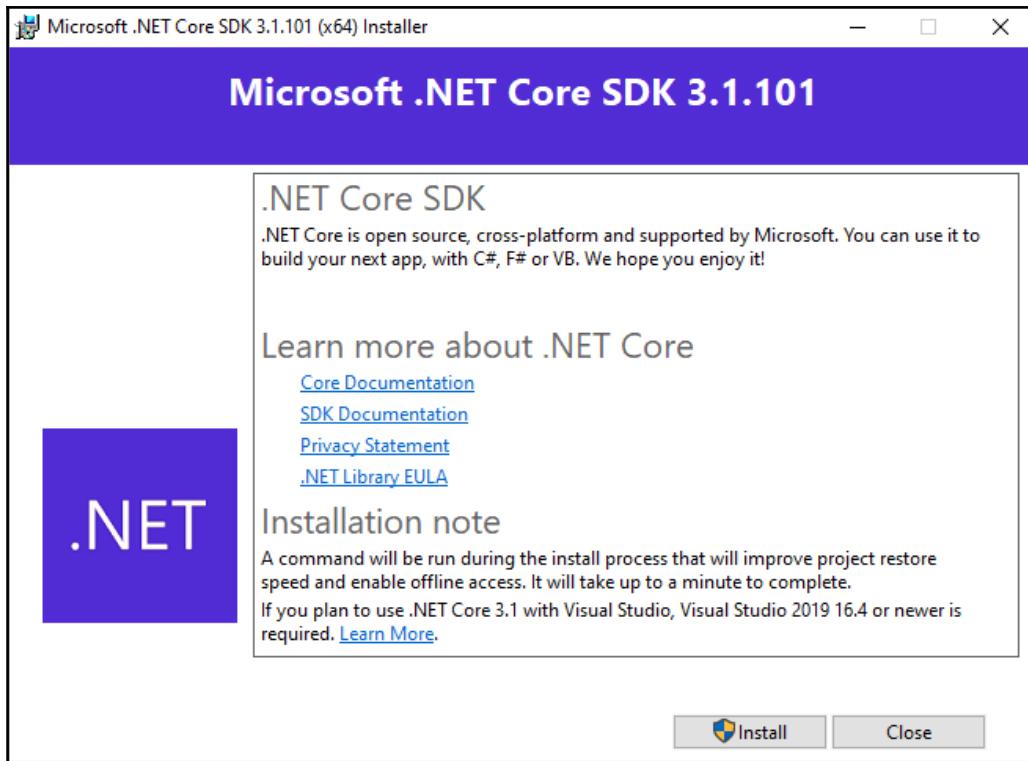
1. Download and install the .NET Core SDK
2. Check that the .NET CLI will use that SDK version
3. Create a new .NET Core and Angular project
4. Check out the newly created project within Visual Studio
5. Update all the packages and libraries to our chosen versions

Let's get to work.

Installing the .NET Core SDK

We can download the latest version from either the official Microsoft URL (<https://dotnet.microsoft.com/download/dotnet-core>) or from the GitHub official release page (<https://github.com/dotnet/core/blob/master/release-notes/README.md>).

The installation is very straightforward – just follow the wizard until the end to get the job done, as follows:



The whole installation process shouldn't take more than a couple of minutes.

Checking the SDK version

Once the .NET Core SDK has been installed, we need to confirm that the new SDK PATH has been properly set and/or that the .NET CLI will actually use it. The fastest way to check that is opening a Command Prompt and typing the following:

```
> dotnet --help
```

Be sure that the .NET CLI executes without issue and that the given version number is the same as we installed a moment ago.



If the prompt is unable to execute the command, go to **Control Panel** | **System** | **Advanced System Settings** | **Environment Variables** and check that the C:\Program Files\dotnet\ folder is present within the PATH environment variable; manually add it if needed.

Creating the .NET Core and Angular project

The next thing we have to do is create our first .NET Core plus Angular project – in other words, our first app. We'll do that using the Angular project template shipped with the .NET Core SDK as it provides a convenient starting point by adding all the required files and also a general-purpose configuration that we'll be able to customize later on to better suit our needs.

From the command line, create a root folder that will contain all our projects and get inside it.



In this book, we're going to use \Projects\ as our root folder: non-experienced developers are strongly advised to use the same folder to avoid possible path errors and/or issues related to path names being too long (Windows 10 has a 260-character limit that can create some issues with some deeply nested NPM packages). It would also be wise to use something other than the C: drive to avoid permission issues.

Once there, type the following command to create the Angular app:

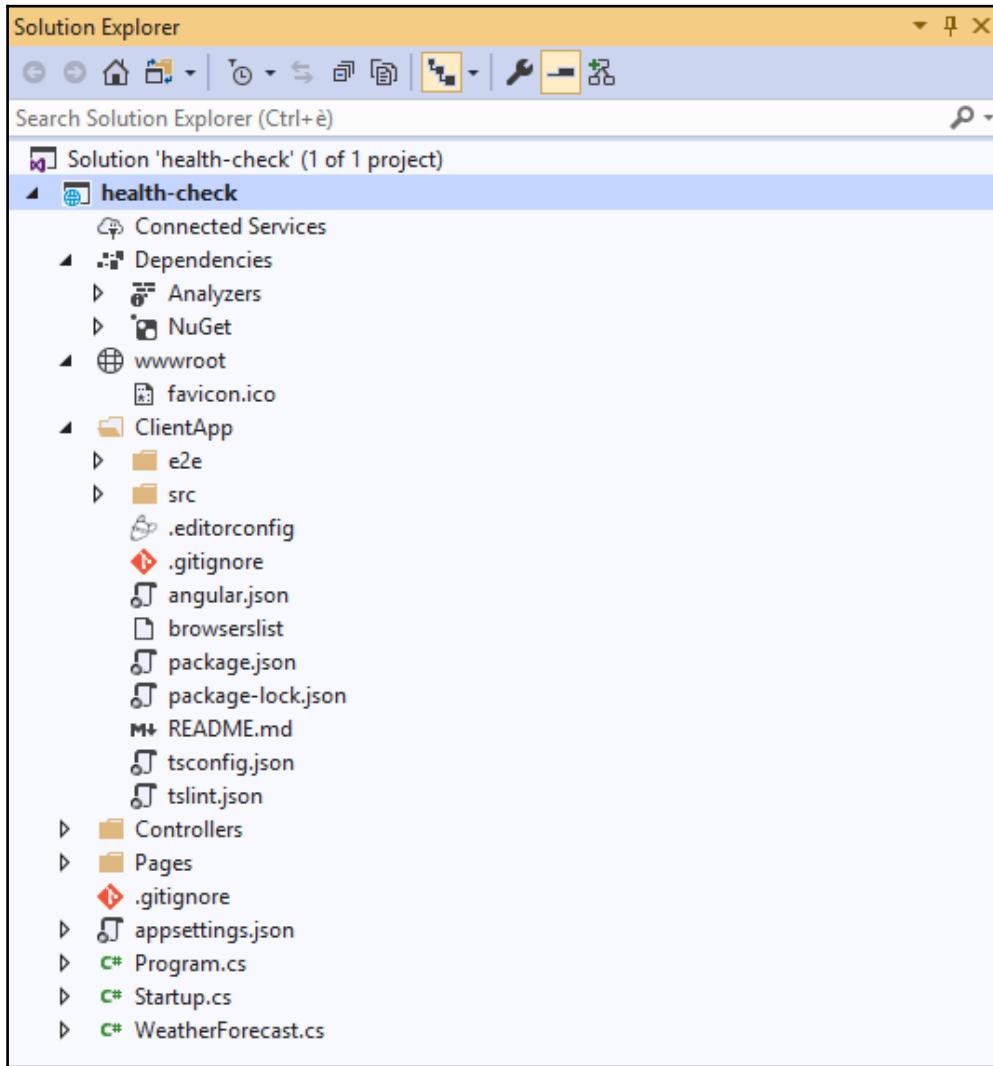
```
> dotnet new angular -o HealthCheck
```

This command will create our first Angular app in the C:\Projects\HealthCheck\ folder. As we can easily guess, its name will be HealthCheck: there's a good reason for such a name, as we're going to see in a short while (no spoilers, remember?).

Opening the new project in Visual Studio

It's now time to launch Visual Studio 2019 and perform a quick checkup of our newly created project. This can be done by either double-clicking on the HealthCheck.csproj file or through the VS2019 main menu (**File** | **Open** | **Project/Solution**).

Once done, we should be able to see our project's source tree in all its lightweight glory, as shown in the following screenshot:



As we can see from the previous screenshot, it's a rather compact boilerplate that only contains the required .NET Core and Angular configuration files, resources, and dependencies: just what we need to start coding!

However, before doing that, let's continue our brief review. As we can see by looking at the various folders, the working environment contains the following:

- The default ASP.NET MVC /Controllers/ and /Pages/ folders, both containing some working samples.
- The /ClientApp/src/ folder with some TypeScript files containing the source code of a sample Angular app.
- The /ClientApp/e2e/ folder containing some sample E2E tests built with the Protractor testing framework.
- The /wwwroot/ folder, which will be used by Visual Studio to build an optimized version of the client-side code whenever we need to execute it locally or have it published elsewhere. That folder is initially empty, but it will be populated upon the project's first run.

If we spend some time browsing through these folders and taking a look at their content, we will see how the .NET Core developers did a tremendous job in easing the .NET with the Angular project setup process. If we compare this boilerplate with the built-in Angular 2.x/5.x templates shipped with Visual Studio 2015/2017, we will see huge improvement in terms of readability and code cleanliness, as well as a better file and folder structure. Also, those who fought with task runners such as Grunt or Gulp and/or client-side building tools such as webpack in the recent past will most likely appreciate the fact that this template is nothing like that: all the packaging, building, and compiling tasks are entirely handled by Visual Studio via the underlying .NET Core and Angular CLIs, with specific loading strategies for development and production.

Truth be told, the choice to use a pre-made template such as this one comes with its flaws. The fact that the *back-end* (the .NET Core APIs) and the *front-end* (the Angular app) are both hosted within a single project can be very useful, and will greatly ease up the learning and development phase, but it's not a recommended approach for production.

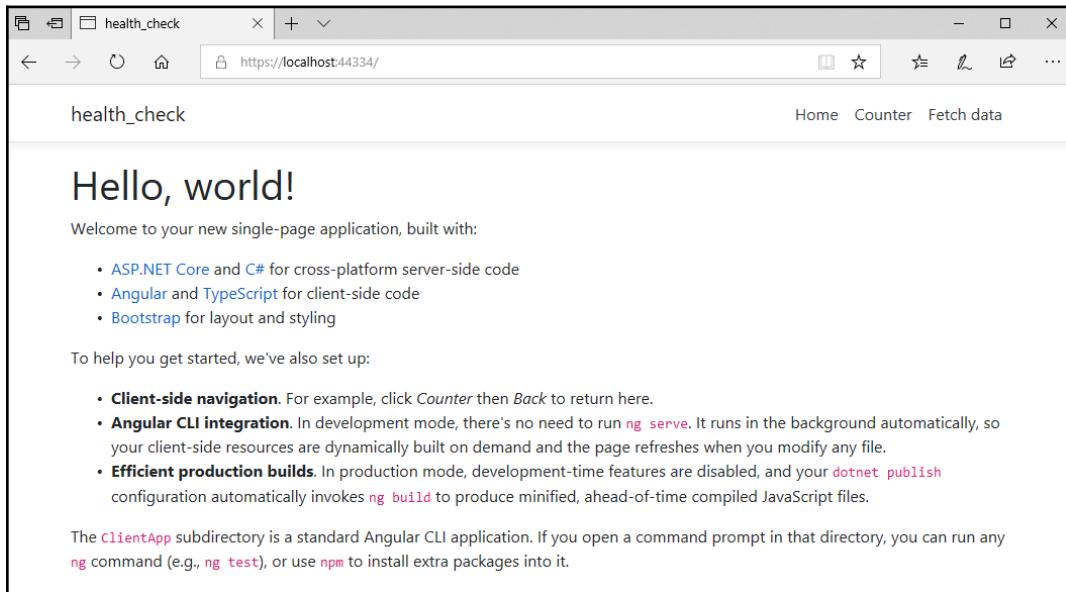


Ideally, it would be better to split the server-side and the client-side parts into two separate projects to enforce decoupling, which is paramount when building microservice-based architectures. That said, being able to work with the *back-end* and the *front-end* within the same project is a good approach for learning, thus making these templates an ideal approach for the purpose of a programming book – and that's why we're going to always use them.

Before moving on, we should definitely perform a quick test run to ensure that our project is working properly. This is what the next section is all about.

Performing a test run

Luckily enough, performing a test run at this point is just as easy as hitting the **Run** button or the *F5* key:



This is an excellent consistency check to ensure that our development system is properly configured. If we see the sample Angular SPA up and running, as shown in the preceding screenshot, it means that we're good to go; if we don't, it probably means that we're either missing something or that we've got some conflicting software preventing Visual Studio and/or the underlying .NET Core and Angular CLIs from properly compiling the project.

In order to fix that, we can try to do the following:

- Uninstall/reinstall Node.js, as we can possibly have an outdated version installed.
- Uninstall/reinstall Visual Studio 2019, as our current installation might be broken or corrupted. The .NET Core SDK should come shipped with it already; however, we can try reinstalling it as well.

If everything still fails, we can try to install VS2019 and the previously mentioned packages in a clean environment (be it either a physical system or a VM) to overcome any possible issue related to our current operating system configuration.



If none of these work, the best thing we can do is to ask for specific support on the .NET Core community forum at <https://forums.asp.net/1255.aspx/1?ASP+NET+Core>.

If we manage to successfully perform the test run, it means that the sample app is working; we're ready to move on.

Summary

So far, so good; we've just set up a working skeleton of what's about to come. Before moving on, let's do a quick recap of what we just did (and arguably learned) in this chapter.

We briefly described our platforms of choice – ASP.NET Core and Angular – and acknowledged their combined potential in the process of building a modern web application. We spent some valuable time recollecting what's happened in these last 3 years, and summarizing the efforts of both development teams to reboot and improve their respective frameworks. These recaps were very useful to enumerate and understand the main reasons why we're still using them over their ever-growing competitors.

Right after that, we did our best to understand the differences between the various approaches that can be adapted to create web apps nowadays: SPAs, MPAs, and PWAs. We also explained that, since we'll be using .NET Core and Angular, we'll stick to the SPA approach, but we'll also implement most PWA features such as service workers and web manifest files. In an attempt to reproduce a realistic production-case scenario, we also went through the most common SPA features, first from a technical point of view, and then putting ourselves in the shoes of a typical product owner while trying to enumerate their expectations.

Last, but not least, we learned how to properly set up our development environment; we chose to do that using the latest Angular SPA template shipped with the .NET Core SDK, thus adopting the standard ASP.NET Core approach. We created our app using the .NET Core CLI and then tested it on Visual Studio to ensure it was working properly.

In the next chapter, we'll take an extensive look at the sample app we just created in order to properly understand how the .NET Core *back-end* and the Angular *front-end* perform their respective tasks and what they can do together.

Suggested topics

Agile development, Scrum, Extreme Programming, MVC and MVVM architectural patterns, ASP.NET Core, .NET Core, Roslyn, CoreCLR, RyuJIT, Single-Page Application (SPA), Progressive Web Application (PWA), Native Web Application (NWA), Multi-Page Application (MPA), NuGet, NPM, ECMAScript 6, JavaScript, TypeScript, webpack, SystemJS, RxJS, Cache-Control, HTTP Headers, .NET middleware, Angular Universal, server-side rendering (SSR), Ahead-of-Time (AOT) compiler, service workers, web manifest files.

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- *ASP.NET 5 is dead – Introducing ASP.NET Core 1.0 and .NET Core 1.0*: <http://www.hanselman.com/blog/ASPNET5IsDeadIntroducingASPNETCore10AndNETCore10.aspx>

- *An Update on ASP.NET Core and .NET Core:* <https://blogs.microsoft.com/webdev/2016/02/01/an-update-on-asp-net-core-and-net-core/>
- *ASP.NET Core 1.1.0 release notes:* <https://github.com/aspnet/AspNetCore/releases/1.1.0>
- *ASP.NET Core 1.1.0 Commits list:* <https://github.com/dotnet/core/blob/master/release-notes/1.1/1.1-commits.md>
- *ASP.NET Core 2.1.0 release notes:* <https://docs.microsoft.com/en-US/aspnet/core/release-notes/aspnetcore-2.1>
- *ASP.NET Core 2.1.0 Commits list:* <https://github.com/dotnet/core/blob/master/release-notes/2.1/2.1.0-commit.md>
- *ASP.NET Core 2.2.0 release notes:* <https://docs.microsoft.com/en-US/aspnet/core/release-notes/aspnetcore-2.2>
- *ASP.NET Core 2.2.0 Commits list:* <https://github.com/dotnet/core/blob/master/release-notes/2.2/2.2.0/2.2.0-commits.md>
- *ASP.NET Core 3.0.0 release notes:* <https://docs.microsoft.com/en-us/dotnet/core/whats-new/dotnet-core-3-0>
- *ASP.NET Core 3.0 releases page:* <https://github.com/dotnet/core/tree/master/release-notes/3.0>
- *ASP.NET Core 3.1.0 release notes:* <https://docs.microsoft.com/en-us/dotnet/core/whats-new/dotnet-core-3-1>
- *Libscore: JavaScript library usage stats:* <http://libscore.com/#libs>
- *Usage of JavaScript libraries for websites:* https://w3techs.com/technologies/overview/javascript_library/all
- *Misko Hevery and Brad Green - Keynote - NG-Conf 2014:* <https://www.youtube.com/watch?v=r1A1VR0ibIQ>
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- *ASP.NET Core 2 and Angular 5:* <https://www.packtpub.com/application-development/aspnet-core-2-and-angular-5>
- *ASP.NET Core 2 and Angular 5 - Video Course:* <https://www.packtpub.com/web-development/asp-net-core-2-and-angular-5-video>
- *Angular Update Guide:* <https://update.angular.io>
- *Angular Language Service:* <https://angular.io/guide/language-service>

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- *Scrum (software development)*: [https://en.wikipedia.org/wiki/Scrum_\(software_development\)](https://en.wikipedia.org/wiki/Scrum_(software_development))
- *Waterfall model*: https://en.wikipedia.org/wiki/Waterfall_model
- *ASP.NET Core Forums*: <https://forums.asp.net/1255.aspx/1?ASP+NET+Core>

2

Looking Around

Now that our project has been created, it's time to take a quick look around and try to understand some of the hard work that the .NET Core SPA template has done to make it work.

...Hey, wait a minute! Shouldn't we skip all these setup technicalities and just jump into coding?

As a matter of fact, yes, we'll definitely be doing that in a little while. However, before doing that, it's wise to highlight a couple of aspects of the code that has been put in place already so that we'll know how to move effectively within our project in advance: where to find the *server-side* and *client-side* code, where to put new content, how to change our initialization parameters, and so on. It will also be a good chance to review our basic knowledge of the Visual Studio environment and the packages we will need.

That's precisely what we're going to do in this chapter. More precisely, the following are the main topics we're going to cover:

- **Solution overview:** A high-level summary of what we'll be dealing with
- **The .NET Core back-end:** Razor Pages, controllers, configuration files, and so on
- **The Angular front-end:** The workspace, the `ClientApp` folder, the Angular initialization cycle, and so on
- **Getting to work:** Caching concepts, removing some .NET controllers and Angular Components that we don't need anymore, and so on



IMPORTANT! The sample code we're reviewing here is the code that comes with the default Angular SPA Visual Studio template shipped by .NET Core SDK 3.1 at the time of writing—the one created with the `dotnet new angular` command. In the (likely) event that this sample code is updated in future releases, ensure you get the former source code from the web using this book's official NuGet repository and use it to replace the contents of your project folder. Caution: failing to do that could result in you working with different sample code from the code featured in this book.

Technical requirements

In this chapter, all of the previous technical requirements listed in Chapter 1, *Getting Ready*, will apply, with no additional resources, libraries, or packages.

The code files for this chapter can be found here: https://github.com/PacktPublishing/ASP.NET-Core-3-and-Angular-9-Third-Edition/tree/master/Chapter_02/.

Solution overview

The first thing that catches the eye is that, as we've already mentioned, the layout of a standard ASP.NET Core solution is quite different from what it used to be in ASP.NET 4 and earlier versions. However, provided that we already have some ASP.NET MVC experience, we should be able to distinguish the .NET Core *back-end* part from the Angular *front-end* part, and also figure out how these two aspects can interact.

The .NET Core *back-end* stack is contained in the following folders:

- The `Dependencies` virtual folder, which basically replaces the old `Resources` folder and contains all the internal, external, and third-party references required to build and run our project. All the references to the NuGet packages we'll add to our project will also be put there.
- The `/Controllers/` folder, which has been shipped with any MVC-based ASP.NET application since the preceding release of the MVC framework.

- The `/Pages/` folder, which contains a single Razor Page—`Error.cshtml`—to handle runtime and/or server errors (more on that later on).
- The root-level files—`Program.cs`, `Startup.cs`, and `appsettings.json`—which will determine our web application's configuration, including the modules and middlewares, compilation settings, and publishing rules; we'll address them all in a while.

As for the Angular *front-end*, it comprises the following folders:

- The `/wwwroot/` folder, which will contain the compiled, *ready-to-publish* contents of our application: HTML, JS, and CSS files, along with fonts, images, and everything else we want our users to have access to in terms of **static files**.
- The `/ClientApp/` root folder, which hosts the Angular (and package manager) configuration files, as well as a couple of important sub-folders of which we're about to give an overview.
- The `/ClientApp/src/` folder, which contains the Angular app source code files. If we look at them, we can see that they all have a `.ts` extension, which means we'll be using the **TypeScript** programming language (we'll say more about this in a bit).
- The `/ClientApp/e2e/` folder, containing some sample **end-to-end (E2E)** tests built with the *Protractor* testing framework.

Let's quickly review the most important parts of this structure.

The .NET Core back-end

If you hail from the ASP.NET MVC framework(s), you might want to know why this template doesn't contain a `/views/` folder: where did our Razor views go?

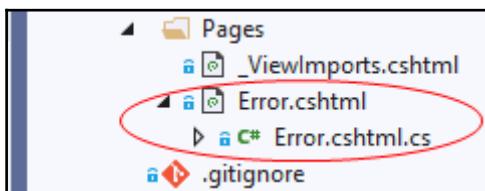
As a matter of fact, this template doesn't make use of views. If we think about it, the reason is quite obvious: a **Single-Page Application (SPA)** might as well get rid of them since they are meant to operate within a single HTML page that gets served only once. In this template, such a page is the `/ClientApp/src/folder/index.html` file—and, as we can clearly see, it's also a static page. The only *server-side*-rendered HTML page provided by this template is the `/Pages/Error.cshtml` Razor Page, which is used to handle runtime and/or server errors that could happen *before* the Angular Bootstrap phase.

Razor Pages

Those who have never heard of Razor Pages should spend 5-10 minutes taking a look at the following guide, which explains what they are and how they work: <https://docs.microsoft.com/en-us/aspnet/core/razor-pages/>.

In a nutshell, Razor Pages were introduced in .NET Core 2.0 and represent an alternative way to implement the ASP.NET Core MVC pattern. A Razor Page is rather similar to a Razor view, with the same syntax and functionality, but it also contains the controller source code—which is placed in a separate file: such files share the same name as the page with an additional `.cs` extension.

To better show the *dependence* between the `.cshtml` and the `.cshtml.cs` files of a Razor Page, Visual Studio conveniently nests the latter within the former, as we can see from the following screenshot:



...Hey, wait a minute: where have I seen this movie before?

Yes, this definitely rings a bell: being a slimmer version of the standard MVC *Controller + view* approach, a Razor Page is pretty similar to an old `.aspx + .aspx.cs` ASP.NET Web Form.

Controllers

If a Razor Page includes the controller, why we do still have a `/Controller/` folder? The reason is pretty simple: not all controllers are meant to serve *server-rendered* HTML pages (or views). For example, they can output a JSON output (REST APIs), XML-based response (SOAP web services), a static or dynamically-created resource (JPG, JS, and CSS files), or even a simple HTTP response (such as an HTTP 301 redirect) without the content body.

As a matter of fact, one of the most important benefits of Razor Pages is the fact that they allow a *decoupling* between what is meant to serve standard HTML content—which we usually call *pages*—and the rest of the HTTP response, which can be loosely defined as *service APIs*. Our .NET Core + Angular template fully supports such a division, which offers two main benefits:

- **Separation of concerns:** Using pages would force a separation between how we load the *server-side* pages (1%) and how we serve our APIs (99%). The percentages shown are valid for our specific scenario: we're going to follow the SPA approach, which is all about serving and calling Web APIs.
- **Single responsibility:** Each Razor Page is *self-contained*, as its view and controller are intertwined and organized together. This follows the *single responsibility principle*, a computer programming good practice that advises that every module, class, or function should have responsibility for a single part of the functionality provided by the software and that this responsibility should also be entirely encapsulated by that class.

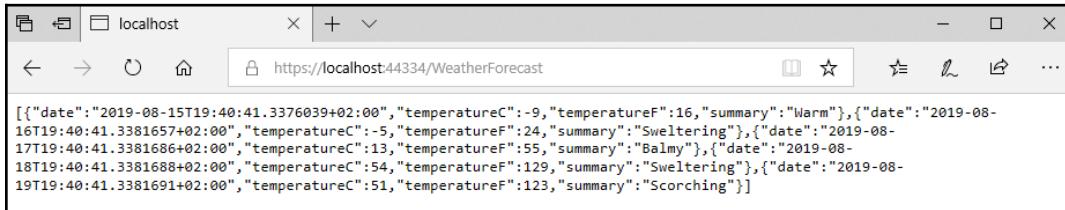
By acknowledging all this, we can already infer that the single sample `WeatherForecastController` contained in the `/Controllers/` folder is there to expose a bunch of Web APIs that will be used by the Angular *front-end*. To quickly check it out, hit `F5` to launch the project in *debug mode* and execute the default route by typing the following URL: <https://localhost:44334/WeatherForecast>.



The actual port number may vary, depending on the project configuration file: to set a different port for debug sessions, change the `iisSettings` | `iisExpress` | `applicationUrl` and/or `iisSettings` | `iisExpress` | `sslPort` values in the `Properties/launchSettings.json` file.

This will execute the `Get()` method defined in the `WeatherForecastController.cs` file. As we can see by looking at the source code, such a method has an `IEnumerable<WeatherForecast>` return value, meaning that it will return an array of objects of the `WeatherForecast` type.

If you copy the preceding URL into the browser and execute it, you should see a JSON array of randomly generated data, as shown in the following screenshot:



It's not difficult to imagine who'll be asking for these values.

Configuration files

Let's now take a look at root-level configuration files and their purpose: `Program.cs`, `Startup.cs`, and `appsettings.json`. These files contain our web application's configuration, including the modules and middlewares, compilation settings, and publishing rules.

As for the `WeatherForecast.cs` file, it's just a strongly typed class designed to *deserialize* the JSON objects returned by the `WeatherForecastController`, which we've seen in action in the previous section: in other words, it's a **JSON View Model**—a view model specifically made to contain *deserialized* JSON objects. In our humble opinion, the template authors should have put it within the `/ViewModel/` folder (or something like that) instead of leaving it at the root level. Anyway, let's just ignore it for now, since it's not a configuration file, and focus on the rest.

Program.cs

The `Program.cs` file will most likely intrigue most seasoned ASP.NET programmers, as it's not something we usually see in a web application project. First introduced in ASP.NET Core 1.0, the `Program.cs` file's main purpose is to create a `WebHostBuilder`, an object that will be used by the .NET Core framework to set up and build the `IWebHost` and which will host our web application.

Web host versus web server

That's great to know, but what is a **web host**? In very few words, a *host* is the execution context of any ASP.NET Core app. In a web-based application, the host must implement the `IWebHost` interface, which exposes a collection of web-related features and services and also a `Start` method. The web host references the server that will handle requests.

The preceding statement can lead to the assumption that the web host and the web server are the same thing; however, it's very important to understand that they're not, as they serve very different purposes. Simply put, the host is responsible for application startup and lifetime management, while the server is responsible for accepting HTTP requests. Part of the host's responsibility includes ensuring that the application's services and the server are available and properly configured.

We can think of the host as being a wrapper around the server: the host is configured to use a particular server, while the server is unaware of its host.



For further info regarding the web host, the `WebHostBuilder` class, and the purpose of the `Setup.cs` file, take a look at the following guide: <https://docs.microsoft.com/en-us/aspnet/core/fundamentals/>.

If we open the `Program.cs` file and take a look at the code, we can easily see that the `WebHostBuilder` is built in an extremely easy way, as follows:

```
public class Program
{
    public static void Main(string[] args)
    {
        CreateWebHostBuilder(args).Build().Run();
    }

    public static IWebHostBuilder CreateWebHostBuilder(string[] args) =>
        WebHost.CreateDefaultBuilder(args)
            .UseStartup<Startup>();
}
```

`WebHost.CreateDefaultBuilder(args)` was introduced in .NET Core 2 and is a great improvement on its 1.x counterpart, as it simplifies the amount of source code required to set up basic use cases, thus making it easier to get started with a new project.

To understand this better, let's take a look at the sample `Program.cs` equivalent, like it was in .NET Core 1.x:

```
public class Program
{
    public static void Main(string[] args)
    {
        var host = new WebHostBuilder()
            .UseKestrel()
            .UseContentRoot(Directory.GetCurrentDirectory())
            .UseIISIntegration()
            .UseStartup<Startup>()
            .UseApplicationInsights()
            .Build();

        host.Run();
    }
}
```

This is used to perform the following steps:

1. Setting up the `Kestrel` web server
2. Setting up the content root folder, that is, where to look for the `appsettings.json` file and other configuration files
3. Setting up IIS Integration
4. Defining the `Startup` class to use (usually defined in the `Startup.cs` file)
5. Finally, executing `Build` and `Run` on the now configured `IWebHost`

In .NET Core 1.x, all these steps must be called explicitly here and also manually configured within the `Startup.cs` file; although .NET Core 2 and 3 we can still do this, using the `WebHost.CreateDefaultBuilder()` method is generally better as it takes care of most of the job, and also lets us change the defaults whenever we want.



If you're curious about this method, you can even take a peek at the source code on GitHub: <https://github.com/aspnet/MetaPackages/blob/master/src/Microsoft.AspNetCore/WebHost.cs>.

At the time of writing, the `WebHost.CreateDefaultBuilder()` method implementation starts at line #148.

As we can see, the `CreateWebHostBuilder` method ends with a chained call to `UseStartup<Startup>()` to specify the startup type that will be used by the web host. That type is defined in the `Startup.cs` file, which is what we're going to talk about.

Startup.cs

If you're a seasoned .NET developer, you might already be familiar with the `Startup.cs` file since it was first introduced in OWIN-based applications to replace most of the tasks previously handled by the good old `Global.asax` file.



Open Web Interface for .NET (OWIN) comes as part of project **Katana**, a flexible set of Components released by Microsoft back in 2013 for building and hosting OWIN-based web applications. For additional info, refer to <https://www.asp.net/aspnet/overview/owin-and-katana>.

However, the similarities end here; the class has been completely rewritten to be as pluggable and lightweight as possible, which means that it will include and load only what's strictly necessary to fulfill our application's tasks.

More specifically, in .NET Core, the `Startup.cs` file is the place where we can do the following:

- Add and configure Services and Dependency Injection, in the `ConfigureServices()` method
- Configure an HTTP request pipeline by adding the required *middleware*, in the `Configure()` method

To better understand this, let's take a look at the following lines taken from the `Startup.cs` source code shipped with the project template we chose:

```
// This method gets called by the runtime. Use this method to
// configure the HTTP request pipeline.
public void Configure(IApplicationBuilder app, IWebHostEnvironment
env)
{
    if (env.IsDevelopment())
    {
        app.UseDeveloperExceptionPage();
    }
    else
    {
```

```
    app.UseExceptionHandler("/Error");
    // The default HSTS value is 30 days.
    // You may want to change this for production scenarios,
    // see https://aka.ms/aspnetcore-hsts.
    app.UseHsts();
}

app.UseHttpsRedirection();
app.UseStaticFiles();
if (!env.IsDevelopment())
{
    app.UseSpaStaticFiles();
}

app.UseRouting();

app.UseEndpoints(endpoints =>
{
    endpoints.MapControllerRoute(
        name: "default",
        pattern: "{controller}/{action=Index}/{id?}");
});

app.UseSpa(spa =>
{
    // To learn more about options for serving an Angular SPA
    // from ASP.NET Core,
    // see https://go.microsoft.com/fwlink/?linkid=864501

    spa.Options.SourcePath = "ClientApp";

    if (env.IsDevelopment())
    {
        spa.UseAngularCliServer(npmScript: "start");
    }
});
}
```

This is the `Configure()` method implementation, where—as we just said—we can set up and configure the HTTP request pipeline.

The code is very readable, so we can easily understand what happens here:

- The first bunch of lines features an `if-then-else` statement that implements two different behaviors to handle runtime exceptions in development and production, throwing the exception in the former case and showing an opaque error page to the end user in the latter; that's a neat way to handle runtime exceptions in very few lines of code.
- Right after that, we can see the first block of middlewares: `HttpsRedirection`, to handle HTTP-to-HTTPS redirects; `StaticFiles`, to serve static files placed under the `/wwwroot/` folder; and `SpaStaticFiles`, to serve static files in the `/ClientApp/src/assets/` folder (the `assets` folder of our Angular app). Without these last two middlewares, we won't be able to serve locally hosted assets such as JS, CSS, and images; this is the reason they are in a pipeline. Also, note how these methods are called with no parameters: this just means that their default settings are more than enough for us, so there's nothing to configure or override here.
- Right after the three-pack, there is the `Endpoints` middleware, which will add the required routing rule(s) to map certain HTTP requests to our Web API controllers. We'll extensively talk about that in upcoming chapters, when we'll deal with *server-side* routing aspects; for now, let's just understand that there's an active mapping rule that will *catch* all HTTP requests resembling a `controller` name (and/or an optional `action` name, and/or an optional ID `GET` parameter) and route them to that controller. That's precisely why we were able to call the `WeatherForecastController.Get()` method from our web browser and receive a result.
- Last but not least comes the `UseSpa` middleware, which gets added to the HTTP pipeline with two configuration settings. The first one is pretty easy to understand: it's just the source path of the Angular app's root folder. In this template's scenario, it's the `/ClientApp/` folder. The second one, which will only be executed in development scenarios, is way more complex: to explain it in few words, the `UseAngularCliServer()` method tells .NET Core to pass through all the requests addressed to the Angular app to an in-memory instance of the Angular CLI server: this is great for development scenarios because our app will always serve up-to-date CLI-built resources without having to run the Angular CLI server manually each time; at the same time, it's not ideal for production scenarios because of the additional overhead and an obvious performance impact.



It's worth noting that middlewares added to the HTTP pipeline will be processed in registration order, from top to bottom; this means that the `StaticFile` middleware will take priority over the `Endpoint` middleware, which will take place before the `Spa` middleware, and so on. Such behavior is very important and could cause unexpected results if taken lightly, as shown in the following StackOverflow thread:

<https://stackoverflow.com/questions/52768852/>.

Let's perform a quick test to ensure that we properly understand how these middlewares work:

1. From Visual Studio's **Solution Explorer**, go to the `/wwwroot/` folder and add a new `test.html` page to our project.
2. Once done, fill it with the following contents:

```
<!DOCTYPE html>
<html>
<head>
<meta charset="utf-8" />
<title>Time for a test!</title>
</head>
<body>
Hello there!
<br /><br />
This is a test to see if the StaticFiles middleware is
working properly.
</body>
</html>
```

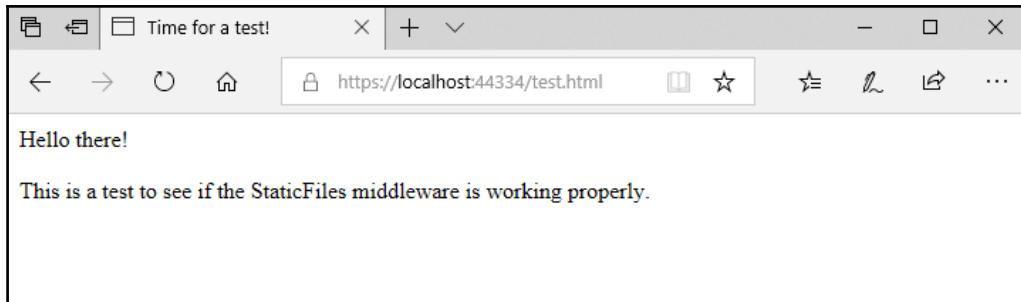
Now, let's launch the application in *debug* mode—using the **Run** button or the *F5* keyboard key—and point the address bar to the following URL:

<https://localhost:44334/test.html>.



Again, the TCP/IP port number may vary: edit the `Properties/launchSettings.json` file if you want to change it.

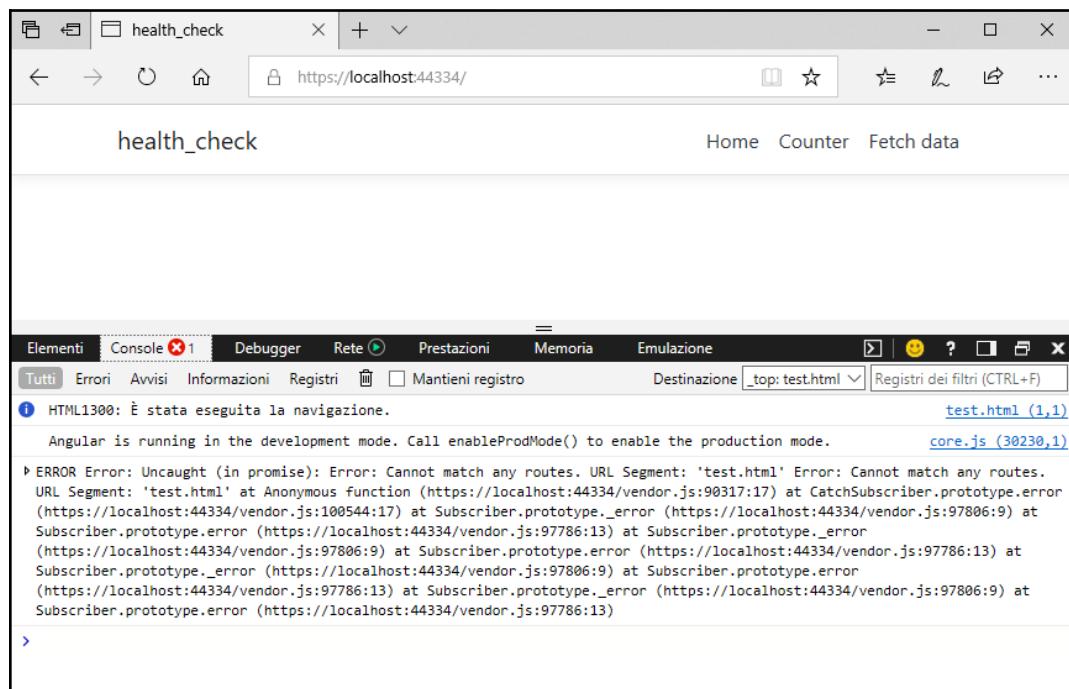
We should be able to see our `test.html` file in all its glory, as shown in the following screenshot:



Based on what we learned a moment ago, we know that this file is being served thanks to the `StaticFiles` middleware. Let's now go back to our `Startup.cs` file and comment out the `app.UseStaticFiles()` call to prevent the `StaticFiles` middleware from being loaded:

```
app.UseHttpsRedirection();
// app.UseStaticFiles();
app.UseSpaStaticFiles();
```

Once done, run the application again and try to go back to the previous URL, as shown in the following screenshot:



As expected, the `test.html` static file isn't served anymore: the file is still there, but the `StaticFile` middleware is not registered and cannot handle it. Therefore, the now-unhandled HTTP request goes all the way through the HTTP pipeline until it reaches the `Spa` middleware, which acts as a catch-all and tosses it to the *client-side* Angular app. However, since there is no *client-side* routing rule that matches the `test.html` pattern, the request is eventually redirected to the app's starting page.

The last part of the story is fully documented in the browser's **Console** log, as shown in the preceding screenshot: the *Cannot match any routes* error message comes from Angular, meaning that our request passed through the whole .NET Core *back-end* stack.

Now that we proved our point, we can bring the `StaticFiles` middleware back in place by removing the comments and go ahead.



For additional information regarding the `StaticFiles` middleware and static file handling in .NET Core, visit the following URL:

<https://docs.microsoft.com/en-us/aspnet/core/fundamentals/static-files>.

All in all, since the `Startup.cs` file shipped with the Angular SPA template already has everything we need, we can leave it as it is for now.

Thanks to this brief overview, we should now be fully aware of how the HTTP request received by our web application will be handled. Let's try to wrap everything up:

1. Each request will be received by the **.NET Core back-end**, which will try to handle it at the *server-side* level by checking the various middlewares registered in the HTTP pipeline (in registration order): in our specific scenario, we'll first check the static files in the `/wwwroot/` folder, then the static files in the `/ClientApp/src/assets/` folder, then those in the routes mapped to our Web API controllers/endpoints.
2. If one of the aforementioned middlewares is able to match and handle the request, the **.NET Core back-end** will take care of it; conversely, the `Spa` middleware will pass the request through to the Angular *client-side* app, which will handle it using its *client-side* routing rules (more on them later on).

appsettings.json

The `appsettings.json` file is just a replacement for the good old `Web.config` file; the XML syntax has been replaced by the more readable and considerably less verbose JSON format. Moreover, the new configuration model is based upon key/value settings that can be retrieved from a wide variety of sources, including—yet not limited to—JSON files, using a centralized interface.

Once retrieved, they can be easily accessed within our code using **Dependency Injection** via literal strings (using the vanilla `IConfiguration` class):

```
public SampleController(IConfiguration configuration)
{
    var myValue = configuration["Logging:IncludeScopes"];
}
```

Alternatively, we can achieve the same result with a *strongly typed* approach using a custom POCO class (we'll get to that later on).

It's worth noting that there's also an `appsettings.Development.json` file nested below the main one. Such a file serves the same purpose as the old `Web.Debug.config` file, which was widely used during the ASP.NET 4.x period. In a nutshell, these additional files can be used to specify additional configuration key/value pairs (and/or override existing ones) for specific environments.

To better understand the concept, let's take a look at the two files' contents.

The following is the `appsettings.json` file:

```
{
  "Logging": {
    "LogLevel": {
      "Default": "Warning"
    }
  },
  "AllowedHosts": "*"
}
```

And here's the `appsettings.Development.json` file:

```
{  
  "Logging": {  
    "LogLevel": {  
      "Default": "Debug",  
      "System": "Information",  
      "Microsoft": "Information"  
    }  
  }  
}
```

As we can see, the `Logging(LogLevel.Default)` value for our app is set to `Warning` in the first file; however, whenever our app runs in *development* mode, the second file will overwrite the value, setting it to `Debug`, and add the `System` and `Microsoft` log levels, setting them both to `Information`.



Back in .NET Core 1.x, this overriding behavior had to be specified manually within the `Startup.cs` file; in .NET Core 2, the `WebHost.CreateDefaultBuilder()` method within the `Program.cs` file takes care of that automatically, by assuming that you can rely on this default naming pattern and don't need to add another custom `.json` configuration file.

Assuming that we understood everything here, we're done inspecting the .NET Core *back-end* part; it's time to move on to the Angular *front-end* folders and files.

The Angular front-end

The *front-end* part of the template will probably be seen as more complex to understand, because Angular—just like most *client-side* frameworks—has evolved at a dramatic pace, thus experiencing many breaking changes in its core architecture, toolchain management, coding syntax, template, and setup.

For this very reason, it's very important to take our time understanding the role of the various files shipped with the template: this brief overview will start with root-level configuration files, which will also be updated with the latest versions of the Angular packages (and their dependencies) we'll need to use.

Workspace

The Angular workspace is the filesystem place containing the Angular files: a collection of application files, libraries, assets, and so on. In our template, as in most .NET Core and Angular projects, the workspace is located within the `/ClientApp/` folder, which is defined as the workspace root.

The workspace is usually created and initialized by the CLI command used to create the app: do you remember the `dotnet new` command we used in [Chapter 1, Getting Ready](#)? That's what we're talking about: the Angular part of the template was created by that command. We could achieve that same result with the Angular CLI, using the `ng new` command.

Any CLI commands operating on the app and/or their libraries (such as adding or updating new packages) will be executed from within the workspace folder.

angular.json

The most important role within the workspace is played by the `angular.json` file, created by the CLI in the workspace root: this is the workspace configuration file and contains workspace-wide and project-specific configuration defaults for all build and development tools provided by the Angular CLI.



It's worth noting that all the paths defined within this file are meant to be relative to the workspace root folder: in our scenario, for example, `src/main.ts` will resolve to `/ClientApp/src/main.ts`.

The first few properties at the top of the file define the workspace and project configuration options:

- `version`: The configuration file version.
- `newProjectRoot`: The path where new projects are created, relative to the workspace root folder. We can see that this value is set to the `projects` folder, which doesn't even exist. That's perfectly normal since our workspace is meant to contain two Angular projects in two already defined folders: our `HealthCheck` Angular app, located in the `/ClientApp/src/` folder, and *end-to-end* tests, located in the `/ClientApp/e2e/` folder. Therefore, there is no need to define a `newProjectRoot`—and it's also important to not use an existing folder to avoid the risk of overwriting some existing stuff.

- `projects`: A container item that hosts a sub-section for each project in the workspace, containing project-specific configuration options.
- `defaultProject`: The default project name—any CLI command that doesn't specify a project name will be executed on this project.



It's worth noting that the `angular.json` file follows a standard generic-to-specific *cascading* rule. All configuration values set at the workspace level will be the default values for any project, and can be overridden by those set at the *project* level. These, in turn, can be overridden by *command-line* values available when using the CLI.

It's also worth mentioning that, before **Angular 8**, manually modifying the `angular.json` file was the only way to make changes to the workspace config.

That's all we need to know, at least for the time being: all the configuration values are already good enough for our scenario, hence we'll just leave them as they are for now.



Up to **Angular 7**, manually modifying the `angular.json` file was the only way to make changes to the workspace config: this changed with **Angular 8** with the introduction of the **workspace API**, which now allows us to read and modify these configurations much more conveniently. For additional info regarding this new feature, we suggest taking a look at the following page:

https://github.com/angular/angular-cli/blob/master/packages/angular_devkit/core/README.md#workspaces.

package.json

The `package.json` file is the **Node Package Manager (npm) configuration file**; it basically contains a list of **npm packages** that the developer wants to be restored before the project starts. Those who already know what npm is and how it works can skip to the next section, while those who don't should definitely keep reading.

npm started its life as the default package manager for the JavaScript runtime environment known as Node.js. During recent years, though, it has also been used to host a number of independent JavaScript projects, libraries, and frameworks of any kind, including *Angular*. Eventually, it became the de facto package manager for JavaScript frameworks and tooling. Those who have never used it can think of it as the *NuGet* for the JavaScript world.

Although npm is mostly a *command-line* tool, the easiest way to use it from Visual Studio is to properly configure a `package.json` file containing all the npm packages we want to get, restore, and keep up-to-date later on. These packages get downloaded in the `/node_modules/` folder within our project directory, which is hidden by default within Visual Studio; however, all retrieved packages can be seen from the npm virtual folder. As soon as we add, delete, or update the `package.json` file, Visual Studio will automatically update that folder accordingly.

In the Angular SPA template we've been using, the shipped `package.json` contains a huge number of packages—all **Angular** packages—plus a good bunch of dependencies, tools, and third-party utilities such as **Karma** (a great test runner for JavaScript/TypeScript).

Before moving ahead, let's take a further look at our `package.json` file and try to get the most out of it. We can see how all packages are listed within a standard JSON object entirely made up of *key-value* pairs; the package name is the *key*, while the *value* is used to specify the version number. We can either input precise build numbers or use the standard **npmJS** syntax to specify *auto-update rules* bound to custom version ranges using supported prefixes, such as the following:

- **The Tilde (~)**: A value of "`~1.1.4`" will match all `1.1.x` versions, excluding `1.2.0`, `1.0.x`, and so on.
- **The Caret (^)**: A value of "`^1.1.4`" will match everything above `1.1.4`, excluding `2.0.0` and above.

This is another scenario where *IntelliSense* comes in handy, as it will also visually explain the actual meaning of these prefixes.



For an extensive list of available npmJS commands and prefixes, it's advisable to check out the official npmJS documentation at <https://docs.npmjs.com/files/package.json>.

Upgrading (or downgrading) Angular

As we can see, the Angular SPA template uses fixed version numbers for all Angular-related packages; this is definitely a wise choice since we have no guarantees that newer versions will seamlessly integrate with our existing code without raising some potentially breaking issues and/or compiler errors. Needless to say, the version number will naturally increase with the passage of time, because template developers will definitely try to keep their good work up to date.

That said, here are the most important Angular packages and releases that will be used throughout this book (excluding a small bunch of additional packages that might be added later on):

```
"@angular/animations": "9.0.0",
"@angular/common": "9.0.0",
"@angular/compiler": "9.0.0",
"@angular/core": "9.0.0",
"@angular/forms": "9.0.0",
"@angular/platform-browser": "9.0.0",
"@angular/platform-browser-dynamic": "9.0.0",
"@angular/platform-server": "9.0.0",
"@angular/router": "9.0.0",
"@nguniversal/module-map-ngfactory-loader": "9.0.0-next.9",

"@angular-devkit/build-angular": "0.900.0",
"@angular/cli": "9.0.0",
"@angular/compiler-cli": "9.0.0",
"@angular/language-service": "9.0.0"
```

The former group can be found in the `dependencies` section, while the latter is part of the `devDependencies` section. As we can see, the version number is mostly the same for all packages and corresponds to the latest Angular final release available at the time of writing.



The version of **Angular 9** that we use in this book was released a few weeks before this book hit the shelves: we did our best to use the latest available (*non-beta*, *non-rc*) version to give the reader the best possible experience with the most recent technology available. That said, that *freshness* will eventually decrease over time and this book's code will start to become obsolete: when it happens, try to not blame us for that!

If we want to ensure the highest possible level of compatibility between our project and this book's source code, we should definitely adopt that same release, which, at the time of writing, also corresponds to the latest stable one. We can easily perform the upgrade—or downgrade—by changing the version numbers; as soon as we save the file, Visual Studio *should* automatically fetch new versions through **npm**. In the unlikely scenario that it doesn't, manually deleting the old packages and issuing a full rebuild should be enough to fix the issue.

As always, we're free to overwrite such behavior and get newer (or older) versions of these packages, assuming that we properly understand the consequences and according to the **Disclaimer** in Chapter 1, *Getting Ready*.



If you encounter problems while updating your package.json file, such as conflicting packages or *broken* code, ensure that you download the full source code from the official GitHub repository of this book, which includes the same package.json file that has been used to write, review, and test this book; it will definitely ensure a great level of compatibility with the source code you'll find here.

Upgrading (or downgrading) the other packages

As we might expect, if we upgrade (or downgrade) Angular to 5.0.0, we also need to take care of a series of other npm packages that might need to be updated (or downgraded).

Here's the full package list (including the Angular packages) we'll be using in our package.json file throughout the book, split into dependencies, devDependencies, and optionalDependencies sections: important packages are highlighted in the following snippet—be sure to triple-check them!

```
"dependencies": {  
    "@angular/animations": "9.0.0",  
    "@angular/common": "9.0.0",  
    "@angular/compiler": "9.0.0",  
    "@angular/core": "9.0.0",  
    "@angular/forms": "9.0.0",  
    "@angular/platform-browser": "9.0.0",  
    "@angular/platform-browser-dynamic": "9.0.0",  
    "@angular/platform-server": "9.0.0",  
    "@angular/router": "9.0.0",  
    "@nguniversal/module-map-ngfactory-loader": "9.0.0-next.9",  
    "aspnet-prerendering": "3.0.1",  
    "bootstrap": "4.4.1",  
    "core-js": "3.6.1",  
    "jquery": "3.4.1",  
    "oidc-client": "1.9.1",  
    "popper.js": "1.16.0",  
    "rxjs": "6.5.4",  
    "zone.js": "0.10.2"  
},  
"devDependencies": {  
    "@angular-devkit/build-angular": "0.900.0",  
}
```

```
    "@angular/cli": "9.0.0",
    "@angular/compiler-cli": "9.0.0",
    "@angular/language-service": "9.0.0",
    "@types/jasmine": "3.5.0",
    "@types/jasminewd2": "2.0.8",
    "@types/node": "13.1.1",
    "codelyzer": "5.2.1",
    "jasmine-core": "3.5.0",
    "jasmine-spec-reporter": "4.2.1",
    "karma": "4.4.1",
    "karma-chrome-launcher": "3.1.0",
    "karma-coverage-istanbul-reporter": "2.1.1",
    "karma-jasmine": "2.0.1",
    "karma-jasmine-html-reporter": "1.5.1",
    "typescript": "3.7.5"
},
"optionalDependencies": {
  "node-sass": "4.13.0",
  "protractor": "5.4.2",
  "ts-node": "5.0.1",
  "tslint": "5.20.1"
}
```



It's advisable to perform a manual *command-line* `npm update` from the project's root folder right after applying these changes to the `package.json` file, in order to trigger a batch update of all the project's npm packages: sometimes Visual Studio doesn't update the packages automatically and doing that using the GUI can be tricky. For this very reason, a convenient `update-npm.bat` batch file has been added to this book's source code repository on GitHub (inside the `/ClientApp/` folder) to handle that without having to type the preceding command manually.

Those who run into `npm` and/or `ngcc` compilation issues after the `npm update` command can also try to delete the `/node_modules/` folder and then perform a `npm install` from scratch.

For further reference and/or future updates, please also check the updated source code in this book's official GitHub repository, which will always contain the latest improvements, bug fixes, compatibility fixes, and so on.

tsconfig.json

The `tsconfig.json` file is the TypeScript configuration file. Again, those who already know what TypeScript is won't need to read all this, although those who don't should.

In fewer than 100 words, TypeScript is a free, open source programming language developed and maintained by Microsoft that acts as a JavaScript superset; this means that any JavaScript program is also a valid TypeScript program. TypeScript also compiles to JavaScript, so it can seamlessly work on any JavaScript-compatible browser without external Components. The main reason to use it is to overcome JavaScript's syntax limitations and overall shortcomings when developing large-scale applications or complex projects: simply put, it eases the developer's life when he/she is forced to deal with non-trivial JavaScript code.

In this project, we will definitely use TypeScript for a number of good reasons; the most important ones are as follows:

- TypeScript has a number of features over JavaScript, such as static typing, classes, and interfaces. Using it in Visual Studio also gives us the chance to benefit from the *built-in* IntelliSense, which is a great benefit and often leads to a remarkable productivity burst.
- For a large *client-side* project, TypeScript will allow us to produce more robust code, which will also be fully deployable anywhere a plain JavaScript file would run.

Not to mention the fact that the Angular SPA template we chose already uses TypeScript. Hence we can say that we already have a foot in the water!

Jokes aside, we're not the only ones praising TypeScript; this is acknowledged by the Angular team itself, considering the fact that *the Angular source code has been written using TypeScript since Angular 2*, as proudly announced by Microsoft in the following MDSN blog post in March 2015: <https://devblogs.microsoft.com/typescript/angular-2-built-on-typescript/>.

This was further emphasized in this great post by *Victor Savkin* (cofounder of Narwhal Technologies and acknowledged Angular consultant) on his personal blog in October 2016: <https://vsavkin.com/writing-angular-2-in-typescript-1fa77c78d8e8>.

Getting back to the `tsconfig.json` file, there's not much to say; the option values used by the Angular SPA template are more or less what we need to configure both Visual Studio and the **TypeScript compiler (TSC)** to properly transpile the TypeScript code files included in the `/ClientApp/` folder. However, while we're here, we can take the chance to tweak them a little more:

```
{  
  "compileOnSave": false,  
  "compilerOptions": {  
    "baseUrl": "./",  
    "module": "esnext",  
    "outDir": "./dist/out-tsc",  
    "sourceMap": true,  
    "declaration": false,  
    "moduleResolution": "node",  
    "emitDecoratorMetadata": true,  
    "experimentalDecorators": true,  
    "target": "es2015",  
    "typeRoots": [  
      "node_modules/@types"  
    ],  
    "lib": [  
      "es2017",  
      "dom"  
    ]  
  },  
  "angularCompilerOptions": {  
    "strictMetadataEmit": true  
  }  
}
```

As shown by the highlighted lines, we added a new `angularCompilerOptions` section, which can be used to configure the behavior of the Angular AoT compiler. More specifically, the `strictMetadataEmit` setting that we added will tell the compiler to report syntax errors immediately rather than produce a `.metadata.json` error log file. Such behavior can be easily turned off in production but comes in very handy during development.



For more info regarding the new Angular AoT compiler, read the following URL: <https://angular.io/guide/aot-compiler>.

Other workspace-level files

There are also other notable files created by the CLI in the workspace root. Since we'll not be changing them, we'll just briefly mention them in the following list:

- `.editorconfig`: Workspace-specific configuration for code editors.
- `.gitignore`: A text file that tells Git—a version-control system you most likely know quite well—which files or folders to ignore in the workspace: these are intentionally untracked files that shouldn't be added to the version control repository.
- `README.md`: Introductory documentation for the workspace. The `.md` extension stands for **Markdown**, a lightweight markup language created by *John Gruber* and *Aaron Swartz* in 2004.
- `package-lock.json`: Provides version information for all packages installed in the `/node_modules/` folder by the **npm** client. If you plan to replace **npm** with **Yarn**, you can safely delete this file (the `yarn.lock` file will be created instead).
- `/node_modules/`: A folder containing all the **npm** packages for the entire workspace: this folder will be populated with packages defined in the `package.json` file located on the workspace root, which will be visible to all projects.
- `tslint.json`: Default **TSLint** configuration options for all projects in the workspace. These general rules will be integrated and/or overwritten with the project-specific `tslint.json` file included in the project root folder.



TSLint is an extensible static analysis tool that checks TypeScript code for readability, maintainability, and functionality errors: it's very similar to **JSLint**, which performs the same tasks for JavaScript code. The tool is widely supported across modern editors and build systems and can be customized with your own lint rules, configurations, and formatters.

The /ClientApp/src/ folder

It's now time to pay a visit to our sample Angular app and see how it works. Rest assured, we won't stay for long; we just want to get a glimpse of what's under the hood.

By expanding the `/ClientApp/src/` directory, we can see that there are the following sub-folders:

- The `/ClientApp/src/app/` folder, along with all its subfolders, contains all the TypeScript files related to our Angular app: in other words, the whole *client-side* application source code is meant to be put here.
- The `/ClientApp/src/app/assets/` folder is meant to store all the application's images and other asset files: these files will be copied and/or updated *as-is* in the `/wwwroot/` folder whenever the application is built.
- The `/ClientApp/src/app/environment/` folder contains build configuration options that target specific environments: this template, just like any Angular new project default, includes an `environment.ts` file (for development) and an `environment.prod.ts` file (for production).

There is also a bunch of root-level files:

- `browserslist`: Configures the sharing of target browsers and Node.js versions among various *front-end* tools.
- `index.html`: The main HTML page that is served when someone visits your site. The CLI automatically adds all JavaScript and CSS files when building your app, so you typically don't need to add any `<script>` or `<link>` tags here manually.
- `karma.conf.js`: Application-specific *Karma* configuration. Karma is a tool used to run *Jasmine*-based tests: we can safely ignore the whole topic for now, as we'll get to it later on.
- `main.ts`: The main entry point for your application. Compiles the application with the JIT compiler and bootstraps the application's *root module* (`AppModule`) to run in the browser. You can also use the AOT compiler without changing any code by appending the `--aot` flag to CLI build and serve commands.
- `polyfills.ts`: Provides polyfill scripts for browser support.
- `styles.css`: A list of CSS files that supply styles for a project.
- `test.ts`: The main entry point for the project's unit tests.
- `tsconfig.*.json`: Project-specific configuration options for various aspects of our app: `.app.json` for *application-level*, `.server.json` for *server-level*, and `.specs.json` for *tests*. These options will override those set in the generic `tsconfig.json` file in the workspace root.
- `tslint.json`: The **TSLint** configuration for the current project.

The /app/ folder

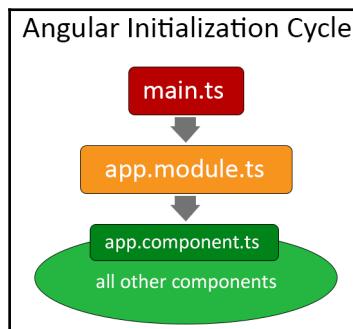
Our template's `/ClientApp/src/app/` folder follows Angular folder structure best practices and contains our project's logic and data, thus including all Angular *Modules*, *Services*, and *Components*, as well as *templates* and *styles*. It's also the only sub-folder worth investigating, at least for the time being.

AppModule

As we briefly anticipated in [chapter 1, Getting Ready](#), the basic building blocks of an Angular application are **NgModules**, which provide a compilation context for Components. The role of NgModules is to collect related code into functional sets: therefore, the whole Angular app is defined by a set of one or more NgModules.

An Angular app requires a *root module*—conventionally called `AppModule`—that tells Angular how to assemble the application, thus enabling bootstrapping and starting the initialization life cycle (see the diagram that follows). The remaining modules are known as **feature modules** and serve a different purpose. The *root module* also contains a reference list of all available **Components**.

The following is a schema of the standard **Angular Initialization Cycle**, which will help us better visualize how it works:



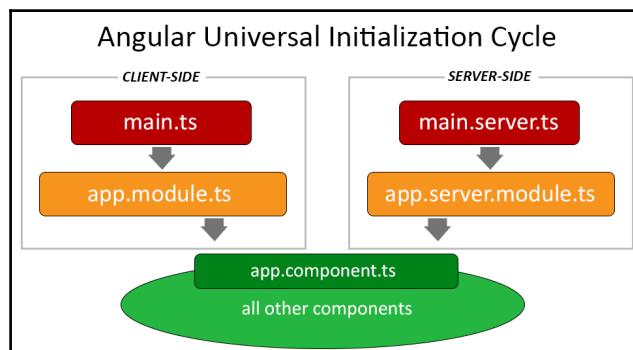
As we can see, the `main.ts` file bootstraps `app.module.ts` (`AppModule`), which then loads the `app.component.ts` file (`AppComponent`); the latter, as we'll see in a short while, will then load all the other Components whenever the application needs them.

The *root module* of the sample Angular app created by our template can be found in the `/ClientApp/src/app/` folder and is defined within the `app.module.ts` file. If we take a look at the source code, we can see that it contains a bunch of import statements and some arrays referencing *Components*, other *modules*, *providers*, and so on: this should be no mystery since we just said that the *root module* is basically a reference file.

Server-side AppModule for SSR

As we can see, the `/ClientApp/src/app/` folder also contains an `app.server.module.ts` file, which will be used to enable the **Angular Universal Server-Side Rendering (SSR)**—a technology that renders Angular applications on the server, provided that the *back-end* framework supports it. The template generated this file because .NET Core natively supports such convenient features.

The following is the improved Angular initialization schema when using SSR:



That's about it, at least for now. If you feel like you're still missing something here, don't worry—we'll come back to this soon enough to help you understand all of this better.



To avoid losing too much time on the theoretical aspects of .NET Core and Angular, we won't enter into the details of SSR. For a more detailed look at different techniques and concepts surrounding **Angular Universal** and SSR, we suggest checking out the following article:

<https://developers.google.com/web/updates/2019/02/rendering-on-the-web>.

AppComponent

If NgModules are Angular building blocks, **Components** can be defined as the bricks used to put the app together, to the extent that we can say that an Angular app is basically a tree of Components working together.

Components define **views**, which are sets of screen elements that Angular can choose among and modify according to your program logic and data, and use **services**, which provide specific functionality not directly related to views. **Service providers** can also be injected into Components as *dependencies*, thus making the app code modular, reusable, and efficient.

The cornerstone of these Components is conventionally called `AppComponent`, which is also the only Component that—according to Angular folder structure conventions—should be placed in the `/app/` root folder. All other Components should be put in a sub-folder, which will act as a dedicated *namespace*.

As we can see, our sample `AppComponent` consists of two files:

- `app.component.ts`: Defines the Component logic, that is, the Component class source code.
- `app.component.html`: Defines the HTML template associated with the `AppComponent`. Any Angular Component can have an optional HTML file containing its UI layout structure instead of defining it within the Component file itself. This is almost always a good practice unless the Component comes with a very minimal UI.

Since the `AppComponent` is often lightweight, it doesn't have other optional files that could be found in other Components, such as:

- `<*>.component.css`: Defines the base CSS style sheet for a Component. Just like the `.html` file, this file is optional and should always be used unless the component doesn't require UI styling.
- `<*>.component.spec.ts`: Defines a unit test for the Component.

Other components

Other than `AppComponent`, our template contains four more Components, each one in a dedicated folder, as follows:

- `CounterComponent`: Placed in the `counter` subfolder
- `FetchDataComponent`: Placed in the `fetch-data` subfolder

- HomeComponent: Placed in the home subfolder
- NavMenuComponent: Placed in the nav-menu subfolder

As we can see by looking at the source files within their respective subfolders, only one of them has some defined tests: CounterComponent, which comes with a `counter.component.spec.ts` file containing two tests. It might be useful to run them to see if the *Karma + Jasmine* testing framework that has been set up by our template actually works. However, before doing that, it might be wise to take a look at those Components to see how they are meant to function within the Angular app.

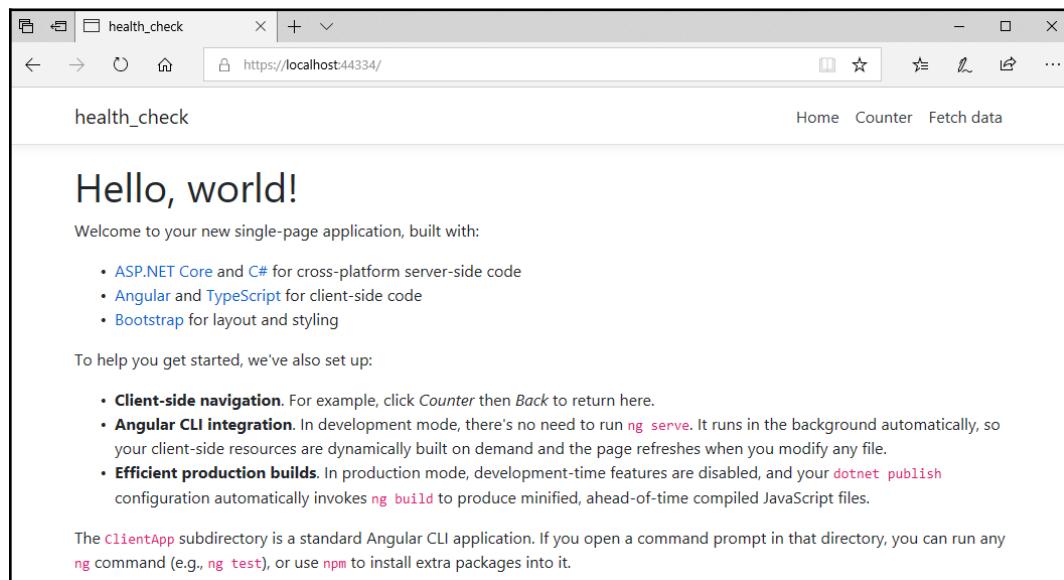
In the next sections, we'll take care of both of these tasks.

Testing the app

Let's start by taking a look at those Components to see how they are meant to work.

HomeComponent

As soon as we hit *F5* to run the app in *debug* mode, we'll be greeted by HomeComponent, as seen in the following screenshot:



As the name clearly suggests, the `HomeComponent` could be considered the *home page* of our app; however, since the *page* concept might be rather misleading when dealing with *single-page apps*, we'll call them *views* instead of *pages* throughout the book. The word *view* basically refers to the combined HTML template generated by the Angular Component (including all sub-Components) that corresponds to a given navigation *route*.

NavMenuComponent

Do we have sub-Components already? Yes, we do. The `NavMenuComponent` is a perfect example of that, since it doesn't have a dedicated *route* for itself but is rendered as part of other Components within their corresponding view.

More precisely, it's the top portion of each view, as we can see from the following screenshot:



The main purpose of the `NavMenuComponent` is to let users navigate through the main views of the app. In other words, it's where we implement all **first-level navigation routes** defined in `AppModule` , all pointing to a given Angular Component.

First-level navigation routes are those that we want our users to reach with a single click, that is, without having to navigate through other Components first. In the sample app we're reviewing now, there are three of them:

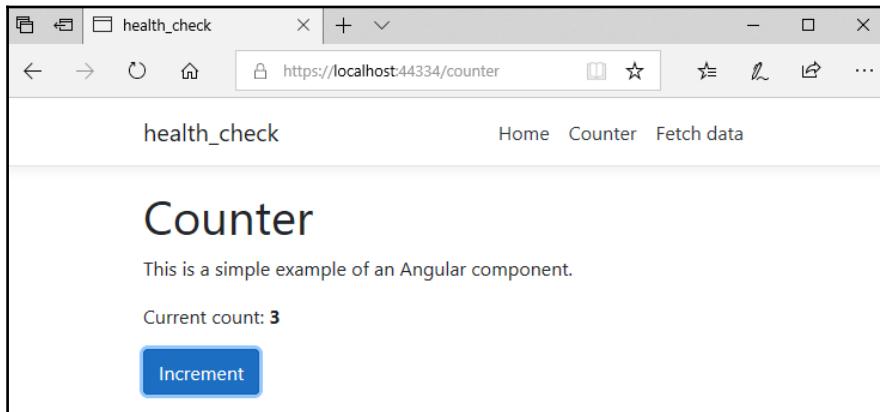
- `/home`: Pointing to the `HomeComponent`
- `/counter`: Pointing to the `CounterComponent`
- `/fetch-data`: Pointing to the `FetchDataComponent`

As we can see, these *navigation routes* have been implemented in the `NavMenuComponent` by using anchor links placed within a single unordered list: a bunch of `<a>` elements placed inside a `` / `` structure, which is rendered on the right-hand side of the Component—and at the top-right corner of any Component containing it.

Let's now review the designed to handle the two remaining *first-level navigation routes*: `CounterComponent` and `FetchDataComponent` .

CounterComponent

The CounterComponent shows an incrementing counter that we can increase by pressing an **Increment** button:



The FetchDataComponent is an interactive table populated with the JSON array generated by the *server-side* Web API via WeatherForecastController, which we saw a while ago when we were examining the *back-end* part of our project:

A screenshot of a Microsoft Edge browser window. The title bar says "health_check". The address bar shows "https://localhost:44334/fetch-data". The page content is titled "Weather forecast". It contains the text "This component demonstrates fetching data from the server." followed by a table with five rows of weather forecast data.

Date	Temp. (C)	Temp. (F)	Summary
2019-08-17T02:57:41.2775478+02:00	1	33	Bracing
2019-08-18T02:57:41.2775817+02:00	8	46	Chilly
2019-08-19T02:57:41.2775822+02:00	5	40	Warm
2019-08-20T02:57:41.2775825+02:00	43	109	Sweltering
2019-08-21T02:57:41.2775828+02:00	5	40	Chilly

The specs.ts file(s)

If we take a look at the source files within the above Component's subfolders, we can see that the CounterComponent comes with a `counter.component.spec.ts` file. Those files, as per the Angular naming convention, are meant to contain **unit tests** for the `counter.component.ts` source file and are run using the *Jasmine* JavaScript test framework through the *Karma* test runner.

For additional info regarding *Jasmine* and *Karma*, check out the following guides:



Jasmine:

<https://jasmine.github.io/>

Karma:

<https://karma-runner.github.io/>

Angular Unit Testing:

<https://angular.io/guide/testing>

While we're there, it could be useful to give them a run them to see if the *Jasmine* + *Karma* testing framework that has been set up by our template actually works.

Our first app test

Before running the test, it may be useful to understand a little more about *Jasmine* and *Karma*. If you don't know anything about them, don't worry—you will soon. For now, just know that **Jasmine** is an open source testing framework for JavaScript that can be used to define *tests*, while **Karma** is a test runner tool that automatically spawns a web server that will execute JavaScript source code against *Jasmine*-made *tests* and output their respective (and combined) results on a command line.

In this quick test, we'll basically launch **Karma** to execute the source code of our sample Angular app against the **Jasmine** *tests* defined by the template in the `counter.component.spec.ts` file: this is actually a much easier task than it might seem.

Open a Command Prompt, navigate to the `<project>/ClientApp/` folder, then execute the following command:

```
> npm run ng test
```

This will call the Angular CLI using **npm**.

Alternatively, we can install the Angular CLI globally using the following command:

```
> npm install -g @angular/cli
```

Once done, we'll be able to directly call it in the following way:

```
> ng test
```



In the unlikely event that the `npm` command returns a program not found error, check that the `Node.js/npm` binary folder is properly set within the `PATH` variable. If it's not there, be sure to add it, then close and re-open the command-line window and try again.

Right after we hit *Enter*, a new browser window should open with the Karma console and a list of results for the Jasmine tests, as shown in the following screenshot:

The terminal window shows the command `ng test` being run, followed by the Node.js output of the Karma test runner. The browser window shows the Karma v4.1.0 interface connected to a Chrome browser. The test results for a `Counter` component are displayed, showing 2 specs, 0 failures, and a seed of 57441. The component code is shown with two test cases: `should start with count 0, then increments by 1 when clicked` and `should display a title`. The current count is 0, and there is an `Increment` button.

```
C:\Projects\health-check\ClientApp>npm run ng test
> health_check@0.0.0 ng C:\Projects\health-check\ClientApp
> ng "test"

10% building 2/2 modules 0 active16 08 2019 01:07:19.337 WARN [karma]: No captured browser, open http://localhost:9876/
16 08 2019 01:07:19.413 INFO [launcher]: Launching browsers Chrome with concurrency unlimited
16 08 2019 01:07:19.418 INFO [launcher]: Starting browser Chrome
16 08 2019 01:07:23.685 INFO [Chrome 76.0.3809 (Windows 10.0.0)]: Connected on socket xao7oY4AddCGhAvAAAA with id 47171050
Chrome 76.0.3809 (Windows 10.0.0): Executed 2 of 2 SUCCESS (0.192 secs / 0.088 secs)
TOTAL: 2 SUCCESS

Karma v4.1.0 - connected
Chrome 76.0.3809 (Windows 10.0.0) is idle
Jasmine 3.3.0
2 specs, 0 failures, randomized with seed 57441
finished in 0.106s
```



IMPORTANT: At the time of writing, there's a critical path error in the template-generated `angular.json` file that will prevent any test from running. To fix it, open that file, scroll down to line #74 (**Project | HealthCheck | Test | Options | Styles**) and change the `styles.css` value with `src/styles.css`.

As we can see, both tests have been completed successfully—that's everything we need to do for now. There's no need to peek at the `counter.component.specs.ts` source code since we're going to ditch it—together with all the template Components—and create new ones (with their own tests).



For the sake of simplicity, we're going to stop here with Angular app tests for the time being; we'll discuss them in far greater depth in Chapter 9, *ASP.NET Core and Angular Unit Testing*.

Getting to work

Now that we've got a general picture of our new project, it's time to do something. Let's start with two simple exercises that will also come in handy in the future: the first one of them will involve the *server-side* aspects of our application, while the second will be performed on the *client side*. Both will help us discover whether we have really understood everything there is to know before proceeding to subsequent chapters.

Static file caching

Let's start with the *server-side* task. Do you remember the `/wwwroot/test.html` file we added when we wanted to check how the `StaticFiles` middleware works? We will use it to do a quick demonstration of how our application will internally cache static files.

The first thing we have to do is to run the application in *debug* mode (by clicking on the **Run** button or pressing the *F5* key) and put the following URL in the address line, so we can have another good look at it: `http://localhost:<port>/test.html`

Right after that, without stopping the application, open the `test.html` file and add the following lines to the existing content (new lines are highlighted):

```
<!DOCTYPE html>
<html>
<head>
    <meta charset="utf-8" />
    <title>Time for a test!</title>
</head>
<body>
```

```
Hello there!  
<br /><br />  
This is a test to see if the StaticFiles middleware is working  
properly.  
<br /><br />  
What about the client-side cache? Does it work or not?  
</body>  
</html>
```

Save the file, then go back to the browser address bar and press *Enter* again to issue another HTTP request to the `test.html` file. Ensure that you don't use *F5* or the *Refresh* button, as it will force a page refresh on the part of the server, which is not what we want; we'll see that the preceding changes won't be reflected by our browser, which means that we hit a *client-cached* version of that page.

Caching static files on clients can be a good thing in production servers, but is definitely annoying during development. Luckily enough, the in-memory `AngularCliServer` provided by the `Spa` middleware during development will automatically fix this issue for all TypeScript files, and also for all static assets, that we serve through Angular itself. However, what about those served via the *back-end*? We'll most likely have some static HTML files, favicons, image files, audio files, and other things that we would like to be directly served by the web server.

Is there a way to *fine-tune* the caching behavior for static files? If so, can we also set up different behaviors for the debug/development and release/production scenarios?

The answer is Yes, to both questions. Let's see how we can do that.

A blast from the past

Back in ASP.NET 4, we can easily disable static file caching by adding some lines to our main application's `Web.config` file, such as the following:

```
<caching enabled="false" />  
<staticContent>  
  <clientCache cacheControlMode="DisableCache" />  
</staticContent>  
<httpProtocol>  
  <customHeaders>  
    <add name="Cache-Control" value="no-cache, no-store" />  
    <add name="Pragma" value="no-cache" />  
    <add name="Expires" value="-1" />  
  </customHeaders>  
</httpProtocol>
```

That's it; we could even restrict such behavior to the *debug* environment by adding these lines to the `Web.debug.config` file.

We can't use the same approach in .NET Core, as the configuration system has been redesigned from scratch and is now quite different from the previous versions; as we said earlier, the `Web.config` and `Web.debug.config` files have been replaced by the `appsettings.json` and `appsettings.Development.json` files, which also work in a completely different way. Now that we understand the basics, let's see whether we can solve that caching issue by taking advantage of the new configuration model.

Back to the future

The first thing to do is to understand how we can modify default HTTP headers for static files. As a matter of fact, we can do that by adding a custom set of configuration options to the `app.UseStaticFiles()` method call in the `Startup.cs` file that adds the `StaticFiles` middleware to the HTTP request pipeline.

In order to do that, open `Startup.cs`, scroll down to the `Configure` method, and replace that single line with the following code (new/modified lines are highlighted):

```
app.UseStaticFiles(new StaticFileOptions()
{
    OnPrepareResponse = (context) =>
    {
        // Disable caching for all static files.
        context.Context.Response.Headers["Cache-Control"] =
            "no-cache, no-store";
        context.Context.Response.Headers["Pragma"] =
            "no-cache";
        context.Context.Response.Headers["Expires"] =
            "-1";
    }
});
```

That wasn't hard at all; we just added some additional configuration values to the method call, wrapping them all within a dedicated `StaticFileOptions` object instance.

However, we're not done yet; now that we've learned how to change the default behavior, we just need to change these static values with some convenient references pointing to the `appsettings.Development.json` file. To do that, we can add the following *key/value* section to the `appsettings.Development.json` file in the following way (new lines highlighted):

```
{  
    "Logging": {  
        "LogLevel": {  
            "Default": "Debug",  
            "System": "Information",  
            "Microsoft": "Information"  
        }  
    },  
    "StaticFiles": {  
        "Headers": {  
            "Cache-Control": "no-cache, no-store",  
            "Pragma": "no-cache",  
            "Expires": "-1"  
        }  
    }  
}
```

Then change the preceding `Startup.cs` code accordingly (modified lines are highlighted):

```
app.UseStaticFiles(new StaticFileOptions()  
{  
    OnPrepareResponse = (context) =>  
    {  
        // Retrieve cache configuration from appsettings.json  
        context.Context.Response.Headers["Cache-Control"] =  
            Configuration["StaticFiles:Headers:Cache-Control"];  
        context.Context.Response.Headers["Pragma"] =  
            Configuration["StaticFiles:Headers:Pragma"];  
        context.Context.Response.Headers["Expires"] =  
            Configuration["StaticFiles:Headers:Expires"];  
    }  
});
```

Ensure that you add these values to the non-development version of the `appsettings.json` file as well, otherwise, the application won't find them (when executed outside a development environment) and will throw an error.

Since this will most likely happen in a production environment, we can risk relaxing these caching policies a bit:

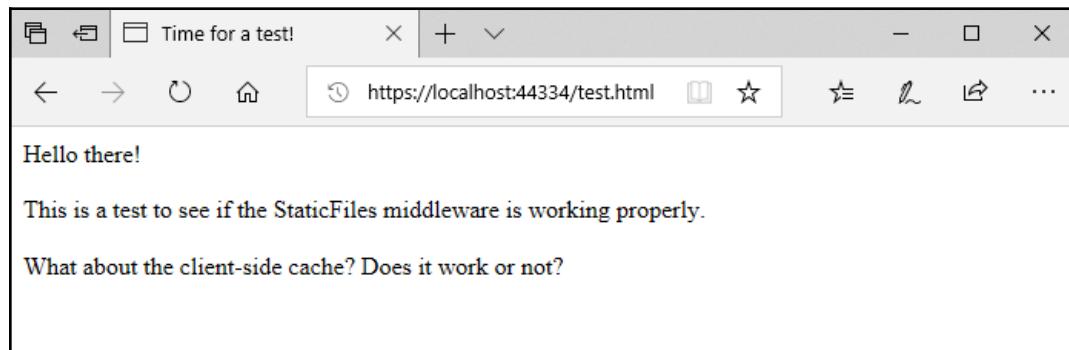
```
{  
    "Logging": {  
        "LogLevel": {  
            "Default": "Warning"  
        }  
    },  
    "AllowedHosts": "*",  
    "StaticFiles": {  
        "Headers": {  
            "Cache-Control": "max-age=3600",  
            "Pragma": "cache",  
            "Expires": null  
        }  
    }  
}
```

That's about it. Learning how to use this pattern is strongly advisable, as it's a great and effective way to properly configure our application's settings.

Testing it out

Let's see whether our new caching strategy works as expected. Run the application in *debug* mode, and then issue a request to the `test.html` page by typing the following URL in the browser address bar `http://localhost:/test.html`

We should be able to see the updated contents with the phrase we wrote earlier; if not, press *F5* in the browser to force page retrieval from the server:



Now, without stopping the application, edit the `test.html` page and update its contents in the following way (updated lines are highlighted):

```
<!DOCTYPE html>
<html>
<head>
    <meta charset="utf-8" />
    <title>Time for a test!</title>
</head>
<body>
    Hello there!
    <br /><br />
    This is a test to see if the StaticFiles middleware is working
    properly.
    <br /><br />
    What about the client-side cache? Does it work or not?
    <br /><br />
It seems like we can configure it: we disabled it during
development, and enabled it in production!
</body>
</html>
```

Right after that, go back to the browser, select the address bar, and press *Enter*; again, do not press the *Refresh* button or the *F5* key, or we'll have to start over. If everything worked properly, we will immediately see the updated contents on-screen:



We did it! Our *server-side* task was successfully completed.

The strongly-typed approach(es)

The approach that we chose to retrieve the `appsettings.json` configuration values makes use of the generic `IConfiguration` object, which can be queried using the preceding string-based syntax. This approach is rather practical; however, if we want to retrieve this data in a more robust way, for example, in a *strongly typed* fashion, we can—and *should*—implement something better. Although we won't cover that in more depth in this book, we suggest you read the following great articles, showing three different approaches to achieving this result:

The first one, written by *Rick Strahl*, explains how to do that using the `IOptions<T>` provider interface:

<https://weblog.west-wind.com/posts/2016/may/23/strongly-typed-configuration-settings-in-aspnet-core>

The second, by *Filip W*, explains how to do that with a simple POCO class, thus avoiding the `IOptions<T>` interface and the extra dependencies required by the preceding approach:

<https://www.strathweb.com/2016/09/strongly-typed-configuration-in-asp-net-core-without-ioptions/>

The third, by *Khalid Abuhakmeh*, shows an alternative way to use a standard POCO class and directly register it as a Singleton with the `ServicesCollection`, while also (optionally) shielding it from unwanted modifications due to development mistakes:

<https://rimdev.io/strongly-typed-configuration-settings-in-asp-net-core-part-ii/>

All of these approaches were originally meant to work with .NET Core 1.x; however, they can still be used with .NET Core 3.x (at the time of writing). That said, if we were to choose, we would probably go with the final option, as we find it to be the cleanest and cleverest.

Client app cleanup

Now that our *server-side* journey has come to an end, it's time to challenge ourselves with a quick *client-side* exercise. Don't worry—it will be just a rather trivial demonstration of how we can update the Angular source code that lies within the `/ClientApp/` folder to better suit our needs. More specifically, we will remove all the stuff we don't need from the sample Angular app shipped with our chosen Angular SPA template and replace it with our own content.



We can never say it enough, so it's worth repeating again: The sample source code explained in the following sections is taken from the **ASP.NET Core with Angular (C#)** project template originally shipped with the *.NET Core 3 SDK*; since it might be updated in the future, it's important to check it against the code published in this book's GitHub repo. If you find relevant differences between the book's code and yours, feel free to get the one from the repository and use that instead.

Trimming down the Component list

The first thing we have to do is delete Angular Components we don't want to use.

Go to the `/ClientApp/src/app/` folder and delete the `counter` and the `fetch-data` folders, together with all the files they contain.



Although they can still be used as valuable code samples, keeping these Components within our client code will eventually confuse us, hence it's better to delete them in order to prevent the Visual Studio TypeScript compiler from messing with the `.ts` files contained there. Don't worry—we'll still be able to check them out via the book's GitHub project.

As soon as we do that, the Visual Studio **Error List** view will immediately raise two blocking TypeScript-based issues:

```
Error TS2307 (TS) Cannot find module './counter/counter.component'.
Error TS2307 (TS) Cannot find module './fetch-data/fetch-
data.component'.
```

All of these errors will point to the `app.module.ts` file, which, as we already know, contains the references of all the TypeScript files used by our Angular application. If we open the file, we'll immediately be able to see the issues:

```
1 import { BrowserModule } from '@angular/platform-browser';
2 import { NgModule } from '@angular/core';
3 import { FormsModule } from '@angular/forms';
4 import { HttpClientModule, HTTP_INTERCEPTORS } from '@angular/common/http';
5 import { RouterModule } from '@angular/router';
6
7 import { AppComponent } from './app.component';
8 import { NavMenuComponent } from './nav-menu/nav-menu.component';
9 import { HomeComponent } from './home/home.component';
10 import { CounterComponent } from './counter/counter.component';
11 import { FetchDataComponent } from './fetch-data/fetch-data.component';
12
13 @NgModule({
14   declarations: [
15     AppComponent,
16     NavMenuComponent,
17     HomeComponent,
18     CounterComponent,
19     FetchDataComponent
20   ],
21   imports: [
22     BrowserModule.withServerTransition({ appId: 'ng-cli-universal' }),
23     HttpClientModule,
24     FormsModule,
25     RouterModule.forRoot([
26       { path: '', component: HomeComponent, pathMatch: 'full' },
27       { path: 'counter', component: CounterComponent },
28       { path: 'fetch-data', component: FetchDataComponent },
29     ])
30   ],
31   providers: [],
32   bootstrap: [AppComponent]
33 })
34 export class AppModule { }
```

In order to fix them, we need to remove the two offending `import` references (lines 10-11); right after that, two more errors will appear:

```
Error TS2304 (TS) Cannot find name 'CounterComponent'.
Error TS2304 (TS) Cannot find name 'FetchDataComponent'.
```

This can be fixed by removing the two offending Component names from the declarations array (lines 18-19, which became 16-17 after the previous deletion) and from the RouterModule configuration (lines 27-28, or 25-26 after the deletion).

Once done, our updated `app.module.ts` file should look like this:

```
import { BrowserModule } from '@angular/platform-browser';
import { NgModule } from '@angular/core';
import { FormsModule } from '@angular/forms';
import { HttpClientModule, HTTP_INTERCEPTORS } from
  '@angular/common/http';
import { RouterModule } from '@angular/router';

import { AppComponent } from './app.component';
import { NavMenuComponent } from './nav-menu/nav-menu.component';
import { HomeComponent } from './home/home.component';

@NgModule({
  declarations: [
    AppComponent,
    NavMenuComponent,
    HomeComponent
  ],
  imports: [
    BrowserModule.withServerTransition({ appId: 'ng-cli-universal' }),
    HttpClientModule,
    FormsModule,
    RouterModule.forRoot([
      { path: '', component: HomeComponent, pathMatch: 'full' }
    ])
  ],
  providers: [],
  bootstrap: [AppComponent]
})
export class AppModule { }
```

Since we're here, those who don't know how Angular works should spend a couple of minutes understanding how an `AppModule` class actually works.

The AppModule source code

Angular **modules**, also known as **NgModules**, were introduced in Angular 2 RC5 and are a great, powerful way to organize and bootstrap any Angular application; they help developers consolidate their own set of **Components**, **directives**, and **pipes** into *reusable* blocks. As we said previously, every Angular application since v2 RC5 must have at least one module, which is conventionally called a *root module* and is thus given the `AppModule` class name.

`AppModule` is usually split into two main code blocks:

- A list of **import** statements, pointing to all the references (in the form of TypeScript files) required by the application.
- The root `NgModule` block, which—as we can see—is basically an array of named arrays, each one containing a set of Angular objects that serve a common purpose: **directives**, **components**, **pipes**, **modules**, **providers**, and so on. The last one contains the Component we want to bootstrap, which in most scenarios—including ours—is the main application Component, the `AppComponent`.

Updating the NavMenu

If we run our project in *debug* mode, we can see that our recent code changes—the deletion of those two *Components*—do not prevent the client app from booting properly. We didn't break it this time—yay! However, if we try to use the navigation menu to go to the Counter and/or Fetch data by clicking the links from the main view, nothing will happen. This is hardly a surprise since we just moved these Components out of the way. To avoid confusion, let's remove these links from the menu as well.

Open the `/ClientApp/app/components/nav-menu/nav-menu.component.html` file, which is the UI template for the `NavMenuItemComponent`. As we can see, it does contain a standard HTML structure containing the header part of our app's main page, including the main menu.

It shouldn't be difficult to locate the HTML part we need to delete to remove the links to CounterComponent and FetchDataComponent—both of them are contained within a dedicated HTML `` element:

```
[...]  
  
<li class="nav-item" [routerLinkActive]=["link-active"]>  
  <a class="nav-link text-dark" [routerLink]=["/counter"]>  
    Counter</a>  
  >  
</li>  
<li class="nav-item" [routerLinkActive]=["link-active"]>  
  <a class="nav-link text-dark" [routerLink]=["/fetch-data"]>  
    Fetch data</a>  
  >  
</li>  
  
[...]
```

Delete the two `` elements and save the file.

Once done, the updated HTML structure of the NavMenuComponent code should look as follows:

```
<header>  
  <nav  
    class="navbar navbar-expand-sm navbar-toggleable-sm navbar-light  
    bg-white border-bottom box-shadow mb-3">  
    <div class="container">  
      <a class="navbar-brand" [routerLink]=["/'"]>HealthCheck</a>  
      <button  
        class="navbar-toggler"  
        type="button"  
        data-toggle="collapse"  
        data-target=".navbar-collapse"  
        aria-label="Toggle navigation"  
        [attr.aria-expanded]="isExpanded"  
        (click)="toggle()">  
      <span class="navbar-toggler-icon"></span>  
    </button>  
    <div  
      class="navbar-collapse collapse d-sm-inline-flex flex-sm-row-reverse"  
      [ngClass]="{{ show: isExpanded }}>
```

```
<ul class="navbar-nav flex-grow">
  <li
    class="nav-item"
    [routerLinkActive]=["link-active"]
    [routerLinkActiveOptions]={ exact: true }>
    <a class="nav-link text-dark"
      [routerLink]=["'/'"]>Home</a>
  </li>
</ul>
</div>
</div>
</nav>
</header>
```

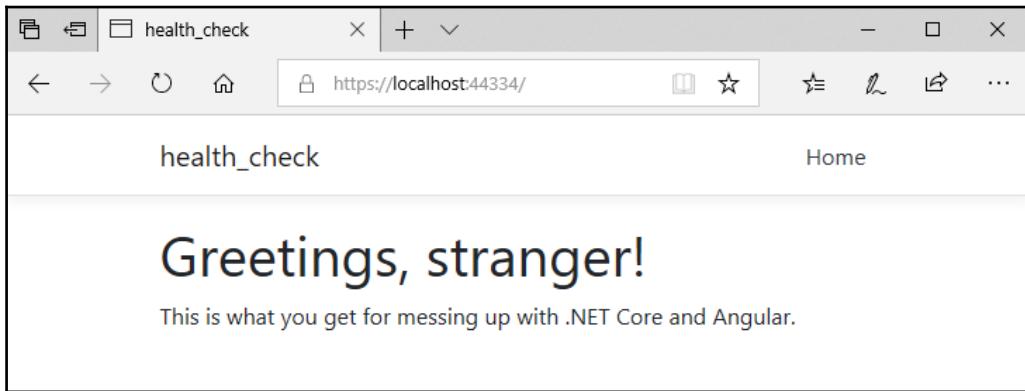
While we're here, let's take the chance to get rid of something else. Do you remember the `Hello, World!` introductory text shown by the browser when we first ran the project? Let's replace it with our own content.

Open the `/ClientApp/src/app/components/home/home.component.html` file and replace its whole content with the following:

```
<h1>Greetings, stranger!</h1>

<p>This is what you get for messing up with .NET Core and Angular.</p>
```

Save, run the project in *debug* mode, and get ready to see the following:



The Counter and Fetch data menu links are gone, and our Home View welcome text couldn't be sleeker.

Now that we've removed any references from the *front-end*, we can do the same with the following *back-end* files, which we don't need anymore:

- WeatherForecastController.cs
- Controllers/WeatherForecastController.cs

Locate these two files using Visual Studio's **Solution Explorer** and delete them.



It's worth noting that, once we do that, we won't have any .NET controllers available in our web application anymore; that's perfectly fine since we don't have Angular Components that need to fetch data either. Don't worry, though—we're going to add them back in upcoming chapters!

That's about it for now. Rest assured, we can easily do the same with other Components and completely rewrite their text, including the navigation menu; we'll do that in the following chapters, where we'll also update the UI layout, add new Components, and so on. For the time being, understanding how easy it is to change the content—and also how rapidly Visual Studio, ASP.NET Core, and Angular will react to our modifications—is good enough.

Summary

In this second chapter, we spent some valuable time exploring and understanding our sample project's core Components, how they work together, and their distinctive roles. For the sake of simplicity, we split the analysis into two parts: the .NET Core *back-end* ecosystem and the Angular *front-end* architecture, each with its own configuration files, folder structure, naming conventions, and overall scope.

At the end of the day, we can definitely say that we met the end goal of this chapter and learned a fair amount of useful things: we know the location and purpose of both *server-side* and *client-side* source code files; we are able to remove existing content and insert new stuff; we are aware of the caching system and other setup parameters; and so on.

Last but not least, we also took the time to perform some quick tests to see whether we're ready to hold our ground against what's coming in upcoming chapters: setting up an improved request-response cycle, building our own controllers, defining additional routing strategies, and more.

Suggested topics

Razor Pages, separation of concerns, the single responsibility principle, JSON, web hosts, Kestrel, OWIN, middlewares, Dependency Injection, the Angular workspace, Jasmine, Karma, unit tests, **Server-Side Rendering (SSR)**, TypeScript, Angular architecture, the Angular initialization cycle, browser cache, and client cache.

References

- *Introduction to ASP.NET Core*: <https://docs.microsoft.com/en-us/aspnet/core/>
- *Angular: Setting up the Local Environment and Workspace*: <https://angular.io/guide/setup-local>
- *Angular architecture overview*: <https://angular.io/guide/architecture>
- *TypeScript - Modules*: <https://www.typescriptlang.org/docs/handbook/modules.html>
- *TypeScript - Module Resolution*: <https://www.typescriptlang.org/docs/handbook/module-resolution.html>
- *Karma*: <https://karma-runner.github.io/>
- *Jasmine*: <https://jasmine.github.io/>
- *Angular - Testing*: <https://angular.io/guide/testing>
- *Strongly Typed Configuration Settings in ASP.NET Core*: <https://weblog.west-wind.com/posts/2016/may/23/strongly-typed-configuration-settings-in-aspnet-core>
- *Strongly typed configuration in ASP.NET Core without IOptions<T>*: <https://www.strathweb.com/2016/09/strongly-typed-configuration-in-asp-net-core-without-options/>
- *Strongly Typed Configuration Settings in ASP.NET Core Part II*: <https://rimdev.io/strongly-typed-configuration-settings-in-asp-net-core-part-ii/>

3

Front-end and Back-end Interactions

Now that we have a minimalistic—yet fully working—.NET Core 3 and Angular 8 web app up and running, we can definitely start to build some stuff. In this chapter, we're going to learn the basics of client-side and server-side interactions: in other words, how the *front-end* (Angular) can fetch some relevant data from the *back-end* (.NET Core) and display it on-screen, in a readable fashion.

Wait a minute... As a matter of fact, we should've already got the gist of how it works, right? We saw this in [Chapter 2, Looking Around](#), before getting rid of Angular's `FetchDataComponent` and .NET Core's `WeatherForecastController.cs` classes and files. The Angular Component (*front-end*) pulls data from the .NET Controller (*back-end*) and then puts it on the browser screen (UI) for display.

Such a statement is absolutely correct. However, Controllers aren't the only way for our .NET Core *back-end* to serve data to the *front-end*: it can also serve static files, Razor Pages, and any other middleware designed to handle requests and output a response stream or content of some sort, as long as we add it into our application pipeline. Such a highly modular approach is one of the most relevant concepts of .NET Core. In this chapter, we'll make use of that by introducing (and playing with) a built-in middleware that has little or nothing to do with .NET Controllers, although being able to deal with requests and responses just like they do: the `HealthChecksMiddleware`.

Here's a quick breakdown of what we're going to achieve:

- **Introducing .NET Core health checks:** What they are and how we can use them to learn some useful concepts about .NET Core and Angular interactions.
- **HealthCheckMiddleware:** How to properly implement it within our .NET Core *back-end*, configure it within our web application's pipeline, and output a JSON-structured message that can be used by our Angular app.
- **HealthCheckComponent:** How to build an Angular Component to fetch the `HealthCheck` structured data from the .NET Core *back-end* and bring them all to the *front-end* in a human-readable fashion.

Are you ready? Let's do this!

Technical requirements

In this chapter, we're going to need all the previous technical requirements listed in the previous chapters, with no additional resources, libraries, or packages.

The code files for this chapter can be found here: https://github.com/PacktPublishing/ASP.NET-Core-3-and-Angular-9-Third-Edition/tree/master/Chapter_03/.

Introducing .NET Core health checks

We called our first project `HealthCheck` for a reason: the web app we're about to build will act as a monitoring and reporting service that will check the *health* status of a target server—and/or its infrastructure—and show it on-screen in real time.

In order to do that, we're going to make good use of the `Microsoft.AspNetCore.Diagnostics.HealthChecks` package, a built-in feature of the .NET Core framework first introduced in 2.2, and then refined and improved for the 3.0 release. This package is meant to be used to allow a monitoring service to check the status of another running service—for example, another web server, which is precisely what we're about to do.



For additional information about .NET Core health checks, we strongly suggest reading the official MS documentation at the following URL:

<https://docs.microsoft.com/en-us/aspnet/core/host-and-deploy/health-checks?view=aspnetcore-3.0>.

Adding the HealthChecks middleware

The first thing we need to do is to add the `HealthChecks` middleware to our web app. This can be done in the following way:

1. Open the `Startup.cs` file.
2. Add the following lines to the `ConfigureServices` method:

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddControllersWithViews();
    // In production, the Angular files will be served
    // from this directory
    services.AddSpaStaticFiles(configuration =>
    {
        configuration.RootPath = "ClientApp/dist";
    });

    services.AddHealthChecks();
}
```

3. And the following lines to the `Configure` method:

```
public void Configure(IApplicationBuilder app,
IWebHostEnvironment env)
{
    // ...existing code...

    app.UseRouting();

    app.UseHealthChecks("/hc");

    app.UseEndpoints(endpoints =>
{
    endpoints.MapControllerRoute(
        name: "default",
        pattern: "{controller}/{action=Index}/{id?}");
});
```

```
// ...existing code...
}
```



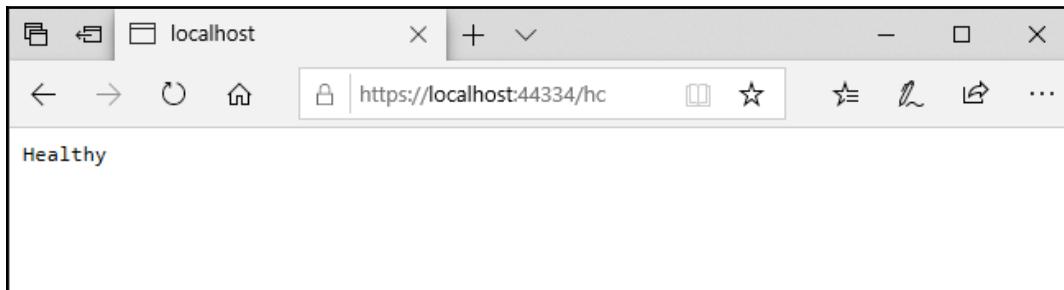
The `// ...existing code...` comment is just a way to tell us to leave the already existing code as it is, without altering it. We're going to use that *keyword* whenever we need to add a few lines of code to an existing block instead of rewriting the unmodified lines—thus saving some valuable space!

The `/hc` parameters we passed to the `UseHealthChecks` middleware will create a server-side route for the health checks. It's also worth noting that we added that middleware right before `UseEndpoints` so that our new route won't be overridden by the general-purpose Controller route pattern specified there.

We can immediately check out the new route by doing the following:

1. Press *F5* so that our web application will run in *debug* mode.
2. Manually type `/hc` at the end of the starting URL and hit *Enter*.

As soon as we do that, we should be able to see something like this:



As we can see, our system is `Healthy`: that's rather obvious since we have no checks defined yet.

How about adding one? That's what we're going to do in the next section.

Adding an Internet Control Message Protocol (ICMP) check

The first check we're going to implement is one of the most popular ones: an **Internet Control Message Protocol (ICMP)** request check to an external host, also known as **PING**.

As we most likely already know, a PING request is a rather basic way to check the presence—and therefore the availability—of a server that we know we should be able to reach within a **local area network (LAN)** or **wide area network (WAN)** connection. In a nutshell, it works in the following way: the machine that performs the PING sends one or more ICMP echo request packets to the target host and waits for a reply; if it receives it, it reports the round-trip time of the whole task; otherwise, it times out and reports a `host not reachable` error.

The `host not reachable` error can be due to a number of possible scenarios, as listed here:

- The target host is **not available**.
- The target host is **available, but actively refuses TCP/IP connections** of any kind.
- The target host is **available and accepts TCP/IP incoming connections, but it has been configured to explicitly refuse ICMP requests** and/or not send ICMP echo replies back.
- The target host is **available and properly configured to accept ICMP requests and send echo replies back, but the connection is very slow or hindered** by unknown reasons (performance, heavy load, and so on), so the round-trip time takes too long—or even times out.

As we can see, this is an ideal scenario for a health check: if we properly configure the target host to accept the PING and always answer to it, we can definitely use it to determine whenever the host is in a healthy status or not.

Possible outcomes

Now that we know the common scenarios behind a PING test request, we can put down a list of possible outcomes, as follows:

- **Healthy:** We can consider the host `Healthy` whenever the PING succeeded with no errors and timeouts.
- **Degraded:** We can consider the host `Degraded` whenever the PING succeeded, but the round-trip takes too long.
- **Unhealthy:** We can consider the host `Unhealthy` whenever the PING failed—that is, the check times out before any reply.

Now that we've identified these three *statuses*, we just need to properly implement them within our health check.

Creating an `ICMPHealthCheck` class

The first thing we have to do is create a new `ICMPHealthCheck.cs` class in our project's root folder.

Once done, fill it with the following content:

```
using Microsoft.Extensions.Diagnostics.HealthChecks;
using System;
using System.Net.NetworkInformation;
using System.Threading;
using System.Threading.Tasks;

namespace HealthCheck
{
    public class ICMPHealthCheck : IHealthCheck
    {
        private string Host = "www.does-not-exist.com";
        private int Timeout = 300;

        public async Task<HealthCheckResult> CheckHealthAsync(
            HealthCheckContext context,
            CancellationToken cancellationToken = default)
        {
            try
            {
                using (var ping = new Ping())
                {
                    var reply = await ping.SendPingAsync(Host);

```

```
        switch (reply.Status)
    {
        case IPStatus.Success:
            return (reply.RoundtripTime > Timeout)
                ? HealthCheckResult.Degraded()
                : HealthCheckResult.Healthy();

        default:
            return HealthCheckResult.Unhealthy();
    }
}
catch (Exception e)
{
    return HealthCheckResult.Unhealthy();
}
}
```

As we can see, we implemented the `IHealthCheck` interface since it's the .NET official way to deal with health checks: such an interface requires a single `async` method—`CheckHealthAsync`—which we used to determine if the ICMP request was successful or not.

The code is very easy to understand and handles the three possible scenarios we defined in the previous section. Let's go over what the host can be considered to be:

- **Healthy**, if the PING request gets a successful reply with a round-trip time of 300 ms or less
- **Degraded**, if the PING request gets a successful reply with a round-trip time greater than 300 ms
- **Unhealthy**, if the PING request fails or an `Exception` is thrown



Notice that the host is hardcoded to a non-existing name, which is rather awkward! Don't worry! We did that for demonstration purposes so that we'll be able to simulate an *unhealthy* scenario: we're going to change it later on.

That's pretty much it. Our health check is ready to be tested—we just need to find a way to *load* it into our web application's pipeline.

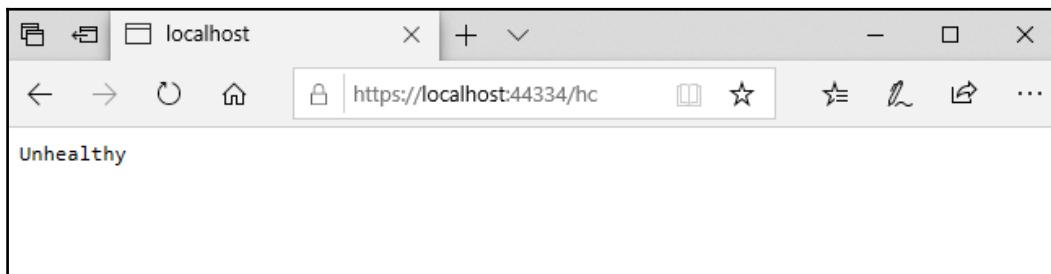
Adding the ICMPHealthCheck to the pipeline

In order to load our ICMP health check into the web application pipeline, we need to add it to the `HealthChecks` middleware. To do that, open the `Startup.cs` class again and change the line we previously added to the `ConfigureServices` method in the following way:

```
public void ConfigureServices(IServiceCollection services)
{
    /// ...existing code...

    services.AddHealthChecks()
        .AddCheck<ICMPHealthCheck>("ICMP");
}
```

That's it: now, we can hit *F5* and try it out. Here's what we should be able to see:



That's great, right?

Well, actually, not that great. Our health check does indeed work, but comes with the following three major flaws:

- **Hardcoded values:** The `Host` and the `Timeout` variables should be passed as parameters so that we can set them programmatically.
- **Uninformative response:** `Healthy` and `Unhealthy` are not that great—we should find a way to have a custom (and better) output message instead.
- **Untyped output:** The current response is being sent in plain text—if we want to fetch it with Angular, a JSON content-type would definitely be better (and way more usable).

Let's fix these issues, one at a time.

Improving the ICMPHealthCheck class

In this section, we'll improve our `ICMPHealthCheck` class by adding the `host` and `timeout` parameters, a custom outcome message for each possible status, and a JSON-structured output.

Adding parameters and response messages

Open the `ICMPHealthCheck.cs` class file and perform the following changes (added/modified lines are highlighted):

```
using Microsoft.Extensions.Diagnostics.HealthChecks;
using System;
using System.Net.NetworkInformation;
using System.Threading;
using System.Threading.Tasks;

namespace HealthCheck
{
    public class ICMPHealthCheck : IHealthCheck
    {
        private string Host { get; set; }
        private int Timeout { get; set; }

        public ICMPHealthCheck(string host, int timeout)
        {
            Host = host;
            Timeout = timeout;
        }

        public async Task<HealthCheckResult> CheckHealthAsync(
            HealthCheckContext context,
            CancellationToken cancellationToken = default)
        {
            try
            {
                using (var ping = new Ping())
                {
                    var reply = await ping.SendPingAsync(Host);

                    switch (reply.Status)
                    {
                        case IPStatus.Success:
                            var msg = String.Format(
                                "IMCP to {0} took {1} ms.",
                                Host,
```

```
        reply.RoundtripTime);

    return (reply.RoundtripTime > Timeout)
        ? HealthCheckResult.Degraded(msg)
        : HealthCheckResult.Healthy(msg);

    default:
        var err = String.Format(
            "IMCP to {0} failed: {1}",
            Host,
            reply.Status);
        return HealthCheckResult.Unhealthy(err);
    }
}
}

catch (Exception e)
{
    var err = String.Format(
        "IMCP to {0} failed: {1}",
        Host,
        e.Message);
    return HealthCheckResult.Unhealthy(err);
}
}
}
}
```

As we can see, we changed a couple of things, as follows:

- We added a constructor accepting the two parameters we'd like to set programmatically: `host` and `timeout`. The old *hardcoded* variables are now properties so that we can use them to store the parameters upon initialization and use them within the class afterward (such as within the main method).
- We created various different *outcome messages* containing the target host, the ping outcome, and the round-trip duration (or the runtime error), and added them as parameters to the `HealthCheckResult` return objects.

That's pretty much about it. Now, we just need to set the `host` name and the `timeout` programmatically since the old *hardcoded defaults* are now gone. In order to do that, we have to update our middleware setup in the `Startup.cs` file.

Updating the middleware setup

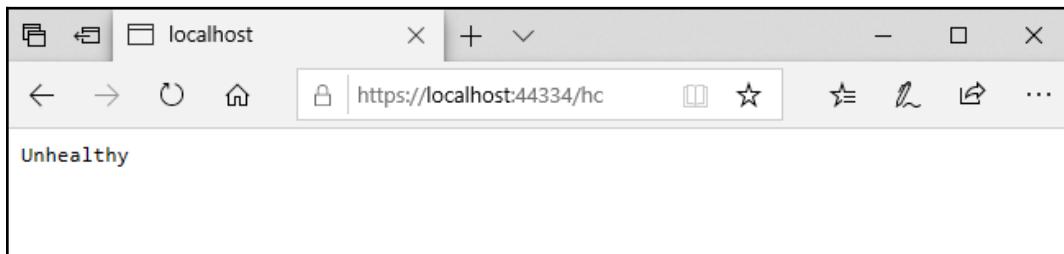
Open the `Startup.cs` file again and change the middleware initialization code within the `ConfigureServices` method in the following way:

```
public void ConfigureServices(IServiceCollection services)
{
    /// ...existing code...

    services.AddHealthChecks()
        .AddCheck("ICMP_01", new ICMPHealthCheck("www.ryadel.com",
    100))
        .AddCheck("ICMP_02", new ICMPHealthCheck("www.google.com",
    100))
        .AddCheck("ICMP_03", new ICMPHealthCheck("www.does-not-
    exist.com", 100));
}
```

Here we go: as we can see, another advantage of being able to programmatically configure the host is that we can add the ICMP health check multiple times—one for each host we'd like to actually check. In the preceding example, we're taking the chance to test three different hosts: `www.ryadel.com`, `www.google.com`, and the same non-existing host we used before, which allows us to emulate an `Unhealthy` status as well as the `Healthy` ones.

Now, we could be tempted to hit *F5* and try it out... However, if we were to do that, we would face a rather disappointing outcome, as shown in the following screenshot:



The reason for this is quite obvious: even if we're running multiple checks, we're still relying on the default outcome message... which is nothing more than a Boolean sum of the statuses returned by all the checked hosts. For that very reason, if at least one of them is `Unhealthy`, the whole check will be flagged as `Unhealthy` as well.

Luckily enough, we can avoid that sum—and get a much more granular output—by dealing with the third flaw of our `ICMPHealthCheck`: implementing a custom, JSON-structured output message.

Implementing a custom output message

To implement a custom output message, we need to override the `HealthCheckOptions` class. To do that, add a new `CustomHealthCheckOptions.cs` file to the project's root folder and fill it with the following contents:

```
using Microsoft.AspNetCore.Diagnostics.HealthChecks;
using Microsoft.AspNetCore.Http;
using System.Linq;
using System.Net.Mime;
using System.Text.Json;

namespace HealthCheck
{
    public class CustomHealthCheckOptions : HealthCheckOptions
    {
        public CustomHealthCheckOptions() : base()
        {
            var jsonSerializerOptions = new JsonSerializerOptions()
            {
                WriteIndented = true
            };

            ResponseWriter = async (c, r) =>
            {
                c.Response.ContentType =
                    MediaTypeNames.Application.Json;
                c.Response.StatusCode = StatusCodes.Status200OK;

                var result = JsonSerializer.Serialize(new
                {
                    checks = r.Entries.Select(e => new
                    {
                        name = e.Key,
                        responseTime =
                            e.Value.Duration.TotalMilliseconds,
                        status = e.Value.Status.ToString(),
                        description = e.Value.Description
                    }),
                    totalStatus = r.Status,
                    totalResponseTime =
                });
            };
        }
    }
}
```

```
        r.TotalDuration.TotalMilliseconds,
        }, jsonSerializerOptions);
    await c.Response.WriteAsync(result);
}
}
}
```

The code is quite self-explanatory: we override the standard class—the one that outputs the one-word output we want to change—with our own custom class so that we can change its `ResponseWriter` property, in order to make it output whatever we want.

More specifically, we want to output a custom JSON-structured message containing a lot of useful stuff from each of our checks, listed here:

- `name`: The identifying string we provided while adding it to the pipeline within the `ConfigureServices` method of the `Startup.cs` file:
"ICMP_01", "ICMP_02", and so on
- `responseTime`: The whole duration of that single check
- `status`: Not to be confused with the status of the whole `HealthCheck`—that is, the Boolean sum of all the inner checks statuses
- `description`: The custom informative message we configured earlier on when we refined the `ICMPHealthCheck` class

All these values will be properties of the array items contained in the JSON output: one for each check. It's worth noting that the JSON file, in addition to that array, will also contain the following two additional properties:

- `totalStatus`: The Boolean sum of all the inner checks statuses
 - `Unhealthy` if there's at least an `Unhealthy` host, `Degraded` if there's at least a `Degraded` host, and `Healthy` otherwise.
- `totalResponseTime`: The whole duration of all the checks.

That's a lot of useful information, right? We just have to configure our middleware to output them, instead of those one-word responses we've seen before.

About health check responses and HTTP status codes

Before going further, it's worth noting that—in the preceding `CustomHealthCheckOptions` class—we did set the `ResponseWriter`'s HTTP status code to a fixed `StatusCodes.Status200OK`. Is there a reason behind that?

As a matter of fact, there is, and it's also quite an important one. The `HealthChecks` middleware's default behavior returns either an HTTP status code 200 if all the checks are OK (`Healthy`) or an HTTP status code 503 if one or more checks are KO (`Unhealthy`). Since we've switched to a JSON-structured output, we don't need the 503 anymore, as it would most likely break our *front-end* client UI logic—unless properly handled. Therefore, for the sake of simplicity, we just forced an HTTP 200 response, regardless of the end result. We'll find a way to properly emphasize the errors within the upcoming Angular UI.

Configuring the output message

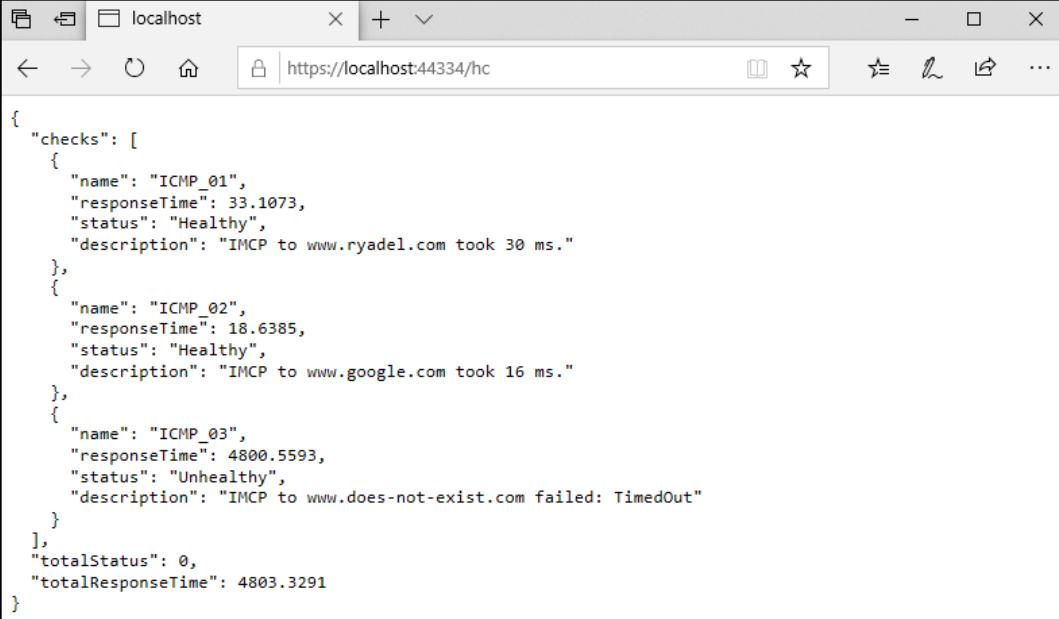
Open the `Startup.cs` file, scroll down to the `Configure` method, and change the following lines accordingly (the updated code is highlighted):

```
public void Configure(IApplicationBuilder app, IWebHostEnvironment env)
{
    /// ...existing code...

    app.UseHealthChecks("/hc", new CustomHealthCheckOptions());

    /// ...existing code...
}
```

Once done, we can finally hit *F5* and properly test it out. This time, we won't be disappointed by the outcome, as shown in the following screenshot:



The screenshot shows a Microsoft Edge browser window with the address bar displaying `https://localhost:44334/hc`. The main content area of the browser shows a JSON object representing the results of three ICMP health checks:

```
{  
  "checks": [  
    {  
      "name": "ICMP_01",  
      "responseTime": 33.1073,  
      "status": "Healthy",  
      "description": "IMCP to www.ryadel.com took 30 ms."  
    },  
    {  
      "name": "ICMP_02",  
      "responseTime": 18.6385,  
      "status": "Healthy",  
      "description": "IMCP to www.google.com took 16 ms."  
    },  
    {  
      "name": "ICMP_03",  
      "responseTime": 4800.5593,  
      "status": "Unhealthy",  
      "description": "IMCP to www.does-not-exist.com failed: TimedOut"  
    }  
  "totalStatus": 0,  
  "totalResponseTime": 4803.3291  
}
```

That's a pretty nice response, isn't it?

Now, each and every check is properly documented, as well as the *total* outcome data, in a structured JSON object. This is just what we need to feed some Angular Components that we can show on-screen in a human-readable (and fashionable) way, which we're just about to do, starting with the next section.

Health checks in Angular

It's now time to build an **Angular Component** that is capable of fetching and displaying the structured JSON data we managed to pull off in the previous sections.

As we know from [Chapter 2, Looking Around](#), an Angular Component is commonly made of three separate files, as follows:

- The **Component** (`.ts`) file, written in TypeScript and containing the Component class, together with all the module references, functions, variables, and so on.

- The **Template** (`.html`) file, written in HTML extended with the *Angular Template Syntax*, which defines the UI layout architecture.
- The **Style** (`.css`) file, written in CSS and containing the cascading style sheets rules and definitions for drawing the UI.



Although the aforementioned *three-files approach* is arguably the most practical one, the only required file is the *Component* one, as both the *Template* and the *Style* files could also be embedded as inline elements within the Component file. The choice between using separate files or going inline is a matter of taste; however, we strongly suggest adopting the *three-files approach* because it enforces the *separation of concerns* embodied within the *Component/template* duality featured by Angular.

If we're used to the **model-view-controller (MVC)** and **model-view-viewmodel (MVVM)** patterns, we can say that, in Angular, the Component is the *Controller/viewmodel* and the template represents the *view*.

In the next section, we'll implement them all.

Creating the Angular Component

From the **Solution Explorer**, navigate through the `/ClientApp/src/app` folder and create a new `health-check` folder.

Once inside, create the following `.ts`, `.html`, and `.css` files:

- `health-check.component.ts`
- `health-check.component.html`
- `health-check.component.css`

Once done, fill them with the following content.

health-check.component.ts

Here's the `/ClientApp/src/app/health-check/health-check.component.ts` source code:

```
import { Component, Inject } from '@angular/core';
import { HttpClient } from '@angular/common/http';

@Component({
  selector: 'app-health-check',
  templateUrl: './health-check.component.html',
  styleUrls: ['./health-check.component.css']
})
export class HealthCheckComponent {
  public result: Result;

  constructor(
    private http: HttpClient,
    @Inject('BASE_URL') private baseUrl: string) {
  }

  ngOnInit() {
    this.http.get<Result>(this.baseUrl + 'hc').subscribe(result => {
      this.result = result;
    }, error => console.error(error));
  }
}

interface Result {
  checks: Check[];
  totalStatus: string;
  totalResponseTime: number;
}

interface Check {
  name: string;
  status: string;
  responseTime: number;
}
```

If you're curious about what we did there, here's a breakdown of the most relevant stuff:

- At the start of the file, we made sure to import all the Angular *directives*, *pipes*, *services*, and *Components*—in one word, *modules*—that we need throughout the whole class.
- In the Component's constructor, we instantiated a `HttpClient` service and a `baseUrl` variable using **Dependency Injection (DI)**; the `baseUrl` value is being set by making use of the `BASE_URL` provider, defined in the `/ClientApp/src/main.ts` file, which we briefly introduced in Chapter 2, *Looking Around*. As we can see by looking at that file's source code, it will resolve to our application's root URL: such a value is required by the `HttpClient` service, to build the URL that will be used to fetch the data from the server with an HTTP GET request to the `.NET HealthChecks` middleware that we set up earlier on (see the '`hc`' string).
- Last but not least, we defined two interfaces to deal with the JSON request we're expecting to receive from the `HealthChecks` middleware: `Result` and `Check`, which we designed to host the whole JSON resulting object and each element of the internal array, respectively.

Before going further, it could be useful to spend some valuable time expanding on some very important topics we've just met by implementing the preceding code, as follows:

- **Imports and modules**
- **DI**
- **ngOnInit** (and other lifecycle hooks)
- **Constructor**
- **HttpClient**
- **Observables**
- **Interfaces**

Since we're going to see them all throughout this book, it's definitely advisable to review them now.

Imports and modules

The static `import` statement that we used multiple times in the preceding `HealthCheckComponent` is used to import bindings that are exported by other JavaScript modules.

The concept of working with *modules* started with ECMAScript 2015 and has been thoroughly adopted by TypeScript and, therefore, Angular. A *module* is basically a collection of variables, functions, classes, and so on, grouped within a class: each *module* is executed within its own scope, not in the global scope, meaning that all the elements declared within it are not visible from the outside unless they are explicitly *exported* using the `export` statement. Conversely, to consume a variable, function, class, interface, and so on contained (and *exported*) within a *module*, that *module* has to be imported using the `import` statement. This is quite similar to what we do with *namespaces* in most programming languages (C# has using statements, for example).

As a matter of fact, all the Angular *directives*, *pipes*, *services*, and *Components* are also packed into collections of *JavaScript modules*, which we have to *import* into any TypeScript class whenever we want to use them. These collections are basically libraries of modules: we can easily recognize them since their name begins with the `@angular` prefix. Our `/ClientApp/packages.json` file (the NPM package file), which we've seen in previous chapters, contains most of them.

To know more about ECMAScript *modules* and better understand the *module resolution* strategy in TypeScript, check out the following URLs:



TypeScript modules:

<https://www.typescriptlang.org/docs/handbook/modules.html>.

Module resolution:

<https://www.typescriptlang.org/docs/handbook/module-resolution.html>.

IMPORTANT: *JavaScript modules* should not be confused with Angular's own modularity system, which is based upon the `@NgModule` decorator. As we already know from Chapter 1, *Getting Ready*, and Chapter 2, *Looking Around*, Angular's *NgModules* are *building blocks*—that is, containers for a cohesive block of code dedicated to an application domain, a workflow, or a common feature set. We know from the aforementioned chapters that each Angular app has at least one `NgModule` class, called the root module, which is conventionally named `AppModule` and resides in the `app.module.ts` file in the application root; additional *NgModules* will be added in the upcoming chapters.

Unfortunately, the *JavaScript module system* and the *Angular NgModule system* use a rather similar vocabulary (*import* versus *imports*, *export* versus *exports*) that might lead to confusion—especially considering that *Angular apps require the developer to use both of them at the same time* (and often in the same class file). Luckily enough, although being forced to intertwine these two systems might be a bit tricky at first, eventually, we'll become familiar with the different contexts in which they are used.

Here's a sample screenshot, taken from our `HealthCheck` app's `AppModule` class file, which should help you distinguish between the two different systems:

The screenshot shows the `AppModule` class file with several annotations:

- A red box highlights the top-level imports (lines 1-10) with the label "JAVASCRIPT MODULE SYSTEM" and the text "import {...}".
- A blue box highlights the `@NgModule` decorator and its properties (declarations, imports, providers, bootstrap) with the label "ANGULAR MODULE SYSTEM" and the text "@NgModule({...});".

```
1 import { BrowserModule } from '@angular/platform-browser';
2 import { NgModule } from '@angular/core';
3 import { FormsModule } from '@angular/forms';
4 import { HttpClientModule, HTTP_INTERCEPTORS } from '@angular/common/http';
5 import { RouterModule } from '@angular/router';
6 ...
7 import { AppComponent } from './app.component';
8 import { NavMenuComponent } from './nav-menu/nav-menu.component';
9 import { HomeComponent } from './home/home.component';
10 import { HealthCheckComponent } from './health-check/health-check.component';
11
12 @NgModule({
13   declarations: [
14     AppComponent,
15     NavMenuComponent,
16     HomeComponent,
17     HealthCheckComponent
18   ],
19   imports: [
20     BrowserModule.withServerTransition({ appId: 'ng-cli-universal' }),
21     HttpClientModule,
22     FormsModule,
23     RouterModule.forRoot([
24       { path: '', component: HomeComponent, pathMatch: 'full' },
25       { path: 'health-check', component: HealthCheckComponent }
26     ])
27   ],
28   providers: [],
29   bootstrap: [AppComponent]
30 })
31 export class AppModule {}
```

For additional information regarding the *Angular module system* and the `NgModule` decorator, check out the following URLs:



NgModule:

<https://angular.io/guide/ngmodules>.

Angular architecture: NgModules and JavaScript modules:

<https://angular.io/guide/architecture-modules#ngmodules-and-javascript-modules>.

DI

We talked about DI a number of times already, and with good reason, because it's an important application design pattern for either .NET Core or Angular, with both frameworks making extensive use of it to increase their efficiency and modularity.

To explain what DI actually is, we must first talk about what *dependencies* are in a class: these can be defined as *services* or *objects* that a class needs to *instantiate* into *variables* or *properties*, in order to perform one or more tasks.

In a *classic* coding pattern, those dependencies are instantiated *on the fly* within the class itself—for example, during its initialization phase, such as within the constructor method. Here's a typical example of that:

```
public MyClass() {  
    var myElement = new Element();  
    myElement.doStuff();  
}
```

In the preceding example, the `myElement` variable is an object instance of the `Element` type, and also a (local) *dependency* of `MyClass`: as we can see, it gets instantiated in the constructor because we most likely need to use it there. From there, we can either use it as a local variable (and let it *die* at the end of the constructor's *lifecycle*) or assign it to a class property to further extend its *life span* and *scope*.

DI is an alternative software design pattern, in which a class asks for dependencies *from external sources* rather than creating them itself. To better understand such a concept, let's try to rewrite the same code as before with a *DI* approach, like this:

```
public MyClass(Element myElement) {  
    myElement.doStuff();  
}
```

As we can see, there's no need to instantiate the `myElement` variable because such a task is already handled by the **Dependency Injector**—an external code that is responsible for creating the *injectable* objects and *injecting* them into the classes.

The whole DI coding pattern is based upon the concept of **Inversion of Control (IoC)**, to resolve dependencies. Such a concept revolves around the basic idea that, formally, if `ObjectA` depends on `ObjectB`, then `ObjectA` must not create or import `ObjectB` directly, but provide a way to *inject* `ObjectB` instead. In the preceding code block example, `ObjectA` is obviously `MyClass`, while `ObjectB` is the `myElement` instance.

For additional information about the DI software design pattern, check out the following links:



DI in .NET Core:

<https://docs.microsoft.com/en-us/aspnet/core/fundamentals/dependency-injection>.

DI in Angular:

<https://angular.io/guide/dependency-injection>.

In Angular, the DI framework provides declared dependencies to a class when that class is instantiated.

In the preceding `HealthCheckComponent` class, we used DI in the Component's constructor method to inject a `HttpClient` service instance and a `baseUrl` instance; as we can see, we also took the chance to assign the `private` access modifier to both of them. Thanks to that modifier, those variables will be accessible through the whole Component class.



As per Angular conventions, a parameter injected without an `access modifier` can only be accessed within the constructor; conversely, if it gets an access modifier such as `private` or `public`, it will be defined as a class member, hence changing its `scope` to the class. Such a technique is called **variable scoping**, and we're going to use it a lot in our Angular Components from now on.

ngOnInit (and other lifecycle hooks)

The `ngOnInit` method that we used in the `HealthCheckComponent` class is one of the Component's *lifecycle hook methods*: in this section, we'll try to shed some light on them, since we're going to use them a lot throughout this book.

Each Angular Component has a *lifecycle*, which is managed by Angular. Each time a user visits a view within our app, the Angular framework creates and renders the required *Components* (and *directives*) along with their children, reacts to their changes whenever the user interacts with them, and eventually destroys and removes them from the **Document Object Model (DOM)** when the user navigates elsewhere. All these "key moments" trigger some *lifecycle hook methods* that Angular exposes to the developers so that they can perform something when each one of them actually occurs: as a matter of fact, they are very similar to the C# *event handlers*.

Here's a list of the available hooks, in order of execution (when possible, since some of them are called multiple times during the Component's lifecycle):

- `ngOnChanges()`: Responds when Angular (re)sets data-bound input properties. The method receives a `SimpleChanges` object of current and previous property values. Called before `ngOnInit()`, and whenever one or more data-bound input properties changes.
- `ngOnInit()`: Initializes the directive/Component after Angular first displays the data-bound properties and sets the directive/Component's input properties. Called once, after the first `ngOnChanges()` method.
- `ngDoCheck()`: Detects and acts upon changes that Angular can't, or won't, detect on its own. Called during every change detection run, immediately after `ngOnChanges()` and `ngOnInit()`.
- `ngAfterContentInit()`: Responds after Angular projects external content into the Component's view/the view that a directive is in. Called once after the first `ngDoCheck()` method.
- `ngAfterContentChecked()`: Responds after Angular checks the content projected into the directive/Component. Called after the `ngAfterContentInit()` method and every subsequent `ngDoCheck()` method.
- `ngAfterViewInit()`: Responds after Angular initializes the Component's views and child views/the view that a directive is in. Called once after the first `ngAfterContentChecked()` method.
- `ngAfterViewChecked()`: Responds after Angular checks the Component's views and child views/the view that a directive is in. Called after the `ngAfterViewInit()` method and every subsequent `ngAfterContentChecked()` method.
- `ngOnDestroy()`: Cleans up just before Angular destroys the directive/Component. Unsubscribes Observables and detaches the event.
- Handlers to avoid memory leaks: Called just before Angular destroys the directive/Component.

The preceding **lifecycle hooks methods** are available for all Angular *Components* and *directives*. To call them, we can just add them to our Component class—which is precisely what we did in the preceding `HealthCheckComponent`.

Now that we have understood the role of `ngOnInit()`, we should take a moment to explain why we put the `HttpClient` source code in the `ngOnInit()` lifecycle hook method instead of using the Component's `constructor()` method: shouldn't we have used that instead?

The next section should greatly help us to understand the reason for such a choice.

Constructor

As we most likely already know, all TypeScript classes have a `constructor()` method that will be called whenever we create an instance of that class: since TypeScript is, by all means, a superset of JavaScript, any TypeScript `constructor()` method will be transpiled into a JavaScript `constructor()` function.

The following code block shows an example of a TypeScript class:

```
class MyClass() {  
  constructor() {  
    console.log("MyClass has been instantiated");  
  }  
}
```

This will be transpiled into the following JavaScript function:

```
function MyClass() {  
  console.log("MyClass has been instantiated");  
}
```

If we omit the `constructor` in TypeScript, the JavaScript transpiled function will be empty; however, whenever the framework needs to instantiate it, it will still call it in the following way, regardless of whether it has the `constructor` or not:

```
var myClassInstance = new MyClass();
```

Understanding this is very important because it greatly helps us to understand the difference between the Component's `constructor()` method and its `ngOnInit()` lifecycle hook, and it's a huge difference, at least from the perspective of the Component initialization phase.

The whole Angular Bootstrap process can be split into two major (and subsequent) stages:

- Instantiating the Components
- Performing change detection

As we can easily guess, the `constructor()` method is called during the former phase, while all the lifecycle hooks—including the `ngOnInit()` method—are called throughout the latter.

If we look at these methods from this perspective, it's pretty easy to understand the following key concepts:

- If we need to create or *inject* some *dependencies* into an Angular Component, we should use the `constructor()` method; as a matter of fact, this is also the only way we can do that since the constructor is the only method that gets called in the context of the Angular injector.
- Conversely, whenever we need to perform any Component *initialization* and/or *update* task—such as performing an HTTP request, updating the DOM, and so on—we should definitely do that by using one of the *lifecycle hooks*.

The `ngOnInit()` method, as its name implies, is often a great choice for the Component's initialization tasks, since it happens right after the directive's and/or Component's input properties are set. That's why we have used this to implement our HTTP request, using the Angular built-in `HttpClient` service.

HttpClient

Being able to efficiently send and receive JSON data from our .NET Core Controllers is probably the most important requirement for our **single page application (SPA)**. We chose to do that using the Angular `HttpClient` service, first introduced in Angular 4.3.0-RC.0, which is among one of the best answers the framework can give to get the job done. For this very reason, we will use it a lot throughout this book; however, before doing that, it might be advisable to properly understand what it is, why is it better than the former implementation, and how to properly implement it.

The new `HttpClient` service was introduced in July 2017 as an improved version of the former Angular HTTP client API, also known as `@angular/http`, or, simply, `HTTP`. Instead of replacing the old version in the `@angular/http` package, the Angular development team has put the new classes in a separate package—`@angular/common/http`. They chose to do that to preserve the *backward compatibility* with the existing code bases, and also to ensure a slow, yet steady, migration to the new API.

Those who used the old Angular HTTP service class at least once will most likely remember its main limitations, listed here:

- **JSON was not enabled by default**, forcing the developers to explicitly set it within the request *headers*—and `JSON.parse` / `JSON.stringify` the data—when working with RESTful APIs.
- **There was no easy way to access the HTTP request/response pipeline**, thus preventing the developer from intercepting or altering the *request* and/or *response* calls after they were issued or received by using some ugly and pattern-breaking hacks. As a matter of fact, extensions and wrapper classes were basically the only way to customize the service, at least on a global scope.
- **There was no native strong-typing for request and response objects**, although that could be addressed by casting JSON-as-interfaces as a workaround.

The great news is that the new `HttpClient` does all of this and much more; other features include testability support and better error handling via APIs entirely based on `Observables`.

It's worth noting that putting the `HttpClient` service within the Component itself is not good practice because it will often lead to unnecessary code repetitions among the various Components that need to perform HTTP calls and handle their results. This is a known issue that greatly affects production-level apps, which will likely require post-processing of the received data, handling errors, adding retry logic to deal with intermittent connectivity, and so on.



To better deal with those scenarios, it's strongly advisable to separate the data access logic and the data presentation role by encapsulating the former in a separate service, which can be then *injected* into all the Components that require it, in a standardized and centralized way. We'll talk more about that in Chapter 7, *Code Tweaks and Data Services*, where we'll eventually replace multiple `HttpClient` implementations and centralize their source code within a couple of *Data Services*.

Observables

Observables are a powerful feature for managing async data; they are the backbone of the **ReactiveX JavaScript (RxJS)** library, which is one of the Angular required dependencies, and are planned to be included in the final release of ECMAScript 7. If you're familiar with ES6 *Promises*, you can think of them as an improved version of that approach.

An *Observable* can be configured to send literal values, structured values, messages, and events, either *synchronously* or *asynchronously*: the values can be received by subscribing to the *Observable* itself using the `subscribe` method hook, meaning that the whole data flow is handled within it—until we programmatically choose to *unsubscribe*. The great thing about this approach is that, regardless of the chosen approach (*sync* or *async*), streaming *frequency*, and *data type*, the programming interface for listening to values and stopping listening is the same.

The great advantages of *Observables* are the reason why Angular makes extensive use of them when dealing with data. If we take a good look at our `HealthCheckComponent` source code, we can see how we use them as well when our `HttpClient` service fetches the data from the server and stores the result in the `this.result` local variable. Such a task is performed by calling two consecutive methods: `get<Result>()` and `subscribe()`.

Let's try to summarize what they do, as follows:

- `get<Result>()`: As the name suggests, this method issues a standard HTTP request to our .NET Core `HealthChecks` middleware to fetch the *Result* JSON response object. This method needs a URL parameter, which we create on the fly by adding the `hc` literal string (the same string that we set early on, within the `Configure` method of the `Startup.cs` file) to the Angular app's `BASE_URL`.
- `subscribe()`: This method instantiates an *Observable* object that will execute two very different actions right after a result and/or in case of an error. Needless to say, all this will be done *asynchronously*, meaning that it will run in a separate thread (or scheduled for later execution) while the rest of the code continues to execute.

Those who want to get additional information can take a look at the following URLs, taken from the RxJS official documentation:

**ReactiveX Library—Observables guide:**

<http://reactivex.io/rxjs/class/es6/Observable.js~Observable.html>.

Angular.io—Observables guide:

<https://angular.io/guide/observables>.

It's very important to understand that we're only scratching the surface of what an *Observable* can do. However, this is all we need for now: we'll have the chance to talk more about them later on.

Interfaces

Now that we know how the Angular `HttpClient` service works, we have every right to ask ourselves a couple of questions: why are we even using those **interfaces**? Can't we just use the raw JSON data sent by the `.NET Core HealthChecks` middleware that we defined early on, consuming them as anonymous JavaScript objects?

Theoretically speaking, we can, just as much as we can output raw JSON from the Controllers, instead of creating all the `ViewModel` classes like we did instead. In a well-written app, though, we should always resist the temptation to handle raw JSON data and/or to use anonymous objects for a number of good reasons:

- **We have chosen TypeScript over JavaScript because we want to work with type definitions:** Anonymous objects and properties are the exact opposite; they lead to the JavaScript way of doing things, which is something we wanted to avoid in the first place.
- **Anonymous objects (and their properties) are not easy to validate:** We don't want our data items to be error-prone or forced to deal with missing properties.
- **Anonymous objects are hardly reusable,** and won't benefit from many Angular handy features —such as *object mapping*—that require our objects to be actual instances of an interface and/or a type.

The first two arguments are very important, especially if we're aiming for a production-ready application; no matter how easy our development task might seem at first, we should never think that we can afford to lose that level of control over our application's source code.

The third reason is also crucial, as long as we want to use Angular to its full extent. If that's the case, using an undefined array of properties—such as raw JSON data—is basically out of the question; conversely, using a structured TypeScript interface is arguably the most lightweight way to work with structured JSON data in a *strongly typed* fashion.



It's worth noting that we've not added the `export` statement to our interface: we did that on purpose since we're only going to use this within the `HealthCheckComponent` class. Should we need to change such behavior in the future—for example, to create an external *Data Service*—we'll have to add such a statement (and, arguably, move each one of them into a separate file) to enable us to `import` them into other classes.

health-check.component.html

Here's the `/ClientApp/src/app/health-check/health-check.component.html` source code:

```
<h1>Health Check</h1>

<p>Here are the results of our health check:</p>

<p *ngIf="!result"><em>Loading...</em></p>

<table class='table table-striped' aria-labelledby="tableLabel"
*ngIf="result">
  <thead>
    <tr>
      <th>Name</th>
      <th>Response Time</th>
      <th>Status</th>
      <th>Description</th>
    </tr>
  </thead>
  <tbody>
    <tr *ngFor="let check of result.checks">
      <td>{{ check.name }}</td>
      <td>{{ check.responseTime }}</td>
      <td class="status {{ check.status }}">{{ check.status }}</td>
      <td>{{ check.description }}</td>
    </tr>
  </tbody>
</table>
```

As we can see, the *template* part of our Angular Component is basically an HTML page, containing a table with some Angular directive. Before moving on, let's have a closer look, as follows:

- `ngIf`: This is a *structural directive* that conditionally includes the container HTML element, based on the Boolean expression value specified after the equals (=) sign: when such an expression evaluates to *true*, Angular renders the element; otherwise, it doesn't. It can be chained with an `else` block that—if present—will be shown when the expression evaluates to *false* or *null*. In the preceding code block, we use it within the `<table>` element so that it only appears when the `result` internal variable (which we defined in the **Component** class earlier on) stops being *null*, which will happen after the data has been fetched from the server.
- `ngFor`: Another *structural directive* that renders a template for each item contained in a given collection. The directive is placed on an element, which becomes the parent of the cloned templates. In the preceding code block, we use it inside the main `<table>` element to create and show a `<tr>` element (a row) for each `check` item within the `result.checks` array.
- `{{ check.name }}`, `{{ check.responseTime }}`, and so on: These are called *interpolations* and can be used to incorporate calculated strings into the text between HTML element tags and/or within attribute assignments. In other words, we can use them as placeholders for our class variables' property values. As we can see, the *interpolation* default delimiters are the double curly braces, `{{` and `}}`.

To understand more about `ngIf`, `ngFor`, *interpolations*, and other Angular UI fundamentals, we strongly suggest taking a look at the official documentation:



Displaying data:

<https://angular.io/guide/displaying-data>.

Template syntax:

<https://angular.io/guide/template-syntax>.

Structural directives:

<https://angular.io/guide/structural-directives>.

health-check.component.css

Here's the `/ClientApp/src/app/health-check/health-check.component.css` source code:

```
.status {  
    font-weight: bold;  
}  
  
.Healthy {  
    color: green;  
}  
  
.Degraded {  
    color: orange;  
}  
  
.Unhealthy {  
    color: red;  
}
```

There's not much to say here; just some vanilla CSS to style out the Component template.

Due to space, we won't be able to talk much about *CSS styling* in this book: we will just take it for granted that the average web programmer knows how to handle the simple definitions, selectors, and styling rules we will use in our examples.



Those who want (or need) to understand more about CSS and CSS3 are encouraged to take a look at this great online tutorial:

<https://developer.mozilla.org/en-US/docs/Web/CSS>.

Notice how we played a bit with the styling of the table cell, which will contain the *status* of the various checks. It's strongly advisable to highlight them as much as we can, so we made them **bold** and with a `color` matching the *status* type: `green` for `Healthy`, `orange` for `Degraded`, and `red` for `Unhealthy`.

Adding the Component to the Angular app

Now that our *Component* is ready, we need to properly add it to our Angular app. In order to do that, we need to make some minimal changes to the following files:

- `app.module.ts`
- `nav-menu.component.ts`
- `nav-menu.component.html`

Let's get this done.

AppModule

As we know from Chapter 2, *Looking Around*, each new *Component* must be referenced in the `AppModule` so that it can be registered within our app. On top of that, we need to create the relevant entry within our `RoutingModule` configuration so that our users will be able to navigate to that page.

Open the `/ClientApp/src/app/app.module.ts` file and add the following highlighted lines:

```
import { BrowserModule } from '@angular/platform-browser';
import { NgModule } from '@angular/core';
import { FormsModule } from '@angular/forms';
import { HttpClientModule, HTTP_INTERCEPTORS } from
  '@angular/common/http';
import { RouterModule } from '@angular/router';

import { AppComponent } from './app.component';
import { NavMenuComponent } from './nav-menu/nav-menu.component';
import { HomeComponent } from './home/home.component';
import { HealthCheckComponent } from './health-check/health-
check.component';

@NgModule({
  declarations: [
    AppComponent,
    NavMenuComponent,
    HomeComponent,
    HealthCheckComponent
  ],
  imports: [
    BrowserModule.withServerTransition({ appId: 'ng-cli-universal' }),
    HttpClientModule,
```

```
FormsModule,
RouterModule.forRoot([
  { path: '', component: HomeComponent, pathMatch: 'full' },
  { path: 'health-check', component: HealthCheckComponent }
])
],
providers: [],
bootstrap: [AppComponent]
})
export class AppModule {}
```

Mission accomplished: let's move on.

NavMenuComponent

Adding our new *Component* navigation path to the `RoutingModule` is a required step to make our users able to reach it; however, we also need to add a link for our users to click on. Since the `NavMenuComponent` is the Component that handles the navigation user interface, we need to perform some stuff there as well.

Open the `ClientApp/src/app/nav-menu/nav-menu.component.ts` file and add the following highlighted lines:

```
// ... existing code...

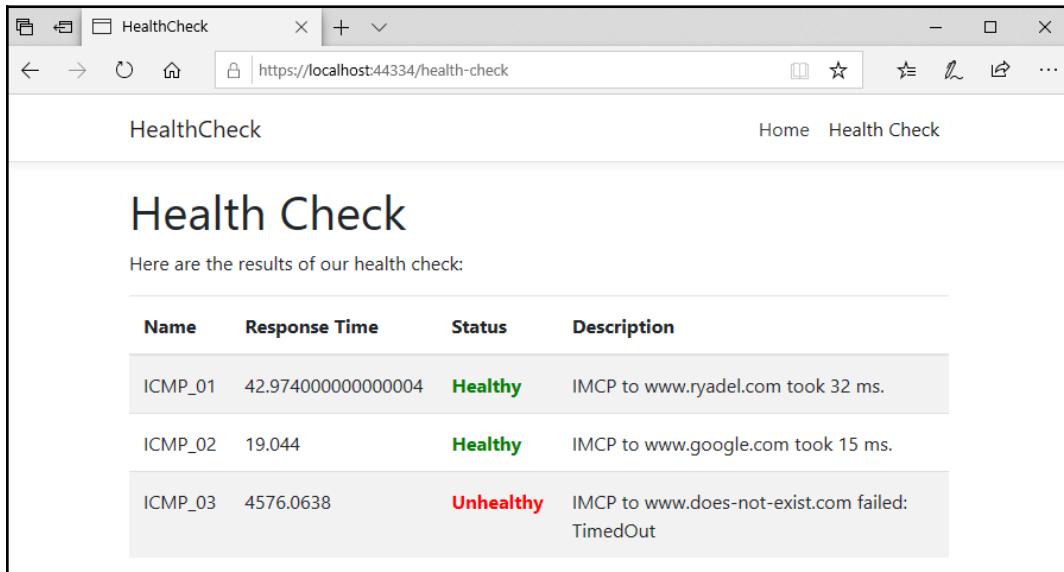
<ul class="navbar-nav flex-grow">
  <li
    class="nav-item"
    [routerLinkActive]=["link-active"]
    [routerLinkActiveOptions]={ exact: true }>
    <a class="nav-link text-dark" [routerLink]=[ '/' ]>Home</a>
  </li>
  <li class="nav-item" [routerLinkActive]=["link-active"]>
    <a class="nav-link text-dark" [routerLink]=[ '/health-check' ]>
      Health Check</a>
  </li>
</ul>

// ... existing code...
```

Now that our new *Component* has been added to our Angular app, we just need to test it out.

Testing it out

To see our new `HealthCheckComponent` in all of its glory, we just need to hit *F5* and take a look at the browser's result, which—if we did everything correctly—should be very similar to the following screenshot:



It definitely seems like we did it!

Our health check is up and running, proudly showing us the results of the three ICMP requests we set up within our .NET Core's `HealthChecksMiddleware`.

Summary

Let's spend a minute to briefly recap what we learned in this chapter. First of all, we acknowledged that `.NET Controllers` are not the only tool in the shed: as a matter of fact, any middleware is virtually able to deal with the HTTP *request and response* cycle—as long as it is in our application's pipeline.

In order to demonstrate such a concept, we introduced `HealthChecksMiddleware`, a neat .NET Core built-in feature that can be used to implement status monitor services.... and that's basically what we did throughout this chapter. We started with the .NET Core *back-end*, refining our work until we were able to create a JSON-structured output; then, we switched to Angular, where we learned how to properly fetch it with a *Component* and show it on-screen through the browser's HTML-based UI. Eventually, the final outcome was good enough to reward us for our hard work.

That's enough for health checks, at least for the time being: starting from the next chapter, we'll bring back the standard .NET *Controllers* pattern and see how we can leverage it to learn something new.

Suggested topics

Health Monitoring, Health Checks, `HealthChecksMiddleware`, `HealthCheckOptions`, HTTP Requests, HTTP Responses, ICMP, PING, `ResponseWriter`, JSON, `JsonSerializerOptions`. Components, Routing, Modules, `AppModule`, `HttpClient`, `ngIf`, `ngFor`, Directives, Structural Directives, Interpolations, `NgModule`, Angular module system, JavaScript module system (import/export).

References

- *Health checks in ASP.NET Core*: <https://docs.microsoft.com/en-US/aspnet/core/host-and-deploy/health-checks>
- *Request and response operations in ASP.NET Core*: <https://docs.microsoft.com/en-us/aspnet/core/fundamentals/middleware/request-response>
- *ASP.NET Core health monitoring*: <https://docs.microsoft.com/en-us/dotnet/architecture/microservices/implement-resilient-applications/monitor-app-health>
- *TypeScript modules*: <https://www.typescriptlang.org/docs/handbook/modules.html>
- *Module Resolution*: <https://www.typescriptlang.org/docs/handbook/module-resolution.html>
- *Dependency Injection in ASP.NET Core*: <https://docs.microsoft.com/en-us/aspnet/core/fundamentals/dependency-injection>

- *Angular.io—Dependency Injection:* <https://angular.io/guide/dependency-injection>
- *Angular—Lifecycle Hooks:* <https://angular.io/guide/lifecycle-hooks>
- *ReactiveX Library—Observables:* <http://reactivex.io/rxjs/class/es6/Observable.js~Observable.html>
- *Angular.io—Observables guide:* <https://angular.io/guide/observables>
- *JavaScript—Import statement:* <https://developer.mozilla.org/en-US/docs/Web/JavaScript/Reference/Statements/import>
- *JavaScript—Export statement:* <https://developer.mozilla.org/en-US/docs/Web/JavaScript/Reference/Statements/export>
- *Angular—HttpClient:* <https://angular.io/guide/http#httpclient>
- *Angular—NgModules:* <https://angular.io/guide/ngmodules>
- *Angular—NgModules and JavaScript modules:* <https://angular.io/guide/architecture-modules#ngmodules-and-javascript-modules>
- *Angular—Displaying Data:* <https://angular.io/guide/displaying-data>
- *Angular—Template Syntax:* <https://angular.io/guide/template-syntax>
- *Angular—Structural Directives:* <https://angular.io/guide/structural-directives>
- *CSS—Cascading Style Sheets:* <https://developer.mozilla.org/en-US/docs/Web/CSS>

4

Data Model with Entity Framework Core

The `HealthCheck` sample app that we've been playing with since [Chapter 1, Getting Ready](#), is working fine, yet it lacks some important features we would likely make use of in a typical web application; among the most important of them is the ability to read and write data from a **Database Management System (DBMS)** since it is an essential requirement for almost any web-related task: content management, knowledge sharing, instant communication, data storage and/or mining, tracking and statistics, user authentication, system logging, and so on.

Truth be told, even our `HealthCheck` app could definitely use some of these tasks: tracking the host statuses over time could be a nice feature; user authentication should be a must-have, especially if we plan to publicly release it to the web; system logging is always great to have; and so on. However, since we prefer to keep our projects as simple as possible, we're going to create a new one and grant some DBMS capabilities to it.

Here's what we're going to do in this chapter:

- **Create a brand-new .NET Core 3 and Angular web application project** called `WorldCities`: a database of cities from all over the world
- **Choose a suitable data source** to fetch a reasonable amount of *real* data to play with
- **Define and implement a data model** using Entity Framework Core
- **Configure and deploy a DBMS engine** that will be used by our project
- **Create the database** using Entity Framework Core's Data Migrations feature

- **Implement a data seeding strategy** to load the data source to the database
- **Read and write data with .NET Core using the Object-Relational Mapping (ORM)** techniques provided by *Entity Framework Core*

Are you ready to get started?

Technical requirements

In this chapter, we're going to need all of the previous technical requirements that were listed in the previous chapters, plus the following external libraries:

- Microsoft.EntityFrameworkCore NuGet package
- Microsoft.EntityFrameworkCore.Tools NuGet package
- Microsoft.EntityFrameworkCore.SqlServer NuGet package
- **SQL Server 2019** (if we opt for the local SQL instance route)
- **MS Azure subscription** (if we opt for the cloud database hosting route)

As always, it's advisable to avoid installing these straight away. We're going to bring them in during this chapter so that we can contextualize their purpose within our project.

The code files for this chapter can be found at https://github.com/PacktPublishing/ASP.NET-Core-3-and-Angular-9-Third-Edition/tree/master/Chapter_04/

The WorldCities web app

The first thing we're going to do is create a new .NET Core and Angular web application project. Remember what we did during the second part of *Chapter 1, Getting Ready?* We can either do the same (and make all of the relevant changes to the sample project that we made in *Chapter 2, Looking Around*) or take our existing `HealthCheck` project, copy it to another folder, rename all of the references to `HealthCheck` (source code *and* filesystem), and undo everything we did in *Chapter 2, Looking Around*, and *Chapter 3, Front-end and Back-end Interactions*.

Although both approaches are fine, the former option would definitely be more practical, not to mention that it's a great chance to put into practice what we've learned until now and ensure we've understood each relevant step.

Let's briefly recap what we need to do:

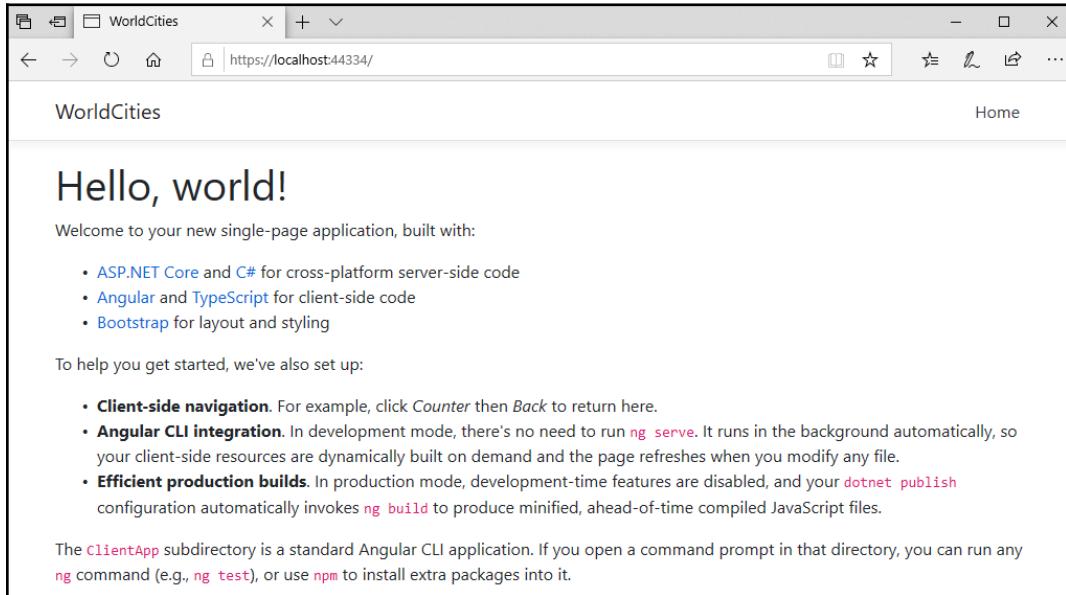
1. Create a new project with the `dotnet new angular -o WorldCities` command.
2. Edit or delete the following .NET Core *back-end* files:
 - `Startup.cs` (edit)
 - `WeatherForecast.cs` (delete)
 - `/Controllers/WeatherForecastController.cs` (delete)
3. Edit or delete the following Angular *front-end* files:
 - `/ClientApp/package.json` (edit)
 - `/ClientApp/src/app/app.module.ts` (edit)
 - `/ClientApp/src/app/nav-menu/nav-menu.component.html` (edit)
 - `/ClientApp/src/app/counter/` (delete—whole folder)
 - `/ClientApp/src/app/fetch-data/` (delete—whole folder)

In the unlikely case that we choose to copy and paste the `HealthCheck` project—which we don't recommend, we would need to remove the `HealthChecks` middleware references from the `Startup.cs` file and the Angular *Components* references within the various Angular configuration files. We would also have to delete the related .NET and Angular class files (`ICMPHealthCheck`, `CustomHealthCheckOptions`, the `/ClientApp/src/app/health-check/` folder, and so on).



As we can see, cloning a project would mean that we would have to perform a lot of undo and/or rename activities: this is precisely why starting from scratch is generally a better approach.

After making all of these changes, we can check that everything is working by pressing *F5* and inspecting the outcome. If everything has been done properly, we should be able to see the following screen:



That's about it: now, we have a brand-new .NET Core + Angular web application to play with. We just need a data source and a data model that can be accessed through a *back-end Web API* to retrieve some data from: in other words, a Data Server.

Reasons to use a Data Server

Before we move on, it would be wise to spend a couple of minutes answering the following question: *do we really need a real Data Server?* Can't we just emulate one somehow? We're only running code samples, after all.

As a matter of fact, we could definitely avoid doing that and skip this entire chapter: Angular provides an **In-memory Web API** package that replaces the `HttpClient` module's `HttpBackend` and emulates **CRUD** operations over a RESTful API; the emulation is performed by intercepting the Angular HTTP requests and redirecting them to an in-memory data store under our control.

This package is great and works really well for most test case scenarios, such as the following:

- To simulate operations against data collections that haven't been implemented on our dev/test server
- To write unit test apps that read and write data without having to intercept multiple HTTP calls and manufacturing sequences of responses
- To perform end-to-end tests without messing with the real database, which is great for **Continuous Integration (CI)** builds

The In-memory Web API service works so well that the entire Angular documentation at <https://angular.io/> relies upon it. However, we're not going to use it for now, for a simple (and rather obvious) reason: this book's focus is not Angular, but the **client/server interoperability between Angular and .NET Core**; for that very reason, developing a real Web API and connecting it to a real data source through a real data model is part of the game.

We don't want to simulate the behavior of a RESTful *back-end* because we need to understand what's going on there and how to implement it properly: we want to implement it, along with the DBMS that will host and provide the data.

That's precisely what we're going to do, starting from the next section.



Those who want to get additional information about the Angular In-memory Web API service can visit the `in-memory-web-api` GitHub project page at <https://github.com/angular/in-memory-web-api/>.

The data source

What kind of data will our *WorldCities* web application will? We already know the answer: a database of cities from all over the world. Does such a repository even exist yet?

As a matter of fact, there are several alternatives we can use to populate our database and then make it available to our end users.

The following is the free world cities database by DSpace-CRIS:

- **URL:** <https://dspace-cris.4science.it/handle/123456789/31>
- **Format:** CSV
- **License:** Free to use

The following is GeoDataSource's world cities database (free edition):

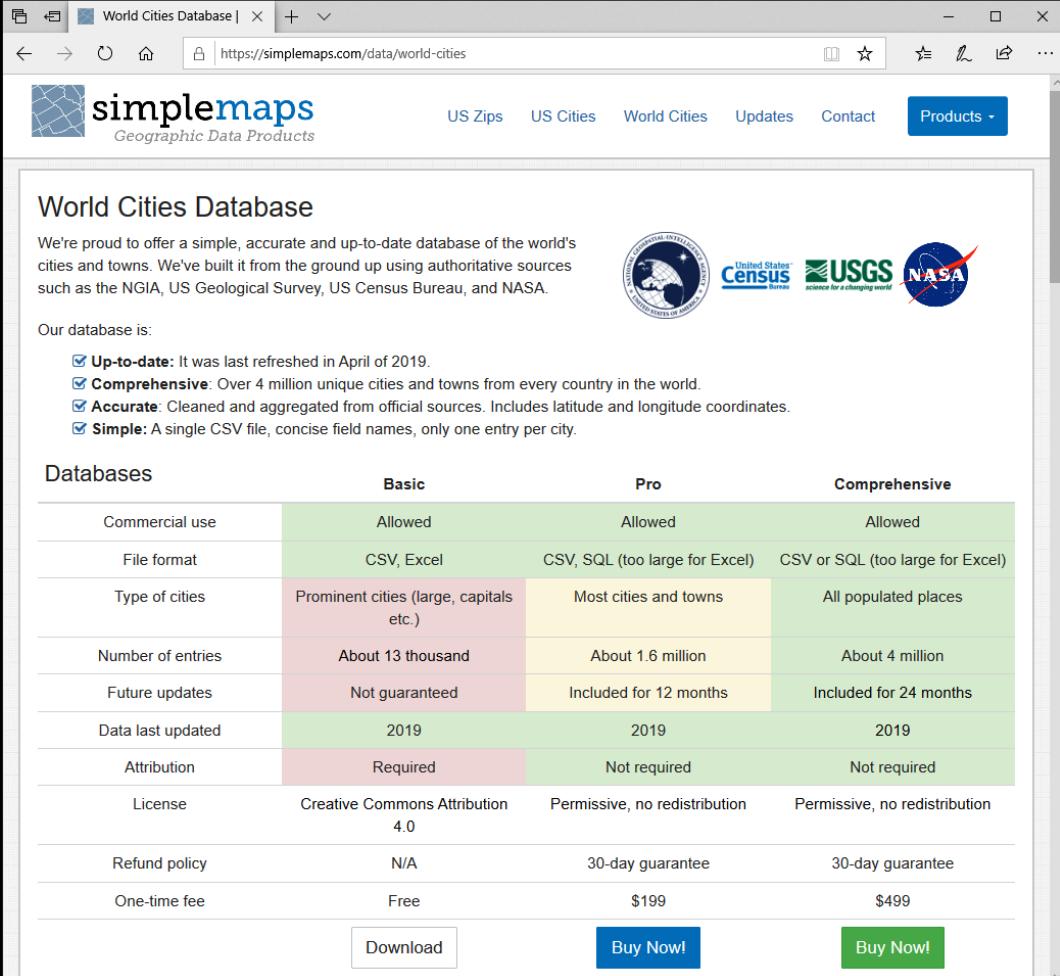
- **URL:** <http://www.geodatasource.com/world-cities-database/free>
- **Format:** CSV
- **License:** Free to use (registration required)

The following is the world cities database by simplemaps.com:

- **URL:** <https://simplemaps.com/data/world-cities>
- **Format:** CSV, XLSX
- **License:** Free to use (CC BY 4.0, <https://creativecommons.org/licenses/by/4.0/>)

All of these alternatives are good enough to suit our needs: we'll go with the latter since it requires no registration and provides a human-readable spreadsheet format.

Open your favorite browser, type in or copy the aforementioned URL, and look for the **Basic** column of the **World Cities Database** section:



The screenshot shows a web browser window for the "World Cities Database" on the simplemaps website. The URL is https://simplemaps.com/data/world-cities. The page features a header with the simplemaps logo and navigation links for US Zips, US Cities, World Cities, Updates, Contact, and Products. Below the header, there's a section titled "World Cities Database" with a brief description of the database's purpose and sources (NGIA, USGS, US Census Bureau, NASA). To the right of the text are logos for the United States Census Bureau, USGS, and NASA. A section titled "Our database is:" lists four checked items: Up-to-date, Comprehensive, Accurate, and Simple. Below this is a table comparing "Basic", "Pro", and "Comprehensive" database plans across various categories like commercial use, file format, and number of entries. At the bottom are "Download" and "Buy Now!" buttons.

Databases		Basic	Pro	Comprehensive
Commercial use	Allowed	Allowed	Allowed	
File format	CSV, Excel	CSV, SQL (too large for Excel)	CSV or SQL (too large for Excel)	
Type of cities	Prominent cities (large, capitals etc.)	Most cities and towns	All populated places	
Number of entries	About 13 thousand	About 1.6 million	About 4 million	
Future updates	Not guaranteed	Included for 12 months	Included for 24 months	
Data last updated	2019	2019	2019	
Attribution	Required	Not required	Not required	
License	Creative Commons Attribution 4.0	Permissive, no redistribution	Permissive, no redistribution	
Refund policy	N/A	30-day guarantee	30-day guarantee	
One-time fee	Free	\$199	\$499	

Click the **Download** button to retrieve the (huge) ZIP file containing both the `.csv` and `.xlsx` files and save it somewhere. That's it for now; we'll deal with these later on.

Starting with the next section, we'll start the building process of our data model: it's going to be a long, but also very rewarding, journey.

The data model

Now that we have our raw data source, we need to find a way to make it available to our web application so that our users will be able to retrieve (and maybe alter) the actual data.

For the sake of simplicity, we won't waste our precious time by introducing the whole data model concept, as well as the various meanings of these two words. Those of you who are experienced, as well as seasoned developers, will probably be aware of all of the relevant stuff. We'll just say that when we are talking about a data model, we don't mean anything more or anything less than a lightweight, definitely-typed set of entity classes representing persistent, code-driven data structures that we can use as resources within our Web API code.

The word *persistent* has been used for a reason; we want our data structure to be stored in a database. That's rather obvious for any application based on data. The brand-new web application we're about to create won't be an exception since we want it to act as a collection—or a repository—of records so that we can read, create, delete, and/or modify according to our needs.

As we can easily guess, all of these tasks will be performed by some *back-end* business logic (.NET Controllers) that's triggered by a *front-end* UI (Angular Components).

Introducing Entity Framework Core

We will create our database with the help of the **Entity Framework Core** (also known as **EF Core**), the well-known open source **Object Relational Mapper (ORM)** for **ADO.NET** that's developed by Microsoft. The reasons for such a choice are as follows:

- Seamless integration with the Visual Studio IDE
- A conceptual model based upon entity classes (**Entity Data Model (EDM)**) that will allow us to work with data using domain-specific objects without the need to write data-access code, which is precisely what we're looking for
- Easy to deploy, use, and maintain in development and production phases

- Compatible with all of the major open source and commercial SQL and NoSQL engines, including **MSSQL**, **SQLite**, **Azure Cosmos DB**, **PostgreSQL**, **MySQL/MariaDB**, **MyCAT**, **Firebird**, **Db2/Informix**, **Oracle DB**, **MongoDB**, and more, thanks to the official and/or third-party providers and/or connectors available via NuGet



It's worth mentioning that **Entity Framework Core** was previously known as **Entity Framework 7** until its latest RC release. The name change follows the ASP.NET 5/ASP.NET Core perspective switch we already talked about as it also emphasizes the Entity Framework Core major rewrite/redesign if we compare it to the previous installments.

You might be wondering why we're choosing to adopt a SQL-based approach instead of going for a NoSQL alternative; there are many good NoSQL products such as MongoDB, RavenDB, and CouchDB that happen to have a C# connector library. What about using one of them instead?

The answer is rather simple: despite being available as third-party providers, they haven't been included in the official **Entity Framework Core Database provider list** (see the link in the following information box). For that very reason, we're going to stick to the relational database, which may also be a more convenient approach for the simple database schemas we're going to design within this book.

For those who want to know more about the upcoming release and/or feel bold enough to use it anyway—maybe with a NoSQL DB as well—we strongly suggest that you take a look at the following links and docs:



Project

roadmap: <https://github.com/aspnet/EntityFramework/wiki/Roadmap>

Source code on GitHub: <https://github.com/aspnet/EntityFramework>

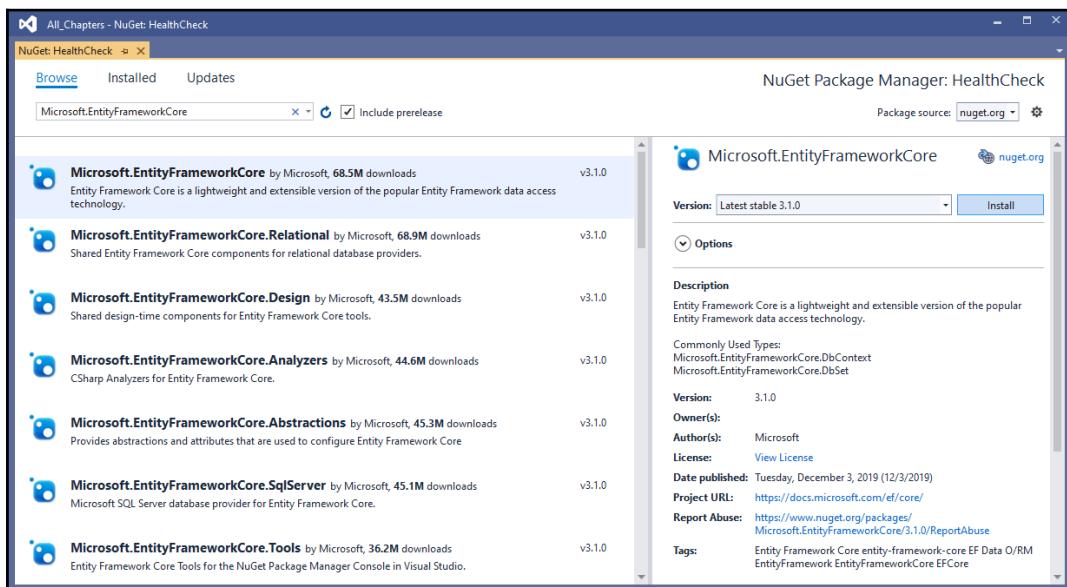
Official documentation: <https://docs.efproject.net/en/latest/>

Official Entity Framework Core Database provider list: <https://docs.microsoft.com/en-us/ef/core/providers/?tabs=dotnet-core-cli>

Installing Entity Framework Core

To install Entity Framework Core, we need to add the relevant packages to the dependencies section of our project file. We can easily do this using the visual GUI in the following way:

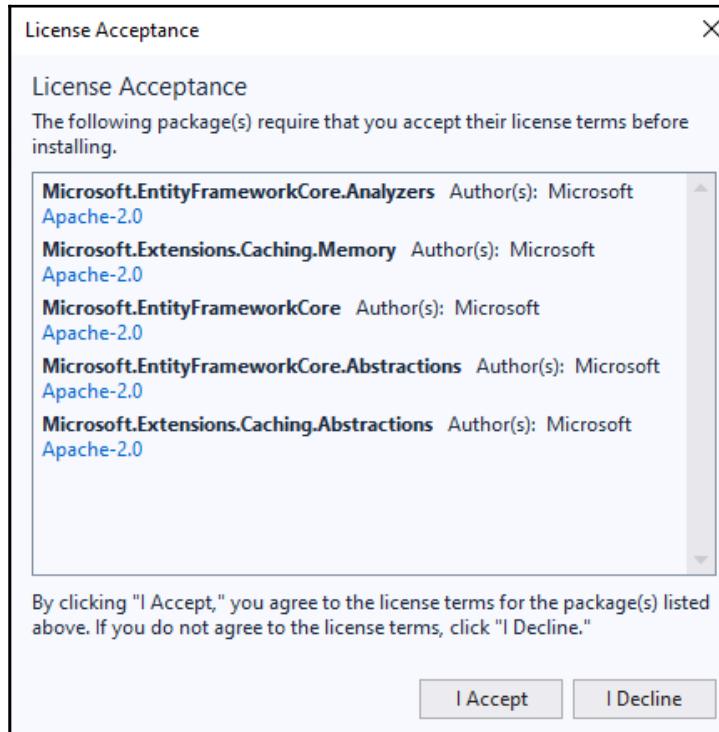
1. Right-click on the `WorldCities` project.
2. Select **Manage NuGet Packages**.
3. Ensure that the **Package source** drop-down list is set to **All**.
4. Go to the **Browse** tab and search for the packages containing the `Microsoft.EntityFrameworkCore` keyword:



Once there, select and install the following packages (the latest at the time of writing):

- `Microsoft.EntityFrameworkCore` version 3.1.1
- `Microsoft.EntityFrameworkCore.Tools` version 3.1.1
- `Microsoft.EntityFrameworkCore.SqlServer` version 3.1.1

All of these packages will also bring some required dependencies, which we'll need to install as well:



If we prefer to do this using the NuGet package manager command line, we can input the following:

```
PM> Install-Package Microsoft.EntityFrameworkCore -Version 3.1.1
PM> Install-Package Microsoft.EntityFrameworkCore.Tools -Version 3.1.1
PM> Install-Package Microsoft.EntityFrameworkCore.SqlServer -Version
3.1.1
```

It's worth noting that the version number, which is the one that's the most recent at the time of writing, might be subject to change: be sure to triple-check it out in this book's GitHub repository as well!

The SQL Server Data Provider

Among the installed namespaces, it's worth noting the presence of `Microsoft.EntityFrameworkCore.SqlServer`, which is the **Microsoft SQL Database Provider** for Entity Framework Core. This highly versatile connector provides an interface for the whole Microsoft SQL Server database family, including the latest SQL Server 2019.

DBMS licensing models

Despite having a rather expensive (to say the least) licensing model, there are at least three Microsoft SQL editions that can be used for free, as long as certain requirements are met:

- **Evaluation Edition** is free, but comes with no production use rights, meaning that we can only use it on development servers. Additionally, it can only be used for 180 days. After that, we'll have to either buy a license or uninstall it (and migrate to a different edition).
- **Developer Edition** is also free and comes with no production use rights. However, it can be used without limitations, providing that we only use it for development and/or testing scenarios.
- **Express Edition** is free and can be used in any environment, meaning that we can use it on development and production servers. However, it has some major performance and size limitations that could hinder the performance of a complex and/or high-traffic web application.

For additional information regarding the various SQL Server editions, including the commercial ones that do require a paid licensing model, check out the following links:



<https://www.microsoft.com/en-us/sql-server/sql-server-2019>
<https://www.microsoft.com/en-us/sql-server/sql-server-2019-comparison>

As we can easily see, both the **Developer** and **Express** editions can be a great deal for small web applications like those we're playing within this book.

What about Linux?

SQL Server 2019 is also available for Linux and officially supported for the following distributions:

- Red Hat Enterprise (RHEL)
- SUSE Enterprise Server
- Ubuntu

Other than that, it can also be set to run on Docker and even provisioned as a virtual machine on Azure, which can often be a great alternative if we don't want to install a local DBMS instance and save our precious hardware resources.

As for the licensing model, all SQL Server products are licensed the same way for all of these environments: this basically means that we can use our license (including the free ones) on the platform of our choice.

SQL Server alternatives

If you don't feel like using Microsoft SQL Server, you're 100% free to pick another DBMS engine such as MySQL, PostgreSQL, or any other product, as long as it got some kind of Entity Framework official (or third-party) support.

Should we make this decision now? This entirely depends on the data modeling approach we want to adopt; for the time being, and for the sake of simplicity, we're going to stick to the Microsoft SQL Server family, which allows us to install a decent DBMS for free on either our local machine (development and/or production) or Azure (thanks to its €200 cost and 12 months free trial): don't worry about this for now—we'll get there later on.

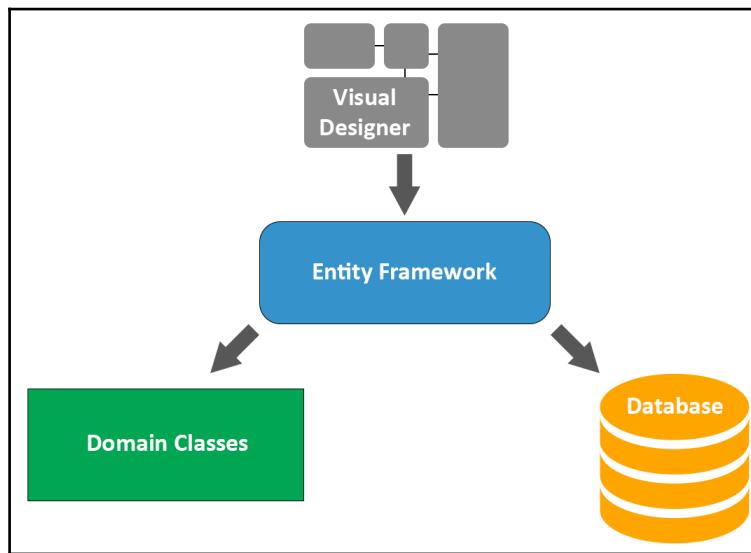
Data modeling approaches

Now that we have Entity Framework installed and we know—more or less—which DBMS we are going to use, we have to choose between one of the three available approaches to model the data structure: **Model-First**, **Database-First**, or **Code-First**. Each one comes with its fair amount of advantages and disadvantages, as those of you with experience and those of you who are seasoned .NET developers will almost certainly know. Although we won't dig too much into these, it could be useful to briefly summarize each before making a choice.

Model-First

If you're not familiar with the Visual Studio IDE design tools such as the **XML-based DataSet Schema (XSD)** and the **Entity Designer Model XML visual interface (EDMX)**, the Model-First approach can be rather confusing. The key to understanding it is to acknowledge the fact that the word Model here is meant to define a visual diagram that's built with the design tools. That diagram will then be used by the framework to autogenerated the SQL script and the data model source code files.

To summarize, we can say that going Model-First will mean *working on a visual EDMX diagram and letting Entity Framework create/update the rest accordingly*:



The pros and cons are explained in the following sections.

Pros

Such an approach has the following benefits:

- We will be able to create the database schema and the class diagram as a whole using a visual design tool, which can be great when the data structure is quite big.
- Whenever the database changes, the model can be updated accordingly without data loss.

Cons

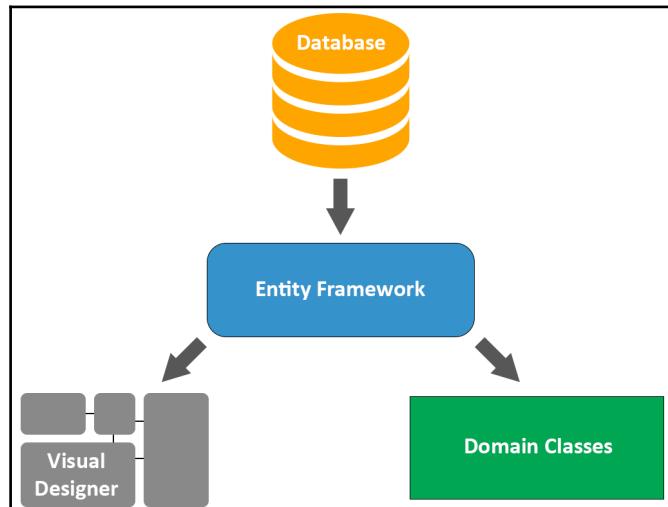
However, there are some downsides, as follows:

- The diagram-driven, autogenerated SQL scripts can lead to data loss in case of updates. An easy workaround for this is generating the scripts on disk and manually modifying them, which will require decent SQL knowledge.
- Dealing with the diagram can be tricky, especially if we want to have precise control over our Model classes; we won't always be able to get what we want as the actual source code will be autogenerated by a tool.

Database-First

Given the disadvantages of Model-First, we can think that Database-First might be the way to go. This can be true if we either have a database already or don't mind building it beforehand. That being the case, the Database-First approach is similar to the Model-First one, except that it goes the other way around; instead of designing the EDMX manually and generating the SQL script to create the database, we build the latter and then generate the former using the Entity Framework designer tool.

We can summarize this by saying that going Database-First will mean *building the database and letting Entity Framework create/update the rest accordingly*:



The pros and cons are explained in the following sections.

Pros

Here are the main advantages of the Database-First approach:

- If we have an already-existing database in place, this will probably be the way to go as it will spare us the need to recreate it.
- The risk of data loss will be kept to a minimum because any structural change or DB model update will always be performed on the database itself.

Cons

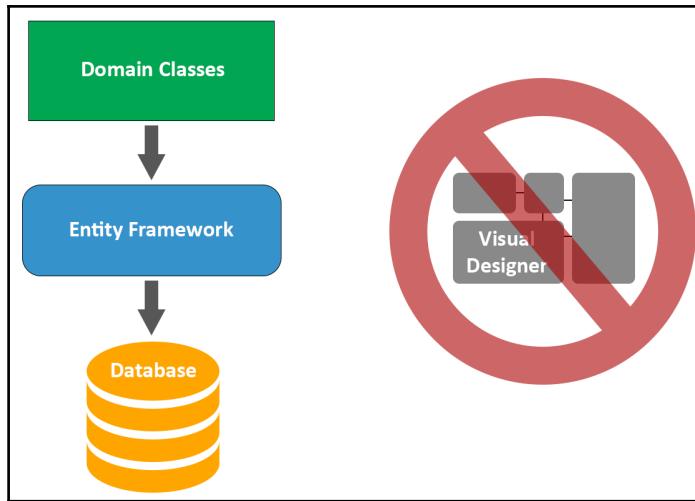
Here are the cons:

- Manually updating the database can be tricky if we're dealing with clusters, multiple instances, or a number of development/testing/production environments as we will have to manually keep them in sync instead of relying on code-driven updates/migrations or autogenerated SQL scripts.
- We will have even less control over the autogenerated model classes (and their source code) than when using the Model-First approach. This will require extensive knowledge over EF conventions and standards; otherwise, we'll often struggle to get what we want.

Code-First

Last but not least comes Entity Framework's flagship approach since version 4, which enables an elegant, highly-efficient data model development workflow. The appeal of this approach can be easily found in its premise; the Code-First approach allows developers to define model objects using only standard classes, without the need for any design tool, XML mapping files, or cumbersome piles of autogenerated code.

To summarize, we can say that going Code-First means writing the data model entity classes *we'll be using within our project and letting Entity Framework generate the database accordingly*:



The pros and cons are explained in the following sections.

Pros

The following are the pros of this approach:

- There is no need for diagrams and visual tools whatsoever, which can be great for small-to-medium size projects as it will save a lot of time.
- It has a fluent code API that allows the developer to follow a convention over configuration approach so that it can handle the most common scenarios, while also giving them the chance to switch to a custom, attribute-based implementation that overrides the need to customize the database mapping.

Cons

The following are the cons of this approach:

- Good knowledge of C# and updated EF conventions is required.
- Maintaining the database can often be tricky, as well as handling updates without suffering data loss. Migration support, which was added in 4.3 to overcome this issue and has been continuously updated since then, greatly mitigates the problem although it also affected the learning curve in a negative way.

Making a choice

By taking the advantages and disadvantages of these three options into account, there is no such thing as an overall *better* or *best* approach; conversely, we can say that each project scenario will likely have a best-suited approach.

Regarding our project, considering the fact that we don't have a database yet and we're aiming for a flexible, mutable small-scale data structure, adopting the Code-First approach will probably be a good choice.

However, to do that, we'll need to create some entities and find a suitable DBMS to store our data: this is precisely what we're going to do in the following sections.

Creating the entities

Now that we have a data source, we can leverage one of the major advantages of the *Code-First* approach we talked about earlier and start writing our **entity** classes early on, without worrying too much about what Database Engine we'll eventually use.

Truth be told, we already know something about what we'll eventually use. We won't be adopting a NoSQL solution as they aren't officially supported by Entity Framework Core yet; we also don't want to commit ourselves to purchasing expensive license plans, so Oracle and the Commercial Editions of SQL Server are probably out of the picture as well.



This leaves us with relatively few choices: SQL Server Developer (or Express) Edition, MySQL/MariaDB, or other less well-known solutions such as PostgreSQL. Furthermore, we are still not 100% sure about installing a local DBMS instance on our development machine (and/or on our production server) or relying on a cloud-hosted solution such as Azure.

That being said, adopting Code-First will give us the chance to postpone the call until our data model is ready.

However, to create the entity classes, we need to know what kind of data they are going to contain and how to structure it: that strongly depends on the data source and the database tables that we eventually want to create using Code-First.

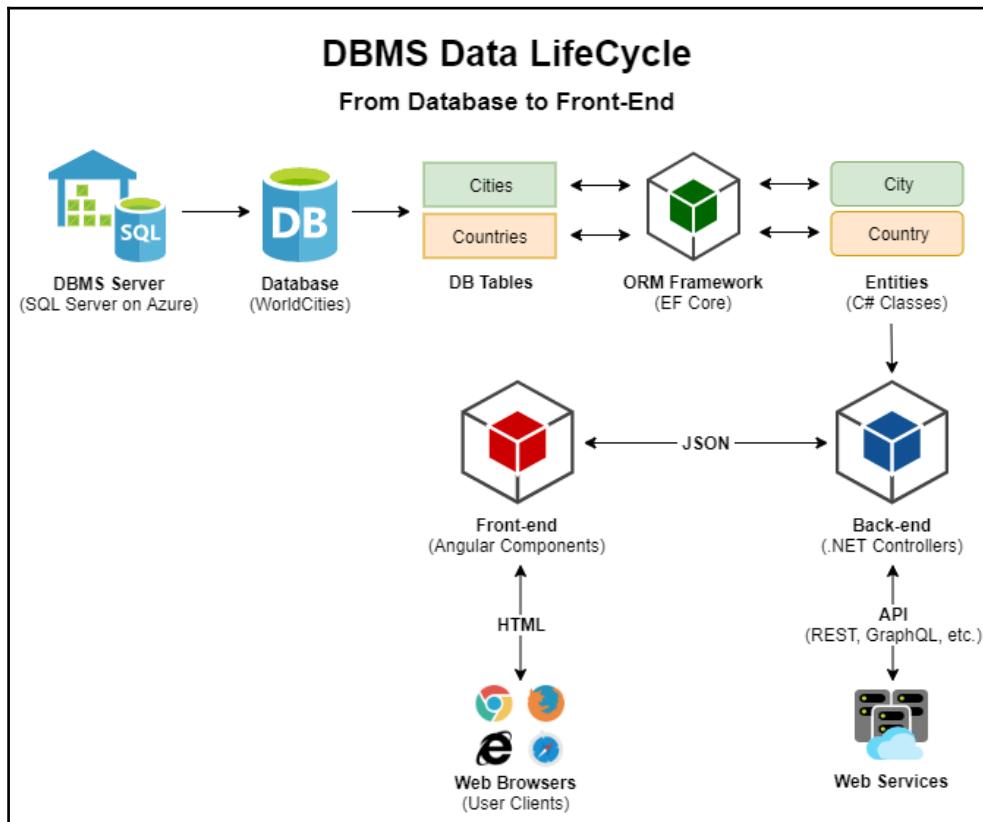
In the following sections, we're going to learn how we can deal with these tasks.

Defining the entities

In Entity Framework, as well as in most ORM frameworks, an **entity** is a class that maps to a given database table. The main purpose of entities is to make us able to work with data in an object-oriented fashion while using strongly-typed properties to access table columns (and data relations) for each row. We're going to use entities to fetch data from the DB and serialize them to JSON for the *front-end*. We will also do the opposite, that is, deserializing them back from the POST data whenever there are *front-end* issues an state that we need to persist the database.

If we try to enlarge our focus and look at the general picture, we will be able to see how the entities play a central role among the whole bi-directional data flow between the DBMS, the *back-end*, and the *front-end* parts of our web application.

To understand such a concept, let's take a look at the following diagram:



As we can clearly see, the main purpose of **Entity Framework Core** is to map the database tables to entity classes: that's precisely what we need to do now.

Unzip the world cities compressed file we downloaded a while ago and open the `worldcities.xlsx` file: if you don't have MS Excel, you can import it on Google Drive using Google Sheets, as shown at the following URL: <http://bit.ly/worldcities-xlsx>.



Right after importing it, I also took the chance to make some small readability improvements to that file: bold column names, resizing the columns, changing the background color and freezing on the first row, and so on.

If we open the preceding URL, we will see what the imported spreadsheet looks like:

	A	B	C	D	E	F	G	H	I	J	K
1	city	city_ascii	lat	lng	country	iso2	iso3	admin_name	capital	population	id
2	Malishevë	Malisheve	42.4822	20.7458	Kosovo	KK	XKS	Malishevë	admin		1901597212
3	Prizren	Prizren	42.2139	20.7397	Kosovo	KK	XKS	Prizren	admin		1901360309
4	Zubin Potok	Zubin Potok	42.9144	20.6897	Kosovo	KK	XKS	Zubin Potok	admin		1901608808
5	Kamenicë	Kamenice	42.5781	21.5803	Kosovo	KK	XKS	Kamenicë	admin		1901851592
6	Viti	Viti	42.3214	21.3583	Kosovo	KK	XKS	Viti	admin		1901328795
7	Shtërpcë	Shterpce	42.2394	21.0272	Kosovo	KK	XKS	Shtërpcë	admin		1901828239
8	Shtime	Shtime	42.4331	21.0397	Kosovo	KK	XKS	Shtime	admin		1901598505
9	Vushtrri	Vushtrri	42.8231	20.9675	Kosovo	KK	XKS	Vushtrri	admin		1901107642
10	Dragash	Dragash	42.0265	20.6533	Kosovo	KK	XKS	Dragash	admin		1901112530
11	Podujevë	Podujeve	42.9111	21.1899	Kosovo	KK	XKS	Podujevë	admin		1901550082
12	Fushë Kosovë	Fushe Kosove	42.6639	21.0961	Kosovo	KK	XKS	Fushë Kosovë	admin		1901134407
13	Kaçanik	Kacanik	42.2319	21.2594	Kosovo	KK	XKS	Kaçanik	admin		1901200321
14	Klinë	Kline	42.6217	20.5778	Kosovo	KK	XKS	Klinë	admin		1901230162
15	Leposaviq	Leposaviq	43.1039	20.8028	Kosovo	KK	XKS	Leposaviq	admin		1901974597
16	Pejë	Peje	42.66	20.2922	Kosovo	KK	XKS	Pejë	admin		1901339694
17	Rahovec	Rahovec	42.3994	20.6547	Kosovo	KK	XKS	Rahovec	admin		1901336358
18	Gjilan	Gjilan	42.4689	21.4633	Kosovo	KK	XKS	Gjilan	admin		1901235642
19	Lipjan	Lipjan	42.5217	21.1258	Kosovo	KK	XKS	Lipjan	admin		1901682048
20	Obiliq	Obiliq	42.6869	21.0703	Kosovo	KK	XKS	Obiliq	admin		1901102771
21	Gjakovë	Gjakove	42.3803	20.4308	Kosovo	KK	XKS	Gjakovë	admin		1901089874
22	Pristina	Pristina	42.6666	21.1724	Kosovo	KK	XKS	Prishtinë	primary		1901760068

By looking at the spreadsheet headers, we can infer at least two database tables we're going to need:

- **Cities:** For columns *A*, *B*, *C*, and *D* (and arguably *K*, if we want to keep those unique IDs)
- **Countries:** For column *E*, *F*, and *G*

This seems to be the most convenient choice in terms of common sense. Alternatively, we could put everything into a single `Cities` table, but we're going to have a lot of redundant content, which is something we would arguably want to avoid.

If we're going to deal with two database tables, this means that we need two entities to map them on and to create them in the first place, since we plan to adopt the Code-First approach.

The City entity

Let's start with the `City` entity.

From the project's **Solution Explorer**, do the following:

1. Create a new `/Data/` folder at the root level of the `WorldCities` project; this will be where all of our Entity Framework related classes will reside.
2. Create a `/Data/Models/` folder.
3. Add a new **ASP.NET Core | Code | Class** file, name it `City.cs`, and replace the sample code with the following:

```
using System;
using System.Collections.Generic;
using System.ComponentModel.DataAnnotations;
using System.ComponentModel.DataAnnotations.Schema;
using System.Linq;
using System.Threading.Tasks;

namespace WorldCities.Data.Models
{
    public class City
    {
        #region Constructor
        public City()
        {

        }
        #endregion

        #region Properties
        /// <summary>
        /// The unique id and primary key for this City
        /// </summary>
        [Key]
        [Required]
        public int Id { get; set; }
```

```
    /// <summary>
    /// City name (in UTF8 format)
    /// </summary>
    public string Name { get; set; }

    /// <summary>
    /// City name (in ASCII format)
    /// </summary>
    public string Name_ASCII { get; set; }

    /// <summary>
    /// City latitude
    /// </summary>
    public decimal Lat { get; set; }

    /// <summary>
    /// City longitude
    /// </summary>
    public decimal Lon { get; set; }
#endregion

    /// <summary>
    /// Country Id (foreign key)
    /// </summary>
    public int CountryId { get; set; }
}
}
```

As we can see, we added a dedicated property for each of the spreadsheet columns we identified early on; we also included a `CountryId` property, which we're going to use to map the *foreign key* for the `Country` related to the city (more on that later on). We also tried to improve the overall readability of the entity class source code by providing each property with some useful comments that will definitely help us to remember what they are meant for.

Last but not least, it's worth noting that we took the chance to decorate our entity class using some **Data Annotations** attributes as they are the most convenient way to override the default Code-First conventions. More specifically, we used the following annotations:

- `[Required]`: This defines the property as a *required* (non-nullable) field.
- `[Key]`: This means that the property hosts the *primary key* of the database table.
- `[ForeignKey]`: This means that the property hosts a *primary key* of a foreign table.

Those of you who have some experience with Entity Framework (and relational databases) will most likely understand what those data annotations are there for: they are a convenient way to instruct Entity Framework on how to properly build our database when using the Code-First approach. There's nothing complex here; we're just telling Entity Framework that the database columns that were created to host these properties should be set as required and that the primary key should be bound in a one-to-many relationship to other *foreign* columns in different tables.



The *binding* that's declared using the `[ForeignKey]` Data Annotation will be formally enforced by creating a *constraint*, as long as the DB engine supports such a feature.

In order to use the Data Annotations, we had to add a reference to the `System.ComponentModel.DataAnnotations` and `System.ComponentModel.DataAnnotations.Schema` namespaces at the beginning of the class. If we take a look at the preceding code, we will see that both of these namespaces have been referenced with a `using` statement.



If you want to find out more about Data Annotations in Entity Framework Core, we strongly suggest reading the official documentation, which can be found at the following URL: <https://docs.efproject.net/en/latest/modeling/index.html>.

Country

The next entity will be the one for identifying the countries, which will have a one-to-many relationship with `Cities`.



This is hardly a surprise: we're definitely going to expect a single country for each `City` and multiple `Cities` for each given `Country`: this is what one-to-many relationships are for.

Right-click on the `/Data/Models/` folder, add a `Country.cs` class file, and fill it with the following code:

```
using System;
using System.Collections.Generic;
using System.ComponentModel.DataAnnotations;
using System.ComponentModel.DataAnnotations.Schema;
using System.Linq;
using System.Threading.Tasks;
```

```
namespace WorldCities.Data.Models
{
    public class Country
    {
        #region Constructor
        public Country()
        {

        }
        #endregion

        #region Properties
        /// <summary>
        /// The unique id and primary key for this Country
        /// </summary>
        [Key]
        [Required]
        public int Id { get; set; }

        /// <summary>
        /// Country name (in UTF8 format)
        /// </summary>
        public string Name { get; set; }

        /// <summary>
        /// Country code (in ISO 3166-1 ALPHA-2 format)
        /// </summary>
        public string ISO2 { get; set; }

        /// <summary>
        /// Country code (in ISO 3166-1 ALPHA-3 format)
        /// </summary>
        public string ISO3 { get; set; }
        #endregion
    }
}
```

Again, there's a property for each spreadsheet column with the relevant Data Annotations and comments.

ISO 3166 is a standard that was published by the **International Organization for Standardization (ISO)** that's used to define unique codes for the names of countries, dependent territories, provinces, and states. For additional information, check out the following URLs:

https://en.wikipedia.org/wiki/ISO_3166
<https://www.iso.org/iso-3166-country-codes.html>



The part that describes the *country codes* is the first one (ISO 3166-1), which defines three possible formats: **ISO 3166-1 alpha-2** (*two-letter country codes*), **ISO 3166-1 alpha-3** (*three-letter country codes*), and **ISO 3166-1 numeric** (*three-digit country codes*). For additional information about the ISO 3166-1 ALPHA-2 and ISO 3166-1 ALPHA-3 formats, which are the ones that are used in our *data source* and therefore in this book, check out the following URLs:

https://en.wikipedia.org/wiki/ISO_3166-1_alpha-2
https://en.wikipedia.org/wiki/ISO_3166-1_alpha-3

Defining relationships

Now that we have built our main `City` and `Country` entity skeleton, we need to enforce the relationship we know exists between them. We want to be able to do stuff such as retrieve a `Country` and then browse to all of their related `Cities`, possibly in a strongly-typed fashion.

To do this, we have to add a couple of new entity-related properties, one for each entity class. More specifically, we will be adding the following:

- A `Country` property in our `City` entity class, which will contain a single country related to that city (the *parent*)
- A `Cities` property in our `Country` entity class, which will contain a collection of the cities related to that country (the *children*)

If we take a deeper look and try to visualize the relationship between those entities, we will be able to see how the former property identifies the *parent* (from each child perspective), while the latter will contain the *children* (from the parent perspective): such a pattern is precisely what we can expect for a *one-to-many relationship* like the one we're dealing with.

In the following sections, we'll learn how we can implement these two *navigation* properties.

Adding the Country property to the City entity class

Add the following code lines near the end of the file, near the end of the *Properties* region (the new lines are highlighted):

```
using System.ComponentModel.DataAnnotations.Schema;

// ...existing code...

/// <summary>
/// Country Id (foreign key)
/// </summary>
[ForeignKey("Country")]
public int CountryId { get; set; }

#endregion

#region Navigation Properties
/// <summary>
/// The country related to this city.
/// </summary>
public virtual Country Country { get; set; }

#endregion

// ...existing code...
```

As we can see, other than adding the new `Country` property, we also decorated the already-existing `CountryId` property with a new `[ForeignKey("Country")]` Data Annotation. Thanks to that annotation, Entity Framework will know that such a property will host a primary key of a foreign table and that the `Country` navigation property will be used to host the *parent* entity.



It's worth noting that the *binding* that's declared using that `[ForeignKey]` data annotation will be also formally enforced by creating a *constraint*, as long as the DB engine supports such a feature.

As we can see by looking at the first line of the preceding source code, to use the `[ForeignKey]` Data Annotation, we had to add a reference to the `System.ComponentModel.DataAnnotations.Schema` namespace at the beginning of the class.

Adding the Cities property to the Country entity class

Again, add the following at the end of the *Properties* region (the new lines are highlighted):

```
// ...existing code...

#region Navigation Properties
/// <summary>
/// A list containing all the cities related to this country.
/// </summary>
public virtual List<City> Cities { get; set; }
#endregion

// ...existing code...
```

That's it. As we can see, no *foreign key properties* have been defined for this entity since *one-to-many* relationships don't need them from the *parent* side: therefore, there's no need to add a `[ForeignKey]` Data Annotation and/or its required namespace.

Entity Framework Core loading pattern

Now that we have a `Cities` property in the `Country` entity and a corresponding `[ForeignKey]` Data Annotation in the `City` entity, you may be wondering how we can use these navigation properties to load the related entities. To put this another way: **how are we going to populate the `Cities` property within the `Country` entity whenever we need to?**

Such a question gives us the chance to spend a couple of minutes enumerating the three ORM patterns supported by Entity Framework Core to load these kinds of related data:

- **Eager Loading:** The related data is loaded from the database as part of the initial query.
- **Explicit Loading:** The related data is explicitly loaded from the database at a later time.
- **Lazy Loading:** The related data is transparently loaded from the database when the entity navigation property is accessed for the first time. This is the most complex pattern among the three and might suffer from some serious performance impacts when not implemented properly.

It's important to understand that, whenever we want to load an entities' *related data*, we need to activate (or implement) one of these patterns. This means that, in our specific scenario, our `Country` entity's `Cities` property will be set to `NULL` whenever we fetch one or more countries from the database, **unless we explicitly tell Entity Framework Core to load the cities as well**. This is a very important aspect to consider when dealing with Web APIs because it will definitely impact how our .NET Core *back-end* will serve their JSON structured data responses to our *front-end* Angular client.

To understand what we mean, let's take a look at a couple of examples.

The following is a standard Entity Framework Core query that's used to retrieve `Country` from a given `Id`:

```
var country = await _context.Countries
    .FindAsync(id);

return country; // country.Cities is still set to NULL
```

As we can see, the `country` variable is returned to the caller with the `Cities` property set to `NULL`, simply because we didn't ask for it: for that very reason, if we convert that variable into a JSON object and return it to the client, the JSON object would contain no cities either.

The following is an Entity Framework Core query that retrieves `country` from a given `id` using **Eager Loading**:

```
var country = await _context.Countries
    .Include(c => c.Cities)
    .FindAsync(id);

return country; // country.Cities is (eagerly) loaded
```

Let's try to understand what happened here:

- The `Include()` method that was specified at the start of the query tells Entity Framework Core to activate the Eager Loading data retrieval pattern.
- As for the new pattern, the EF query will fetch the `country` as well as all of the corresponding cities in a single query.
- For all of these reasons, the returned `country` variable will have the `Cities` property filled with all the `cities` related to `country` (that is, the `CountryId` value will be equal to that `country`'s `id` value).



For additional information regarding **lazy loading**, **eager loading**, and **explicit loading**, we strongly suggest that you take a look at the following URL: <https://docs.microsoft.com/en-US/ef/core/querying/related-data>.

With this, we're done with the entities, at least for the time being. Now, we just need to get ourselves a DBMS so that we can actually create our database.

Getting a SQL Server

Let's close this gap once and for all and provide ourselves with a SQL Server instance. As we already mentioned, there are two major routes we can take:

- **Install a local SQL Server instance** (Express or Developer Edition) on our development machine.
- **Set up a SQL Database (and/or Server) on Azure** using one of the several options available on that platform.

The former option embodies the classic, cloudless approach that software and web developers have been using since the dawn of time: a local instance is easy to pull off and will provide everything we're going to need in development and production environments...as long as we don't care about data redundancy, heavy infrastructure load and possible performance impacts (in case of high-traffic websites), scaling, and other bottlenecks due to the fact that our server is a single physical entity.

In Azure, things work in a different way: putting our DBMS there gives us the chance to have our SQL Server workloads running as either a hosted infrastructure (**Infrastructure as a Service (IaaS)**) or a hosted service (**PaaS**): the first option is great if we want to handle the database maintenance tasks by ourselves, such as applying patches and taking backups; the second option is preferable if we want to delegate such operations to Azure. However, regardless of the path we choose, we're going to have a scalable database service with full redundancy and *no single point of failure* guarantees, plus a lot of other performance and data security benefits. The downsides, as we can easily guess, are as follows: the additional cost and the fact that we're going to have our data located elsewhere, which can be a major issue in terms of privacy and data protection in certain scenarios.

In the following section, we'll quickly summarize how to pull off both of these approaches so that we can make the most convenient choice.

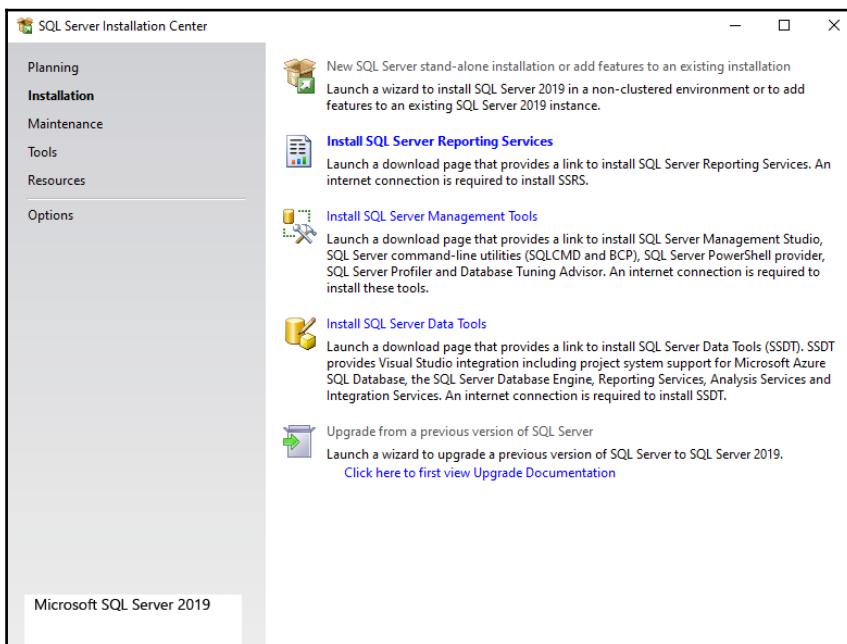
Installing SQL Server 2019

If we want to avoid the cloud and stick to an "old-school" approach, we can choose to install a **SQL Server Express** (or Developer) on-premise instance on our development (and later, on our production) machine.

To do that, perform the following steps:

1. **Download the SQL Server 2019 on-premise installation package** (arguably the Windows build, but the Linux installer is also available) from the following URL: <https://www.microsoft.com/en-us/sql-server/sql-server-downloads>.
2. **Double-click to the executable file** to start the installation process. When prompted for the installation type, select the **Default** option (unless we need to configure some **Advanced** options to accommodate specific needs, providing that we know what we're doing).

The installation package will then start downloading the required files. When it's done, we'll just have to click **New SQL Server stand-alone installation** (the first available option starting from the top, as shown in the following screenshot) to start the actual installation process:



Accept the license terms and go ahead, keeping all of the default options and performing the required operations (such as opening the **Windows Firewall**) when asked to.



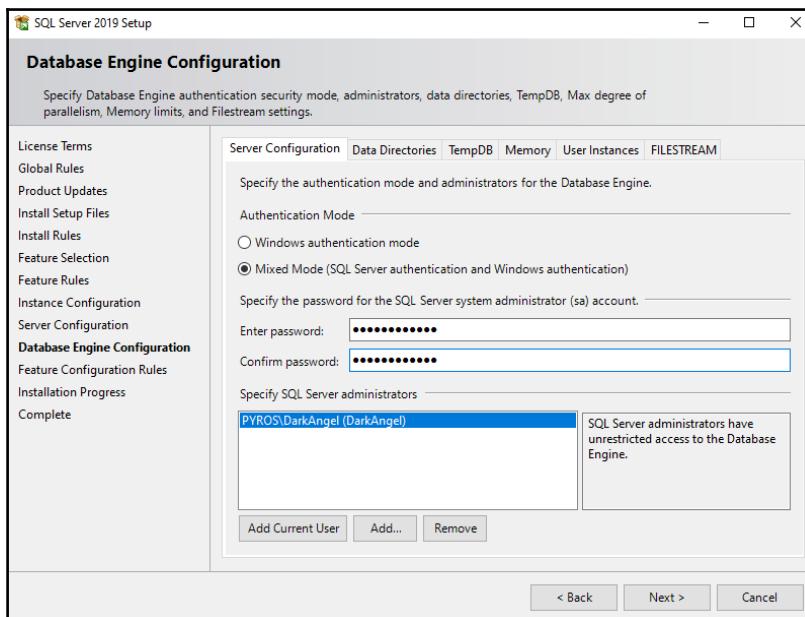
If we want to keep our disk space consumption to a minimum amount, we can safely remove the **SQL Replication** and **Machine Learning** services from the **Feature Selection** section and save roughly 500 GB.

Set the **Instance Name** to `SQLExpress` and the **Instance ID** to `SQLEXPRESS`. Remember that choice: we're going to need it when we have to write down our connection string.

When we're asked to choose **Authentication Mode** (as we can see in the following screenshot), choose one of the following options:

- **Windows authentication mode**, if we want to be able to have unrestricted access to the database engine only from the local machine (using our Windows credentials)
- **Mixed Mode**, to enable the SQL Server system administrator (the `sa` user) and set a password for it

These two options can be seen in the following screenshot:



The former option is great for security, while the latter is much more versatile—especially if we're going to administer the SQL server remotely using the SQL Server built-in administrative interface, which is the tool we're going to use to create our database.

Those who need a more comprehensive guide to perform the SQL Server local instance installation can take a look at the following tutorials:



Installing SQL Server on Windows: <https://docs.microsoft.com/en-US/sql/database-engine/install-windows/installation-for-sql-server>.

Installing SQL Server on Linux: <https://docs.microsoft.com/en-US/sql/linux/sql-server-linux-setup>.

After the SQL Server installation is complete, we should also install the **SQL Server Management tools**—a bunch of useful tools that can be used to manage any SQL instance available locally and/or remotely, as long as the server is reachable and has been configured to allow remote access. More specifically, the tool we're going to need is **SQL Server Management Studio (SSMS)**, which is basically a GUI interface that can be used to create databases, tables, stored procedures, and so on, as well as manipulate data.



Although being available from the SQL Server installation and setup tool, SSMS is a separate product and is available (free of charge) at the following URL: <https://docs.microsoft.com/en-us/sql/ssms/download-sql-server-management-studio-ssms>.

However, before using it, we're going to spend some valuable time talking about the Azure path.

Creating a SQL Database on Azure

If you want to get over the DBMS local instances and embrace the *cloudful Azure* route, our to-do list entirely depends on which of the main approaches provided by the Azure platform we're going to choose from. Here are the three main options available to end users, from the least to the most expensive. They are as follows:

- **SQL Database:** This is a fully-managed SQL Database engine based on SQL Server Enterprise Edition. This option allows us to set up and manage one or more single relational databases hosted in the Azure cloud with a **Platform-as-a-Service (PaaS)** usage and billing model: more specifically, we can define it as a **Database-as-a-Service (DBaaS)** approach. This option provides built-in high availability, intelligence, and management, which means it's great for those who want a versatile solution without the hassle of having to configure, manage, and pay for a whole server host.
- **SQL managed instance:** This is a dedicated SQL managed instance on Azure, this is a scalable database service that provides near 100% compatibility with a standard SQL Server instance and features an IaaS usage and billing model. This option provides all of the PaaS benefits of the previous one (SQL Database) but adds some additional infrastructure-related capabilities, such as a native **Virtual Network (VNet)**, custom private IP addresses, multiple databases with shared resources, and so on.
- **SQL virtual machine:** This is a fully-managed SQL Server consisting of a Windows or Linux virtual machine with a SQL Server instance installed on top of it. This approach, which also adopts an IaaS usage and billing model, offers full administrative control over the whole SQL Server instance and the underlying OS, hence being the most complex and customizable one. The most significant difference from the other two options (SQL Database and SQL managed instance) is that SQL Server VMs also allows full control over the database engine: we can choose when to start maintenance/patching, change the recovery model, pause/start the service, and so on.



For more information regarding the pros and cons of the Azure options described here, we strongly suggest that you read the following guide: <https://docs.microsoft.com/en-US/azure/sql-database/sql-database-paas-vs-sql-server-iaas>.

All of these options are good and, although very different in terms of overall costs, can be activated free of charge: **SQL Database** is arguably the cheapest one because it's free for 12 months, thanks to the trial subscription plan offered by Azure, as long as we keep its size under 250 GB; either **SQL managed instance** and **SQL virtual machine** are rather expensive, since they both provide a virtualized IaaS, but they can be activated for free (at least for a few weeks) with the €200 provided by that same Azure trial subscription plan.

In the following sections, we're going to learn how to set up a SQL Database since it the less expensive approach in the long-term: the only downside is that we'll have to keep its size under 250 GB... which is definitely not an issue, considering that our world cities data source file is less than 1 GB in size.



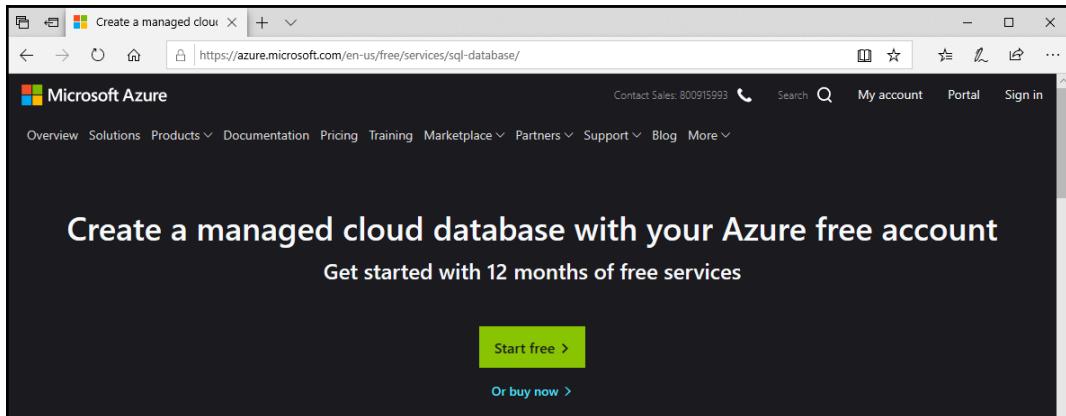
In case we want to opt for an Azure SQL managed instance (option #2), here's a great guide explaining how to do that: <https://docs.microsoft.com/en-us/azure/sql-database/sql-database-managed-instance-get-started>.

If you wish to set up a SQL Server installed on a virtual machine (option #3), here's a tutorial covering that topic: <https://docs.microsoft.com/en-US/azure/virtual-machines/windows/sql/quicksstart-sql-vm-create-portal>.

Setting up a SQL Database

Let's start by visiting the following URL: <https://azure.microsoft.com/en-us/free/services/sql-database/>.

This will bring us to the following web page, which allows us to create an Azure SQL managed instance:



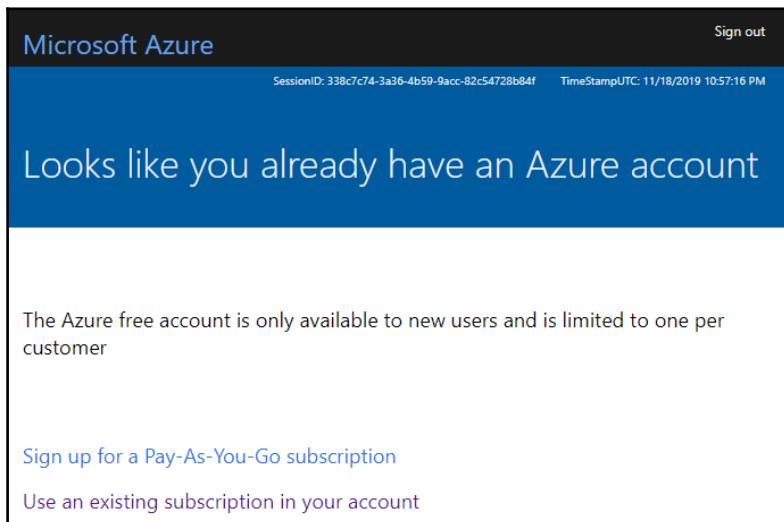
Click the **Start free** button and create a new account.



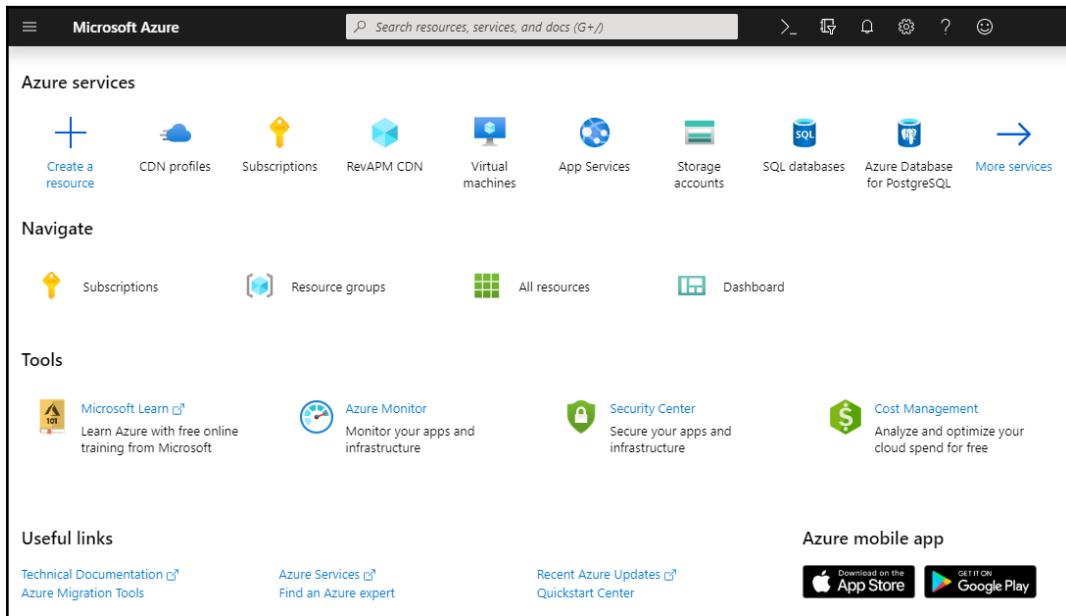
If you already have a valid MS account, you can definitely use it; however, you should only do that if you're sure that you want to use the free Azure trial on it: if that's not the case, consider creating a new one.

After a brief registration form (and/or login phase), we'll be redirected to the Azure portal.

It goes without saying that if the account we've logged in with has already spent its free period or has an active paid subscription plan, we'll be gracefully bounced back:



Eventually, after we've sorted everything out, we should be able to access the Azure portal (<https://portal.azure.com>) in all of its glory:

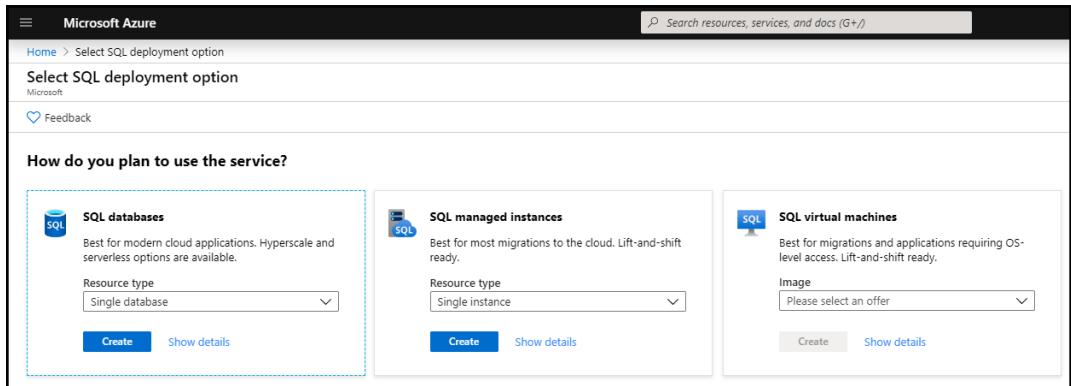


Once there, do the following:

1. Click the **Create a resource** button to access the Azure Marketplace.
2. Search for an entry called **Azure SQL**.
3. Click **Create** to access to the selection page shown in the following screenshot:



IMPORTANT: Be careful that you don't pick the **SQL managed instance** entry instead, which is the one for creating the *SQL Server Virtual Machine*—this is option #2 that we talked about earlier.



From the preceding selection screen, do the following:

1. Select the first option (**SQL databases**).
2. Set the **Resource type** drop-down list to **Single database**.
3. Click the **Create** button to start the main setup wizard.

During this process, we'll be also asked to create our very first **Azure Tenant** (unless we already have one). This is a virtual organization that owns and manages a specific set of Microsoft cloud services. Tenants are identified by unique URLs in the following format: <TenantName>.onmicrosoft.com. Just give it a suitable name and go ahead.

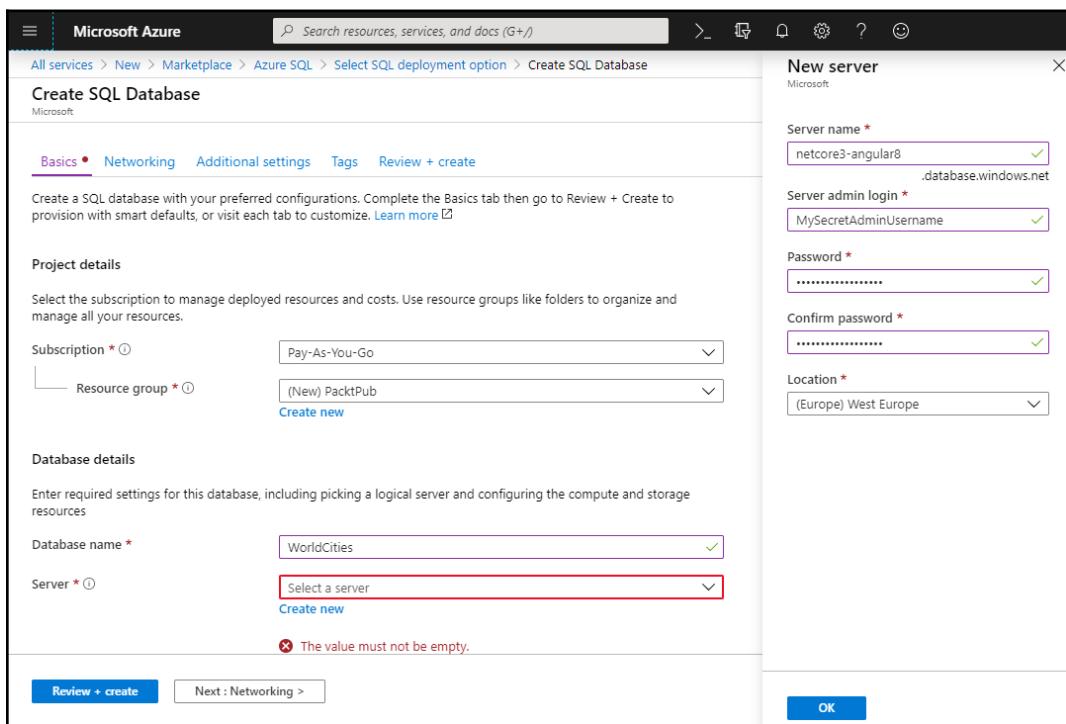
Configuring the instance

As soon as we click the **Create** button, we'll be asked to configure our SQL Database with a wizard-like interface split into the following tabs:

- **Basics:** Subscription type, instance name, admin username and password, and so on
- **Networking:** Network connectivity method and firewall rules
- **Additional settings:** Collation and Time Zone
- **Tags:** A set of name/value pairs that can be applied to logically organize Azure resources into functional categories or groups sharing a common scope (such as Production and Test).
- **Review + Create:** Review and confirm all of the preceding

In the **Basics** tab, we have to insert the database details, such as the database name and the server we would like to use. If this is our first time coming here, we're not going to have any available servers. Due to this, we'll have to create our first one by clicking on the **Create new** link and filling in the pop-over form that will slide into the rightmost side of the screen. Be sure to set a non-trivial **Server admin login** and a complex **Password** as we will need those credentials for our upcoming connection string.

The following screenshot shows an example of how to configure this part of the wizard:



The last option in the **Basics** tab will ask us for the **Compute + storage** type: for this specific project, we can definitely choose the minimum possible tier—a **Basic** storage type with 2 GB maximum space.

However, if we're feeling bold, we can go for a **Standard** type with 250 GB storage instead since it would still be free for 12 months (see the following screenshot):

The screenshot shows the 'Configure' step in the Azure portal for creating a SQL database. It highlights the 'Standard' tier, which is described as 'For workloads with typical performance requirements'. Below this, a slider for 'Data max size' is set to 2 GB. To the right, a summary box provides a cost estimate of 4.21 EUR per month for 5 DTUs selected at 0.84 EUR per DTU.

In the **Networking** tab, be sure to choose a **Public endpoint** to enable external access from the internet so that we'll be able to connect to our database from all of our environments. We should also set both the firewall rules to **Yes** to *allow Azure services and resources to access the server* and *add our current IP address* to the allowed IPs whitelist.

Wait a minute: isn't that a *major* security issue? What if our databases contain personal or sensitive data?



As a matter of fact, it actually is: allowing public access from the internet is something we should always avoid unless we're playing with open data for testing, demonstrative, or tutorial purposes... which is precisely what we're doing right now.

The **Additional Settings** and **Tags** tabs are OK with their default settings: we should only change them if we need to alter some options (such as the **Collation** and the **Time zone** that are most suitable to our language and country) or to activate specific stuff such as the *advanced data security*—which is completely unnecessary for our current needs.

In the **Review + Create** tab, we'll have our last chance to review and change our settings (as shown in the following screenshot): if we're not sure about them, we have the chance to go back and change them. When we're 100% sure, we can hit the **Create** button and have our SQL Database deployed in a few seconds:

Basics	
Subscription	Pay-As-You-Go
Resource group	PacktPub
Region	(Europe) West Europe
Database name	WorldCities
Server	(new) netcore3-angular8
Compute + storage	Basic: 2 GB storage
Networking	
Allow Azure services and resources to access this server	Yes
Add current client IP address	Yes
Private endpoint (preview)	None
Additional settings	
Use existing data	Blank
Collation	SQL_Latin1_General_CI_AS
Advanced data security	Not now
Tags	
Create	< Previous
Download a template for automation	



It's worth noticing that we can also **Download a template for automation**, in case we want to save these settings to create additional SQL Databases in the future.

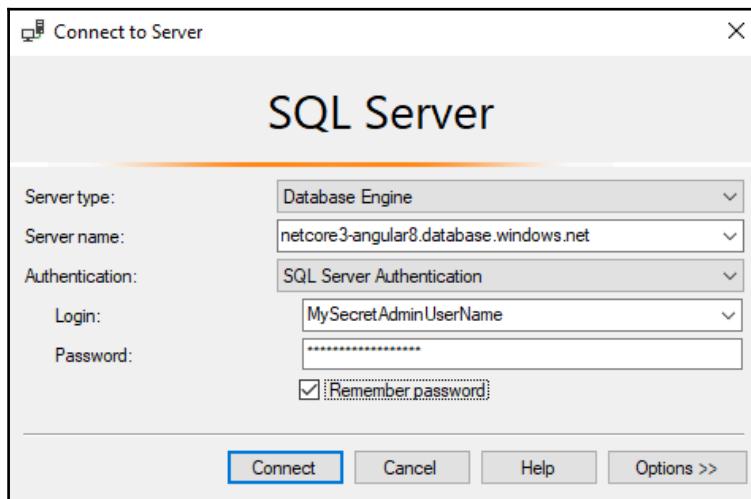
That's it: now, we can focus on configuring our database.

Configuring the database

Regardless of the path, we take—a local instance or Azure—we should be ready to manage our newly-created Azure SQL Database.

The most practical way to do that is using SSMS, the free SQL Server Management GUI, which we can download for free by following the instructions we explained a while ago (see the *Installing SQL Server 2019* section). In case we don't have installed it yet, we can do that right after we've downloaded it.

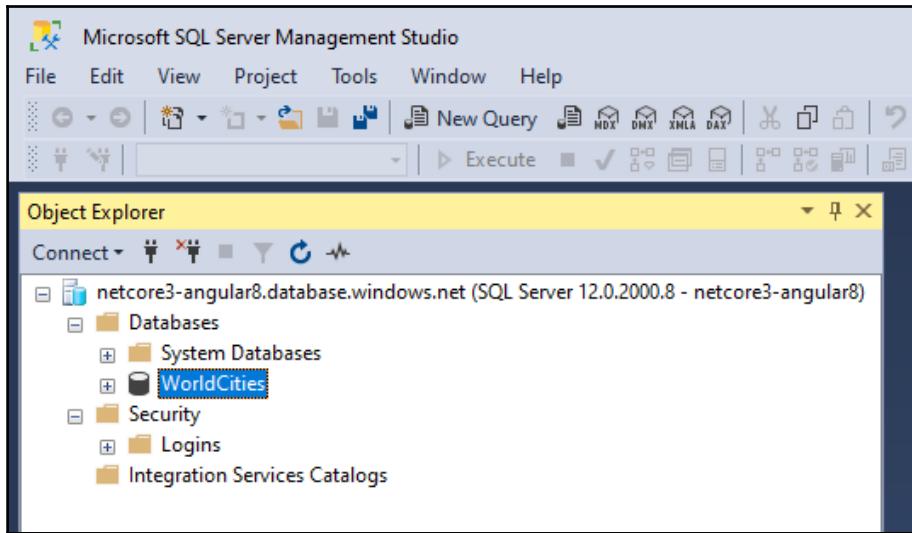
Once done, we just have to select **SQL Server Authentication** and then type in the **Server name**, **Login**, and **Password** we chose when we created the SQL Database on Azure. This can be seen in the following screenshot:



By clicking the **Connect** button, we should be able to log in to our database server. As soon as SSMS connects to the SQL Database Server, a **Server Explorer** window will appear, containing a tree view representing the structure of our SQL Server instance. This is the interface we'll use to create our database, as well as the user/password that our application will use to access it.

Creating the WorldCities database

If we took the Azure SQL Database route, we should already be able to see the **WorldCities** database in the **Databases** folder of the **Object Explorer** tree to the left:



Alternatively, if we installed our local *SQL Server Express* or *Development* instance, we'll have to manually create it by doing the following:

1. Right-click on the **Databases** folder.
2. Choose **Add Database** from the contextual menu.
3. Type in the **WorldCities** name, then click on **OK** to create it.

Once the database has been created, we'll get the chance to expand its tree node by clicking on the plus (+) sign to the left and visually interact with all its child objects—*tables*, *stored procedures*, *users*, and so on—through the SSMS GUI. It goes without saying that if we do that now, we would find no tables because we haven't created them yet: that's something that *Entity Framework* will do for us later on. However, before doing that, we're going to add a **login** account to make our web application able to connect.

Adding the WorldCities login

Go back to the root Databases folders and expand the Security folder, which should be just below it. Once there, do the following:

- Right-click on the Logins subfolder and choose **New Login**.
- In the modal window that appears, set the login name to `WorldCities`.
- From the radio button list below the login name, select **SQL Server Authentication** and set a suitable password with decent strength (such as `MyVeryOwn$721`—we're going to use this one for the code samples and screenshots from now on).
- Be sure to disable the **User must change the password at next login** option (which is *checked* by default); otherwise, Entity Framework Core will be unable to perform the login later on.
- Set the user's **Default Database** to `WorldCities`.
- Review all of the options, then click on **OK** to create the `WorldCities` account.



If we want a simpler password, such as `WorldCities` or **Password**, we might have to disable the **enforce password policy** option.

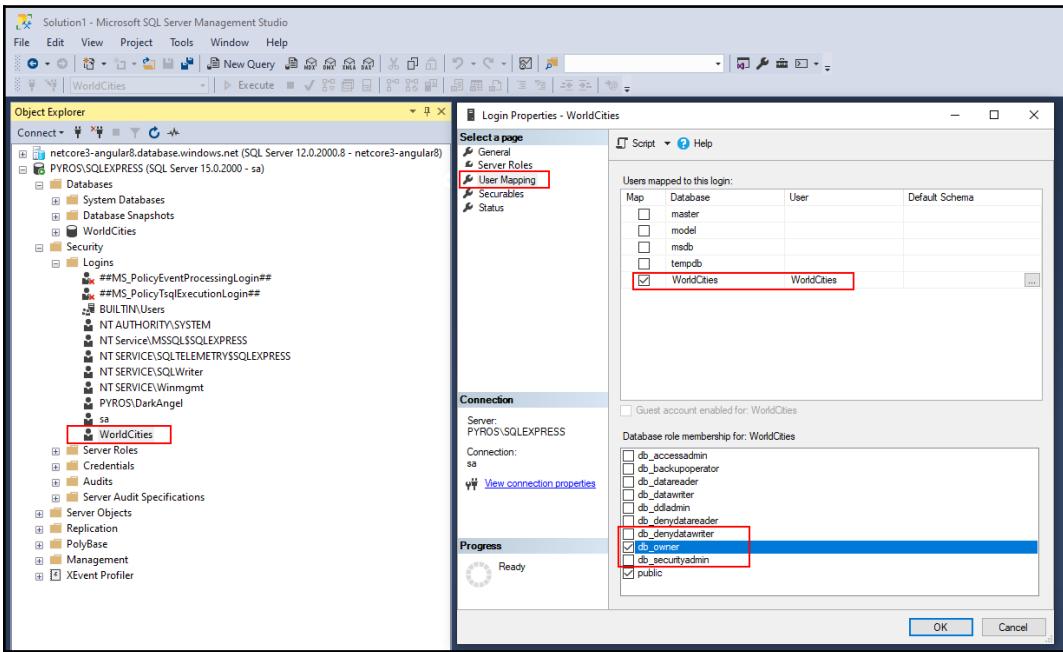
However, we strongly advise against doing that: choosing a weak password is never a wise choice, especially if we do that in a production-ready environment. We suggest that you always use a strong password, even in testing and development environments. Just be sure not to forget it, as we're going to need it later on.

Mapping the login to the database

The next thing we need to do is properly map this login to the `WorldCities` database we added earlier. Here's how to do that:

1. Double-click the `WorldCities` login name from the **Databases | Security** folder to open the same modal we used just a few seconds ago.
2. From the navigation menu to the left, switch to the **User Mapping** tab.
3. Click on the checkbox to the right of the `WorldCities` database: the **User** cell should be automatically filled with the `WorldCities` value. In case it doesn't, we'll need to manually type `WorldCities` into it.
4. In the **Database role membership** for box in the bottom-right panel, assign the `db_owner` membership role.

All of the preceding steps are depicted in the following screenshot:



That's it! Now, we can go back to our web application project, add the connection string, and create our tables (and data) using the Entity Framework Code-First approach.

Creating the database using Code-First

Before going further, let's do a quick checklist:

- Are we done with our entities? **Yes**
- Do we have a DBMS and a `WorldCities` database available? **Yes**
- Have we gone through all of the required steps we need to complete to actually create and fill in the aforementioned database using Code-First? **No**

As a matter of fact, we need to take care of two more things:

- Set up an appropriate **Database Context**.
- Enable **Code-First Data Migrations support** within our project.

Within the following sections, we're going to fill all of these gaps and eventually fill our `WorldCities` database.

Setting up the `DbContext`

To interact with data as objects/entity classes, Entity Framework Core uses the `Microsoft.EntityFrameworkCore.DbContext` class, also called `DbContext` or simply **Context**. This class is in charge of all of the entity objects during runtime, including populating them with data from the database, keeping track of changes, and persisting them to the database during CRUD operations.

We can easily create our very own `DbContext` class for our project—which we will call `ApplicationContext`—by doing the following:

1. From **Solution Explorer**, right-click on the `/Data/` folder we created a while ago and add a new `ApplicationContext.cs` class file.
2. Fill it with the following code:

```
using Microsoft.EntityFrameworkCore;
using WorldCities.Data.Models;

namespace WorldCities.Data
{
    public class ApplicationContext : DbContext
    {
        #region Constructor
        public ApplicationContext() : base()
        {
        }

        public ApplicationContext(DbContextOptions options)
            : base(options)
        {
        }
        #endregion Constructor

        #region Methods
        protected override void OnModelCreating(ModelBuilder
            modelBuilder)
        {
            base.OnModelCreating(modelBuilder);

            // Map Entity names to DB Table names
            modelBuilder.Entity<City>().ToTable("Cities");
        }
    }
}
```

```
        modelBuilder.Entity<Country>().ToTable("Countries");
    }
    #endregion Methods

    #region Properties
    public DbSet<City> Cities { get; set; }
    public DbSet<Country> Countries { get; set; }
    #endregion Properties
}
}
```

There are a couple of important things we did here:

- We overrode the `OnModelCreating` method to manually define our data model relationships for our entity classes. Note that we manually configured the table names for each entity using the `modelBuilder.Entity<TEntityType>().ToTable` method; we did that with the sole purpose of showing you how easy it is to customize the *Code-First* generated database.
- We added a `DbSet<T>` property for each of our entities so that we can easily access them later on.

Database initialization strategies

Creating the database for the first time isn't the only thing we need to worry about; for example, how can we keep track of the changes that will definitely occur for our Data Model?

In previous, non-core versions of EF (up to 6.x), we could choose one of the database management patterns (known as **database initializers** or **DbInitializers**) offered by the *Code-First* approach, that is, by picking the appropriate database initialization strategy for our specific needs: `CreateDatabaseIfNotExists`, `DropCreateDatabaseIfModelChanges`, `DropCreateDatabaseAlways`, or `MigrateDatabaseToLatestVersion`. Additionally, should we need to address specific requirements, we can also set up our own custom initializer by extending one of the preceding ones and overriding their core methods.

The major flaw of `DbInitializers` was them not being immediate and streamlined enough for the average developer. They were viable, yet difficult to handle without extensive knowledge of Entity Framework's logic.

In Entity Framework Core, this pattern has been greatly simplified; there are no `DbInitializers`, and automatic data migrations have also been removed. The database initialization aspect is now entirely handled through PowerShell commands, with the sole exception of a small set of commands that can be placed directly on the `DbContext` implementation constructor to partially automatize the process; they are as follows:

- `Database.EnsureCreated()`
- `Database.EnsureDeleted()`
- `Database.Migrate()`

There's currently no way to create data migrations programmatically; they must be added via PowerShell, as we will see shortly.

Updating the `appsettings.json` file

From **Solution Explorer**, open the `appsettings.json` file and add the following `"ConnectionStrings"` JSON property section right below the `"Logging"` one (the new lines are highlighted):

```
{
  "ConnectionStrings": {
    "DefaultConnection": "Server=localhost\\SQLEXPRESS;
      Database=WorldCities;
      User Id=WorldCities;Password=MyVeryOwn$721;
      Integrated Security=False;MultipleActiveResultSets=True"
  },
  "Logging": {
    "LogLevel": {
      "Default": "Warning"
    }
  },
  "AllowedHosts": "*"
}
```



Unfortunately, JSON doesn't support LF/CR, so we'll need to put the `DefaultConnection` value on a single line. If you copy and paste the preceding text, ensure that Visual Studio doesn't automatically add additional double quotes and/or escape characters to these lines; otherwise, your connection string won't work.

This is the connection string we'll be referencing in our project's `Startup.cs` file later on.

Creating the database

Now that we have set up our own `DbContext` and defined a valid connection string pointing to our `WorldCities` database, we can easily add the initial migration and create our database.

Updating Startup.cs

The first thing we have to do is add the `EntityFramework` support and our `ApplicationDbContext` implementation to our application startup class. Open the `Startup.cs` file and update the `ConfigureServices` method in the following way (the new lines are highlighted):

```
// ...existing code...

public void ConfigureServices(IServiceCollection services)
{
    services.AddControllersWithViews();
    // In production, the Angular files will be served
    // from this directory
    services.AddSpaStaticFiles(configuration =>
    {
        configuration.RootPath = "ClientApp/dist";
    });

    // Add EntityFramework support for SqlServer.
    services.AddEntityFrameworkSqlServer();

    // Add ApplicationDbContext.
    services.AddDbContext<ApplicationDbContext>(options =>
        options.UseSqlServer(
            Configuration.GetConnectionString("DefaultConnection")
        )
    );
}

// ...existing code...
```

The new code will also require the following namespace references:

```
using Microsoft.EntityFrameworkCore;
using WorldCities.Data;
```

Adding the initial migration

Open **PowerShell** Command Prompt and navigate through the project's root folder, which is as follows in our example:

```
C:\ThisBook\Chapter_04\WorldCities\
```

Once there, type the following command to globally install the `dotnet-ef` command-line tool:

```
dotnet tool install --global dotnet-ef
```

Wait until the installation is complete. When we receive the *green* message output, type in the following command to add the first migration:

```
dotnet ef migrations add "Initial" -o "Data\Migrations"
```

The optional `-o` parameter can be used to change the location where the migration code-generated files will be created; if we don't specify it, a root-level `/Migrations/` folder will be created and used by default. Since we put all of the `EntityFrameworkCore` classes into the `/Data/` folder, it's advisable to store migrations there as well.

The preceding command will produce the following output:

```
C:\Projects\Book3\Chapter_04\WorldCities>dotnet ef migrations add "Initial" -o "Data\Migrations"
warn: Microsoft.EntityFrameworkCore.ModelValidation[30000]
  No type was specified for the decimal column 'Lat' on entity type 'City'. This will cause values to be silently truncated if they do not fit in the default precision and scale. Explicitly specify the SQL server column type that can accommodate all the values using 'HasColumnType()'.
warn: Microsoft.EntityFrameworkCore.ModelValidation[30000]
  No type was specified for the decimal column 'Lon' on entity type 'City'. This will cause values to be silently truncated if they do not fit in the default precision and scale. Explicitly specify the SQL server column type that can accommodate all the values using 'HasColumnType()'.
info: Microsoft.EntityFrameworkCore.Infrastructure[10403]
  Entity Framework Core 3.0.0 initialized 'ApplicationDbContext' using provider 'Microsoft.EntityFrameworkCore.SqlServer' with options: None
Done. To undo this action, use 'ef migrations remove'

C:\Projects\Book3\Chapter_04\WorldCities>
```

Hey, wait for a second: what are those **warn** yellow messages?

Let's spend a handful of seconds carefully reading them and acknowledging the issue they are pointing to. It definitely seems that the Lat/Lon properties within the `City` entity (both of decimal type) are both missing an explicit precision value: if we don't provide such information, Entity Framework won't know which precision to set for the database table columns it will create for those properties and will fall back to its default values. That fallback could result in a loss of precision if our actual data has a greater number of decimals.

Even if we couldn't care less about the precision of these Lat/Lon coordinates in our specific scenario, since we're just playing with data, it's definitely advisable to fix these kinds of issues as soon as we see them. Luckily, this can easily be done by adding some Data Annotations to these properties.

Open the `/Data/Models/City.cs` file and change the following code accordingly (the modified lines are highlighted):

```
// ...existing code...

/// <summary>
/// City latitude
/// </summary>
[Column(TypeName = "decimal(7,4)")]
public decimal Lat { get; set; }

/// <summary>
/// City longitude
/// </summary>
[Column(TypeName = "decimal(7,4)")]
public decimal Lon { get; set; }

// ...existing code...
```

Once done, delete the `/Data/Models/Migration` folder (along with all files within it) and launch the `dotnet-ef` command again:

```
dotnet ef migrations add "Initial" -o "Data\Migrations"
```

This time, the migration should be created without *yellow* warning issues, as shown in the following screenshot:

```
C:\Projects\Book3\Chapter_04\WorldCities>dotnet ef migrations add "Initial" -o "Data\Migrations"
info: Microsoft.EntityFrameworkCore.Infrastructure[10403]
      Entity Framework Core 3.0.0 initialized 'ApplicationDbContext' using provider 'Microsoft.EntityFrameworkCore.SqlServer' with options: None
Done. To undo this action, use 'ef migrations remove'
C:\Projects\Book3\Chapter_04\WorldCities>
```

This means that we finally have the *green light* to apply it.



If we go back to Visual Studio and take a look at our project's **Solution Explorer**, we will see that there's a new `/Data/Migrations/` folder containing a bunch of code-generated files. Those files contain the actual low-level SQL commands that will be used by Entity Framework Core to create and/or update the database schema.

Updating the database

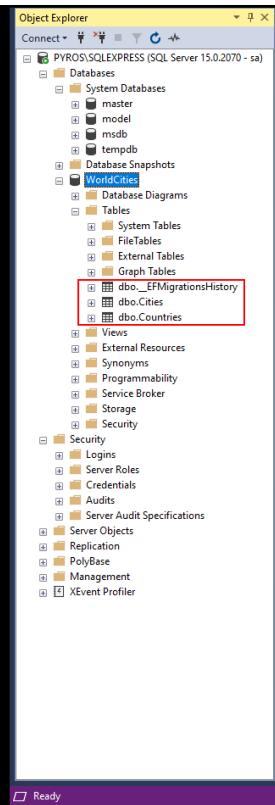
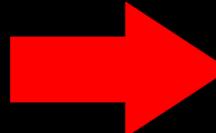
Applying a data migration basically means creating (or updating) the database in order to synchronize its contents (tables structure, constraints, and so on) with the rules that are defined by the overall patterns and definitions within the `DbContext` and by the data annotations within the various Entity classes. More specifically, the first data migration creates the whole database from scratch, while the subsequent ones will update it (creating tables, adding/modifying/removing table fields, and so on).

In our specific scenario, we're about to execute our first migration. Here's the one-liner we need to type from the command-line (within the project root folder, just like before) to do that:

```
dotnet ef database update
```

Once we hit *Enter*, a bunch of SQL statements will fill the output of our command-line Terminal window. When done, if everything is looking good, we can go back to the SSMS tool, refresh the **Server Object Explorer** treeview, and verify that the WorldCities database has been created, along with all of the relevant tables:

```
 1: Microsoft.EntityFrameworkCore.Database.Command[20100]
 2:   EntityCommand: Core 3.0.0 initialized 'ApplicationDbContext' using provider 'Microsoft.EntityFrameworkCore.SqlServer' with options: Non
 3:   info: Microsoft.EntityFrameworkCore.Database.Command[20100]
 4:     Executing DbCommand [Parameters=[], CommandType='Text', CommandTimeout='30']
 5:       SELECT OBJECT_ID('[_EFMigrationsHistory]')
 6:   Executing DbCommand [Parameters=[], CommandType='Text', CommandTimeout='30']
 7:     SELECT OBJECT_ID('[_EFMigrationsHistory]')
 8:   Executing DbCommand [Parameters[], CommandType='Text', CommandTimeout='30']
 9:     SELECT OBJECT_ID([_EFMigrationsHistory])
10:   Executing DbCommand [Parameters[], CommandType='Text', CommandTimeout='30']
11:     SELECT OBJECT_ID([_MigrationHistory])
12:   Executing DbCommand [Parameters[], CommandType='Text', CommandTimeout='30']
13:     SELECT [MigrationId], [ProductVersion]
14:   Executing DbCommand [Parameters[], CommandType='Text', CommandTimeout='30']
15:     ORDER BY [MigrationId]
16:   info: Microsoft.EntityFrameworkCore.Database.Command[20100]
17:     Executing DbCommand [Parameters[], CommandType='Text', CommandTimeout='30']
18:       SELECT [MigrationId], [ProductVersion]
19:         FROM [_MigrationHistory]
20:       ORDER BY [MigrationId];
21:   info: Microsoft.EntityFrameworkCore.Database.Migrations[20402]
22:     Applying migration '20191122080400_Initital'.
23: Applying migration '20191122080400_Initital'.
24: Executing DbCommand [Parameters[], CommandType='Text', CommandTimeout='30']
25: CREATE TABLE [[_MigrationHistory]] (
26:   [Id] int NOT NULL IDENTITY,
27:   [Name] nvarchar(max) NULL,
28:   [IS02] nvarchar(max) NULL,
29:   [IS03] nvarchar(max) NULL,
30:   [CONSTRAINT [PK__MigrationHistory] PRIMARY KEY ([Id])]
31: );
32: info: Microsoft.EntityFrameworkCore.Database.Command[20100]
33: Executing DbCommand [Parameters[], CommandType='Text', CommandTimeout='30']
34: CREATE TABLE [[_Countries]] (
35:   [Id] int NOT NULL IDENTITY,
36:   [Name] nvarchar(max) NULL,
37:   [IS02] nvarchar(max) NULL,
38:   [IS03] nvarchar(max) NULL,
39:   [CONSTRAINT [PK__Countries] PRIMARY KEY ([Id])]
40: );
41: Executing DbCommand [Parameters[], CommandType='Text', CommandTimeout='30']
42: CREATE TABLE [[_Cities]] (
43:   [Id] int NOT NULL IDENTITY,
44:   [Name] nvarchar(max) NULL,
45:   [Name_ASCI] nvarchar(max) NULL,
46:   [Lat] decimal(7,4) NOT NULL,
47:   [Lon] decimal(7,4) NOT NULL,
48:   [CountryId] int NOT NULL,
49:   [CONSTRAINT [PK__Cities] PRIMARY KEY ([Id]),
50:   CONSTRAINT [FK__Cities__CountryId] FOREIGN KEY ([CountryId]) REFERENCES [Countries] ([Id]) ON DELETE CASCADE
51: );
52: info: Microsoft.EntityFrameworkCore.Database.Command[20100]
53: Executing DbCommand [Parameters[], CommandType='Text', CommandTimeout='30']
54: CREATE TABLE [[_Countries_CountryId]] (
55:   [Id] int NOT NULL IDENTITY,
56:   [Name] nvarchar(max) NULL,
57:   [Name_ASCI] nvarchar(max) NULL,
58:   [Lat] decimal(7,4) NOT NULL,
59:   [Lon] decimal(7,4) NOT NULL,
60:   [CountryId] int NOT NULL,
61:   [CONSTRAINT [PK__Cities__CountryId] PRIMARY KEY ([Id]),
62:   CONSTRAINT [FK__Cities__CountryId] FOREIGN KEY ([CountryId]) REFERENCES [Countries] ([Id]) ON DELETE CASCADE
63: );
64: Executing DbCommand [Parameters[], CommandType='Text', CommandTimeout='30']
65: CREATE INDEX IX__Cities_CountryId ON [Cities] ([CountryId]);
66: info: Microsoft.EntityFrameworkCore.Database.Command[20100]
67: Executing DbCommand [Parameters[], CommandType='Text', CommandTimeout='30']
68: CREATE INDEX IX__Countries_CountryId ON [Countries] ([CountryId]);
69:   CREATE INDEX IX__Countries_CountryId ON [Cities] ([CountryId]);
70: Executing DbCommand [Parameters[], CommandType='Text', CommandTimeout='30']
71:   INSERT INTO [[_EFMigrationsHistory]] ([MigrationId], [ProductVersion])
72:     VALUES ('20191122080400_Initital', 'N'3.0.0');
73:   info: Microsoft.EntityFrameworkCore.Database.Command[20100]
74:     Executing DbCommand [Parameters[], CommandType='Text', CommandTimeout='30']
75:       INSERT INTO [_MigrationHistory] ([MigrationId], [ProductVersion])
76:         VALUES ('20191122080400_Initital', 'N'3.0.0');
Done.
```



Those of you who have used migrations before might be asking why we didn't use Visual Studio's Package Manager Console to execute these commands. The reason is simple—unfortunately, doing this won't work because the commands need to be executed within the project root folder, which is not where the Package Manager Console commands are executed. It is unknown whether that behavior will change in the near future. Until it does, we'll have to use the command line.



The "No executable found matching command "dotnet-ef" error

At the time of writing, there's a nasty issue affecting most .NET Core-based Visual Studio projects that can prevent the `dotnet ef` command from working properly. More specifically, we may be prompted by the following error message when trying to execute any `dotnet ef` based command:

```
No executable found matching command "dotnet-ef"
```

If we happen to experience this issue, we can try to check out the following:

- Double-check that we added the `Microsoft.EntityFrameworkCore.Tools` and `Microsoft.EntityFrameworkCore.Tools.DotNet` package libraries (as explained earlier) properly, as they are required for the command to work.
- Ensure that we're issuing the `dotnet ef` command in the project's root folder—the same one that also contains the `<ProjectName>.csproj` file; it won't work anywhere else.

If both of these checks hit their marks, we can try the following workaround: right-click on the project's root folder, select `Edit <ProjectName>.csproj` to open that file so that it can be edited in Visual Studio, and look for the following element:

```
<ItemGroup>
  <DotNetCliToolReference Include="Microsoft.EntityFrameworkCore.Tools" />
  <DotNetCliToolReference
    Include="Microsoft.EntityFrameworkCore.Tools.DotNet" />
</ItemGroup>
```



Alternatively, we can also edit the `<ProjectName>.csproj` file with a text editor such as Notepad++; just ensure that you reload the project when you're done.

The `<ItemGroup>` element is just a container here; we need to look for the highlighted lines (they could have a `version` property or not, depending on the Entity Framework Core version we're using).

If these lines are not present, that's the reason why the `dotnet ef` command is not working. We need to fix that unwanted behavior, either by uninstalling/reinstalling the related NuGet packages or by manually adding them to the project configuration file. If we choose to manually do that, we need to make sure that we wrap them within a new or existing `<ItemGroup>` block.

Right after we've fixed our project configuration file, we can restart Visual Studio (or reload the project) and try to execute the `dotnet ef` command again from our project's root folder. In the unlikely case that we end up with some NuGet package conflicts, we can try issuing the `dotnet update` command to fix them, reload our project again, and try to execute the `dotnet ef` command once more.



A lot more can be said regarding this issue, but doing is outside the scope of this book. Those of you who want to know more can take a look at this article I wrote about it while working on my **ASP.NET Core 2 and Angular 5** book at <https://goo.gl/Ki6mdb>.

Understanding migrations

Before we move on, it would be useful to say a few words explaining what Code-First Migrations actually are and the advantages we gain by using them.

Whenever we're developing an application and defining a data model, we can be sure that it will change a number of times for many good reasons: new requirements from the product owner, optimization processes, consolidation phases, and so on. A bunch of properties will be added, deleted, or have their types changed. Chances are, sooner or later, we'll be adding new entities as well and/or changing their relation pattern according to our ever-changing needs.

Each time we do something like that, we'll also put our Data Model out of sync with its underlying, Code-First generated database. This won't be a problem when we're debugging our app within a development environment because that scenario usually allows us to recreate the database from scratch whenever the project changes.

Upon deploying the application into production, we'll be facing a whole different story: as long as we're handling real data, dropping and recreating our database won't be an option anymore. This is what the Code-First Migrations feature is meant to address: giving the developer a chance to alter the database schema without having to drop/recreate the whole thing.



We won't dig deeper into this topic; Entity Framework Core is a world of its own, and addressing it in detail is out of the scope of this book. If you want to learn more, we suggest that you start with the official Entity Framework Core MS documentation at <https://docs.microsoft.com/en-us/ef/core/>.

Is data migration required?

Data migration can be very useful, but it's not a required feature and we are definitely not forced to use it if we don't want to. As a matter of fact, it can be quite a difficult concept to understand for a lot of developers, especially for those who aren't much into DBMS design and/or scripting. It can also be very complex to manage in most scenarios, such as in companies where the DBA role is covered by someone who is below the IT development team (such as an external IT consultant or specialist).

Whenever we don't want to use them from the beginning—or we get to a point where we don't want to use them anymore—we can switch to a Database-First approach and start to manually design, create, and/or modify our tables: Entity Framework core will work great, as long as the property types that are defined in the Entities 100% match the corresponding DB table fields. We can definitely do that, even while putting the project samples presented within this book into practice (including the `WorldCities` project, therefore literally from now on), as long as we feel we won't need such a technique in our life.

Alternatively, we can give it a try and see how it goes. The choice, as always, is yours.

Populating the database

Now that we have a SQL Database available and a `DbContext` that we can use to read from and write to it, we are finally ready to populate those tables with our world cities data.

To do that, we need to implement a **data seeding** strategy. We can do this using one of the various Entity Framework Core-supported approaches:

- **Model data seed**
- **Manual migration customization**
- **Custom initialization logic**

These three methods are well-explained in the following article, along with their very own sets of pros and cons: <https://docs.microsoft.com/en-us/ef/core/modeling/data-seeding>.

Since we have to handle a relatively big Excel file, we're going to adopt the most customizable pattern we can make use of: some *custom initialization logic* that will rely upon a dedicated .NET Core Controller that we can execute—manually or even automatically—whenever we need to seed our database.

Implementing SeedController

Our *custom initialization logic* implementation will rely upon a brand-new dedicated Controller, which will be called `SeedController`.

From our project's **Solution Explorer**, do the following:

1. Right-click on the `/Controllers/` folder.
2. Click on **Add | Controller**.
3. Choose the `API Controller - Empty` option (the third from the top, at the time of writing).
4. Give the Controller the `SeedController` name and click **Add** to create it.

Once done, open the newly-created `/Controllers/SeedController.cs` file and take a look at the source code: you'll see that there's just an empty class: just as expected for an empty Controller! This is great since we need to understand some key concepts and—most importantly—learn how to properly translate them in source code.

Do you remember when we added our `ApplicationContext` class to the `Startup.cs` file? As we should already know from [Chapter 2, Looking Around](#), this means that we added the Entity Framework Core middleware to our application's pipeline. This means that we can now leverage the dependency injection loading feature provided by the .NET Core architecture to inject an instance of that `DbContext` class within our Controllers.

Here's how we can translate such a concept into source code (the new lines are highlighted):

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Threading.Tasks;
```

```
using Microsoft.AspNetCore.Http;
using Microsoft.AspNetCore.Mvc;
using WorldCities.Data;

namespace WorldCities.Controllers
{
    [Route("api/[controller]")]
    [ApiController]
    public class SeedController : ControllerBase
    {
        private readonly ApplicationDbContext _context;

        public SeedController(ApplicationDbContext context)
        {
            _context = context;
        }
    }
}
```

As we can see, we've added an `_context` private variable and used it to store an object instance of the `ApplicationDbContext` class within the constructor. Such an instance will be provided by the framework—through its dependency injection feature—withing the constructor method of `SeedController`.

Before making good use of that `DbContext` instance to insert a bunch of entities into our database, we need to find a way to read those world cities values from the Excel file. How can we do that?

Importing the Excel file

Luckily enough, there's a great third-party library that does precisely what we need: reading (and even writing!) Excel files using the Office Open XML format (`xlsx`), hence making their content available within any .NET-based application.

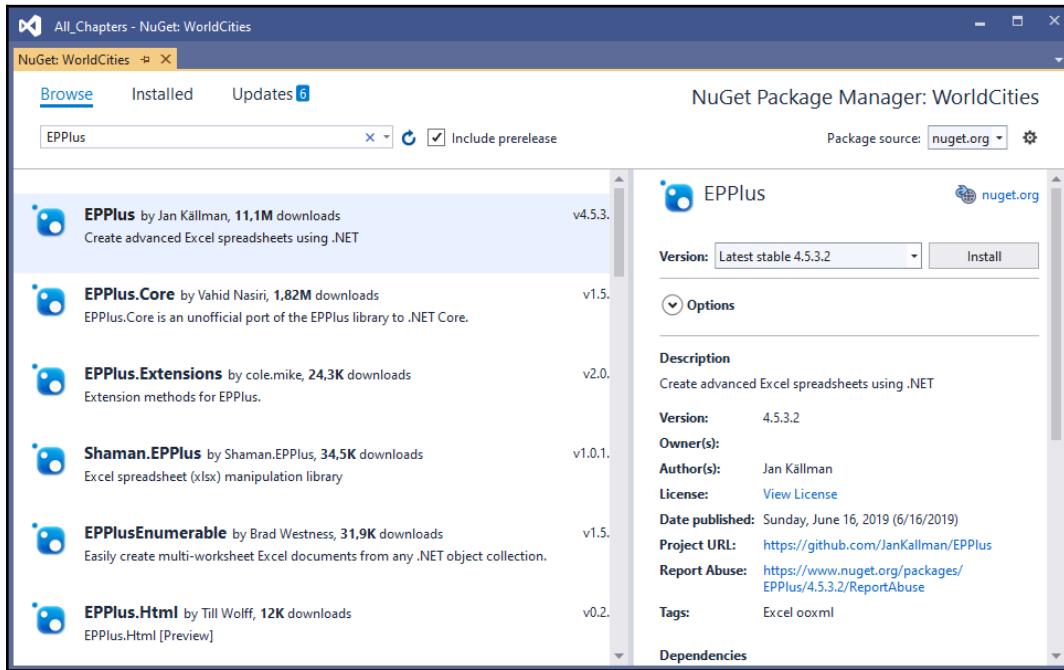
The name of this great tool is EPPlus. Its author, Jan Källman, made it freely available on GitHub and NuGet at the following URLs:

- **GitHub (source code):** <https://github.com/JanKallman/EPPlus>
- **NuGet (.NET Package):** <https://www.nuget.org/packages/EPPlus/4.5.3.2>

As we can see, the project is licensed under the **GNU Library General Public License (LGPL)** v3.0, meaning that we're allowed to integrate it into our software without limitations, as long as we don't modify it.

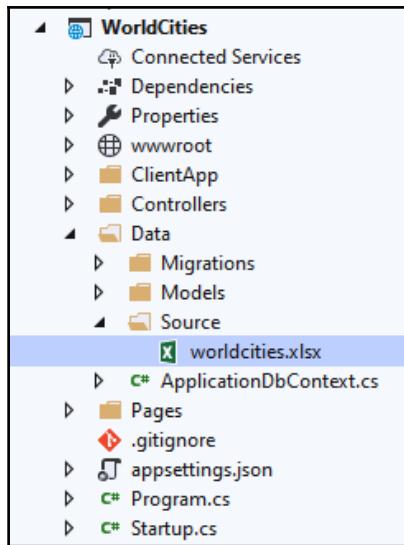
The best way to install EPPlus in our WorldCities project is to add the NuGet package using the NuGet package manager GUI:

1. From the project's **Solution Explorer**, right-click on the WorldCities project.
2. Select **Manage NuGet Packages...**
3. Use the **Browse** tab to search for the EPPlus package and install it by clicking the **Install** button at the top-right:



Once done, we can go back to the `SeedController.cs` file and use the awesome features of EPPlus to read the `worldcities.xlsx` Excel file.

However, before doing that, it could be wise to move that file so that it's within our sample project's `/Data/` folder so that we'll be able to read it using the `.NET Core` filesystem capabilities provided by the `System.IO` namespace. While we're there, let's create a `/Data/Source/` subfolder and put it there to separate it from the other Entity Framework Core files:



Here's the source code that we need to add to our `SeedController.cs` file to read the `worldcities.xlsx` file and store all of the rows in a list of `City` entities:

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Threading.Tasks;
using Microsoft.AspNetCore.Http;
using Microsoft.AspNetCore.Mvc;
using WorldCities.Data;
using OfficeOpenXml;
using System.IO;
using Microsoft.AspNetCore.Hosting;
using WorldCities.Data.Models;
using System.Text.Json;

namespace WorldCities.Controllers
{
    [Route("api/[controller]/[action]")]
    [ApiController]
    public class SeedController : ControllerBase
    {
        private readonly ApplicationDbContext _context;
        private readonly IWebHostEnvironment _env;

        public SeedController(
            ApplicationDbContext context,
            IWebHostEnvironment env)
```

```
{  
    _context = context;  
    _env = env;  
}  
  
[HttpGet]  
public async Task<ActionResult> Import()  
{  
    var path = Path.Combine(  
        _env.ContentRootPath,  
        String.Format("Data/Source/worldcities.xlsx"));  
  
    using (var stream = new FileStream(  
        path,  
        FileMode.Open,  
        FileAccess.Read))  
    {  
        using (var ep = new ExcelPackage(stream))  
        {  
            // get the first worksheet  
            var ws = ep.Workbook.Worksheets[0];  
  
            // initialize the record counters  
            var nCountries = 0;  
            var nCities = 0;  
  
            #region Import all Countries  
            // create a list containing all the countries  
            // already existing into the Database (it  
            // will be empty on first run).  
            var lstCountries = _context.Countries.ToList();  
  
            // iterates through all rows, skipping the  
            // first one  
            for (int nRow = 2;  
                nRow <= ws.Dimension.End.Row;  
                nRow++)  
            {  
                var row = ws.Cells[nRow, 1, nRow,  
                    ws.Dimension.End.Column];  
                var name = row[nRow, 5].GetValue<string>();  
  
                // Did we already created a country with  
                // that name?  
                if (lstCountries.Where(c => c.Name ==  
                    name).Count() == 0)  
                {  
                    // create the Country entity and fill it  
                }  
            }  
        }  
    }  
}
```

```
// with xlsx data
var country = new Country();
country.Name = name;
country.ISO2 = row[nRow,
  6].GetValue<string>();
country.ISO3 = row[nRow,
  7].GetValue<string>();

// save it into the Database
_context.Countries.Add(country);
await _context.SaveChangesAsync();

// store the country to retrieve
// its Id later on
lstCountries.Add(country);

// increment the counter
nCountries++;
}

}

#endregion

#region Import all Cities
// iterates through all rows, skipping the
// first one
for (int nRow = 2;
    nRow <= ws.Dimension.End.Row;
    nRow++)
{
    var row = ws.Cells[nRow, 1, nRow,
        ws.Dimension.End.Column];

    // create the City entity and fill it
    // with xlsx data
    var city = new City();
    city.Name = row[nRow, 1].GetValue<string>();
    city.Name_ASCII = row[nRow,
      2].GetValue<string>();
    city.Lat = row[nRow, 3].GetValue<decimal>();
    city.Lon = row[nRow, 4].GetValue<decimal>();

    // retrieve CountryId
    var countryName = row[nRow,
      5].GetValue<string>();
    var country = lstCountries.Where(c => c.Name
      == countryName)
      .FirstOrDefault();
```

```
        city.CountryId = country.Id;

        // save the city into the Database
        _context.Cities.Add(city);
        await _context.SaveChangesAsync();

        // increment the counter
        nCities++;
    }
#endregion

return new JsonResult(new {
    Cities = nCities,
    Countries = nCountries
});
}
}
}
}
```

As you can see, we're doing a lot of interesting things there. The preceding code features a lot of comments and should be very readable; however, it could be useful to briefly enumerate the most relevant parts:

- We injected an `IWebHostEnvironment` instance through dependency injection, just like we did for `ApplicationContext`, so that we can retrieve the web application path and be able to read the Excel file.
- We added an `Import()` action method that will use `ApplicationContext` and the `EPPlus` package to read the Excel file and add `Countries` and `Cities`; these two tasks, for the sake of convenience, have been split into two parts.
- `Countries` are imported first because the `City` entities require the `CountryId` foreign key value, which will be returned when the corresponding `Country` is created in the database as a new record.
- We defined a `List<Country>` container object to store each `Country` right after we create it so that we can query that list using LINQ to retrieve `CountryId` instead of performing a lot of `SELECT` queries.
- Last but not least, we created a JSON object to show the overall results on the screen.

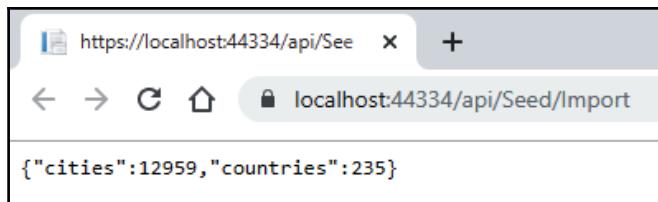
Be aware that the `Import` method is designed to import 230+ countries and 12,000+ cities, so this task will likely require some time—arguably between 10 and 20 minutes on an average development machine. It's definitely a major data seed! We're kind of stressing out the framework here.



In case we don't want to wait for that long, we can always give the `nEndRow` internal variable a fixed value, such as 1,000, to limit the total number of cities (and countries) that will be read and therefore loaded into the database.

If we want to get a closer look at how the whole importing procedure works, we can put some breakpoints inside the `if` loops to check it out while it's running.

Eventually, we should be able to see the following response in our browser window:



The preceding output means that the import has been performed successfully: we did it! Our database is now filled with 12959 cities and 235 countries for us to play with. In the next section, we're going to learn how we can read this data as well so that we'll be able to bring Angular into the loop.

Entity Controllers

Now that we have thousands of cities and thousands of countries in our database, we need to find a way to bring these data to Angular and vice versa. As we already know from [Chapter 2, Looking Around](#), this role is played by the .NET Controllers, so we're going to create two of them:

- `CityController`, to serve (and receive) the cities' data
- `CountryController`, to do the same with the countries

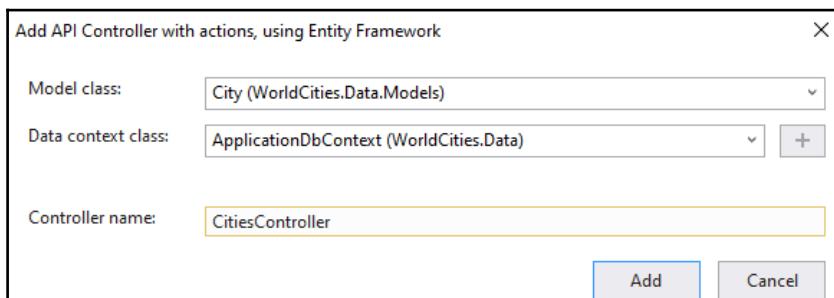
Let's get started.

CitiesController

Let's start with the cities. Remember what we did when we created `SeedController`? What we're going to do now is rather similar, but this time we'll make good use of Visual Studio's code-generation features.

From our project's **Solution Explorer**, follow these steps:

1. Right-click on the `/Controllers/` folder.
2. Click on **Add | Controller**.
3. Choose the **Add API Controller with actions, using Entity Framework** option (the last one from the top, at the time of writing).
4. In the modal window that appears, choose the `City` model class and the `ApplicationDbContext` data Context class, as shown in the following screenshot. Name the Controller `CitiesController` and click **Add** to create it:



The settings we specified during this phase will be used by Visual Studio to analyze our entities (and our `DbContext`) and auto-generate a whole API Controller stuffed with useful methods.

Here's the source code that we're getting for free:

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Threading.Tasks;
using Microsoft.AspNetCore.Http;
using Microsoft.AspNetCore.Mvc;
using Microsoft.EntityFrameworkCore;
using WorldCities.Data;
using WorldCities.Data.Models;
```

```
namespace WorldCities.Controllers
{
    [Route("api/[controller]")]
    [ApiController]
    public class CitiesController : ControllerBase
    {
        private readonly ApplicationContext _context;

        public CitiesController(ApplicationContext context)
        {
            _context = context;
        }

        // GET: api/Cities
        [HttpGet]
        public async Task<ActionResult<IEnumerable<City>>> GetCities()
        {
            return await _context.Cities.ToListAsync();
        }

        // GET: api/Cities/5
        [HttpGet("{id}")]
        public async Task<ActionResult<City>> GetCity(int id)
        {
            var city = await _context.Cities.FindAsync(id);

            if (city == null)
            {
                return NotFound();
            }

            return city;
        }

        // PUT: api/Cities/5
        // To protect from overposting attacks, please enable the
        // specific properties you want to bind to, for
        // more details see https://aka.ms/RazorPagesCRUD.
        [HttpPut("{id}")]
        public async Task<IActionResult> PutCity(int id, City city)
        {
            if (id != city.Id)
            {
                return BadRequest();
            }

            _context.Entry(city).State = EntityState.Modified;
```

```
        try
        {
            await _context.SaveChangesAsync();
        }
        catch (DbUpdateConcurrencyException)
        {
            if (!CityExists(id))
            {
                return NotFound();
            }
            else
            {
                throw;
            }
        }

        return NoContent();
    }

    // POST: api/Cities
    // To protect from overposting attacks, please enable the
    // specific properties you want to bind to, for
    // more details see https://aka.ms/RazorPagesCRUD.
    [HttpPost]
    public async Task<ActionResult<City>> PostCity(City city)
    {
        _context.Cities.Add(city);
        await _context.SaveChangesAsync();

        return CreatedAtAction("GetCity", new { id = city.Id },
            city);
    }

    // DELETE: api/Cities/5
    [HttpDelete("{id}")]
    public async Task<ActionResult<City>> DeleteCity(int id)
    {
        var city = await _context.Cities.FindAsync(id);
        if (city == null)
        {
            return NotFound();
        }

        _context.Cities.Remove(city);
        await _context.SaveChangesAsync();

        return city;
    }
}
```

```
        private bool CityExists(int id)
        {
            return _context.Cities.Any(e => e.Id == id);
        }
    }
```

As we can see, the code generator did a lot of useful work while sticking to a pattern that's similar to the one we followed for our `SeedController` class. Here's a breakdown of the relevant methods, in order of appearance:

- `GetCities()` returns a JSON array containing all of the cities in the database.
- `GetCity(id)` returns a JSON object containing a single `City`.
- `PutCity(id, city)` allows us to modify an existing `City`.
- `PostCity(city)` allows us to add a new `City`.
- `DeleteCity(id)` allows us to delete an existing `City`.

It definitely seems that we do have everything we need for our *front-end*. Before moving on to Angular, let's do the same for our Countries.

CountriesController

From Solution Explorer, right-click the `/Controllers/` folder and perform the same set of tasks we performed to add `CitiesController` – except for the name, which will obviously be `CountriesController`.

For the sake of simplicity, we won't waste additional pages by repeating the auto-generated code: we have a dedicated GitHub repository to look out for that, after all. However, we're going to get the same set of methods we mentioned previously to handle the countries.

That concludes our journey through Entity Framework. Now, we need to connect the dots and plant what we've sown using our favorite *front-end* framework.

Summary

We started this chapter by enumerating a number of things that simply cannot be done without a proper Data Provider. To overcome these limitations, we decided to provide ourselves with a DBMS engine and a persistent database for reading and/or writing data. To avoid messing with what we did in the previous chapters, we created a brand-new web application project to deal with that, which we called `WorldCities`.

Then, we chose a suitable data source for our new project: a list of world cities and countries that we could download for free in a handy MS Excel file.

Right after that, we moved on to the data model: Entity Framework Core seemed an obvious choice to get what we wanted, so we added its relevant packages to our project. We briefly enumerated the available data modeling approaches and resorted to using Code-First due to its flexibility. Once done, we created our two entities, `City` and `Country`, both of which are based on the data source values we had to store within our database, along with a set of data annotations and relationships taking advantage of the renowned Entity Framework Core's convention over configuration approach. Then, we built our `ApplicationDbContext` class accordingly.

After we created our data model, we evaluated the various options for configuring and deploying our DBMS engine: we reviewed the DMBS local instances and cloud-based solutions such as MS Azure, and we explained how to implement both of them.

Last but not least, we created our .NET Controller classes to deal with the data: `SeedController` to read the Excel file and seed our database, `CitiesController` to deal with cities, and `CountriesController` to handle countries.

After completing all of these tasks, we ran our application in debug mode to verify that everything was still working as intended. Now, we're ready to mess with the *front-end* part of our app. In the next chapter, we'll learn how to properly fetch this data from the server and bring it to the user in a fashionable way.

Angular, here we come!

Suggested topics

Web API, In-memory Web API, data source, Data Server, data model, Data Provider, ADO.NET, ORM, Entity Framework Core, Code-First, Database-First, Model-First, Entity Class, Data Annotations, DbContext, CRUD operations, data migration, dependency injection, ORM mapping, JSON, ApiController.

References

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- *Wikipedia: ISO 3166*: https://en.wikipedia.org/wiki/ISO_3166
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- *Wikipedia: ISO 3166 alpha-3*: https://en.wikipedia.org/wiki/ISO_3166-1_alpha-3
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- *SQL Server 2019 on Linux*: <https://docs.microsoft.com/en-US/sql/linux/sql-server-linux-overview>
- *Installing SQL Server on Windows*: <https://docs.microsoft.com/en-US/sql/database-engine/install-windows/installation-for-sql-server>
- *Installing SQL Server on Linux*: <https://docs.microsoft.com/en-US/sql/linux/sql-server-linux-setup>
- *Download SQL Server Management Studio (SSMS)*: <https://docs.microsoft.com/en-us/sql/ssms/download-sql-server-management-studio-ssms>
- *Create a SQL Server Database on Azure*: <https://azure.microsoft.com/en-us/resources/videos/create-sql-database-on-azure/>
- *Azure free account FAQ*: <https://azure.microsoft.com/en-in/free/free-account-faq/>

- *Azure SQL Server Managed Instance:* <https://azure.microsoft.com/en-us/services/sql-database/>
- *Use tags to organize your Azure resources:* <https://docs.microsoft.com/en-us/azure/azure-resource-manager/management/tag-resources>
- *Choose the right deployment option in Azure SQL:* <https://docs.microsoft.com/en-US/azure/sql-database/sql-database-paas-vs-sql-server-iaas>
- *Create an Azure SQL Database managed instance:* <https://docs.microsoft.com/en-us/azure/sql-database/sql-database-managed-instance-get-started>
- *Entity Framework Core: Loading Related Data:* <https://docs.microsoft.com/en-US/ef/core/querying/related-data>
- *Entity Framework Core: Data Seeding:* <https://docs.microsoft.com/en-us/ef/core/modeling/data-seeding>
- *Entity Framework Core: DbContext:* <https://www.entityframeworktutorial.net/efcore/entity-framework-core-dbcontext.aspx>

5

Fetching and Displaying Data

In the previous chapter, we created a new `WorldCities` web application project and made a considerable effort to empower it with a DBMS-based Data Provider, built upon Entity Framework Core using the Code-First approach. Now that we have data persistence, we're ready to entrust our users with the ability to interact with our application; this means that we can implement some much-needed stuff, such as the following:

- **Fetching data:** Querying the Data Provider from the client-side using HTTP requests and getting structured results back from the server-side
- **Displaying data:** Populating typical client-side Components such as tables, lists, and so on, ensuring a good user experience for the end user

In this chapter, we'll cover these two topics by adding a number of client-server interactions handled by standard HTTP request/response chains; it goes without saying that Angular will play a major role here, together with a couple of useful packages that will help us reach our goal.

Technical requirements

In this chapter, we're going to need all the technical requirements listed in the previous chapters, plus the following external libraries:

- `@angular/material` (Angular npm package)
- `System.Linq.Dynamic.Core` (.NET Core NuGet package)

As always, it's advisable to avoid installing them straight away; we're going to bring them in during this chapter to better contextualize their purpose within our project.

The code files for this chapter can be found at https://github.com/PacktPublishing/ASP.NET-Core-3-and-Angular-9-Third-Edition/tree/master/Chapter_05/

Fetching data

As we already know from Chapter 1, *Getting Ready*, reading data from the database is mostly a matter of having the Angular *front-end* send HTTP requests to the .NET Core *back-end* and fetching the corresponding HTTP responses accordingly; these data transfers will be mostly implemented using **JavaScript Object Notation (JSON)**, a lightweight data-interchange format that is natively supported by both frameworks.

In this section, we'll mostly talk about HTTP requests and responses, see how we can fetch data from the .NET Core *back-end*, and lay out some raw UI examples using Angular Components that will be further refined throughout the next sections.

Are we ready? Let's start!

Requests and responses

Let's start by taking a look at those HTTP requests and responses we'll be dealing with: hit *F5* to launch our `WorldCities` project in debug mode and type the following URL in the browser's address bar: `https://localhost:44334/api/Cities/9793`.

Here's what we should see:

```
{"id":9793,"name":"New York","name_ASCII":"New York","lat":40.6943,"lon":-73.9249,"countryId":235,"country":null}
```



The city might or might not be New York, depending on various factors: the world cities file version/progress, the starting auto-incrementing `id` of the `[Cities]` database table we used to store the data source, and so on. Don't mind that – it could be any city, as long as we get a valid JSON depicting it.

JSON conventions and defaults

As we can see, the JSON is basically a serialization of our `City` entity, with some built-in conventions such as the following:

- **CamelCase instead of PascalCase:** We got `name` instead of `Name`, `countryId` instead of `CountryId`, and so on, meaning that all our PascalCase .NET class names and properties will be automatically converted into camelCase when they are serialized to JSON.

- **No indentation and no line feed / carriage return (LF/CR):** Everything is stacked within a single line of text.

These conventions are the default options set by .NET Core when dealing with JSON outputs. Most of them can be changed by adding some customization options to the MVC middleware. However, we don't need to do that as they are perfectly supported by Angular, which is what we're going to use to deal with those strings; we'll just have to ensure that the Angular interfaces that we'll create to mirror the entity classes have their names and properties set to camelCase.



Whoever wants to know why they chose camelCase instead of PascalCase as the default serialization option should check out the following GitHub thread:

<https://github.com/aspnet/Mvc/issues/4283>.

Anyway, for the sake of readability, let's add some indentation so that we'll be able to understand more of those outputs.

Open the `Startup.cs` file, locate the `ConfigureServices` method, and add the following code (new/updated lines highlighted):

```
public void ConfigureServices(IServiceCollection services)
{
    services.AddControllersWithViews()
        .AddJsonOptions(options => {
            // set this option to TRUE to indent the JSON output
            options.JsonSerializerOptions.WriteIndented = true;
            // set this option to NULL to use PascalCase instead of
            // camelCase (default)
            // options.JsonSerializerOptions.PropertyNamingPolicy =
            // null;
        });
}
```



As we can see, we also added the required configuration option to force PascalCase instead of camelCase; however, for the sake of these sample projects, we do prefer to enforce the camelCase convention on JSON and Angular, so we have chosen to comment that line.

Those who want to uncomment it should be aware of the fact that they'll have to use camelCase for their Angular interfaces as well, changing our sample code accordingly.

Save the file, hit *F5*, and type the previous URL once more to see the following changes:

```
{  
  "id": 9793,  
  "name": "New York",  
  "name_ASCII": "New York",  
  "lat": 40.6943,  
  "lon": -73.9249,  
  "countryId": 235,  
  "country": null  
}
```

Here we go: now, the JSON is fully readable, with Angular still being able to properly get it.

A (very) long list

Let's now move to our Angular app and create a sample Component to show a list of Cities. We already created a Component in [Chapter 3, Front-end and Back-end Interactions](#), so we know what to do.

From **Solution Explorer**, do the following:

1. Navigate to the `/ClientApp/src/app/` folder.
2. Create a new `/cities/` folder.
3. Within that folder, create the following new files:
 - `city.ts`
 - `cities.component.ts`
 - `cities.component.html`
 - `cities.component.css`

Once done, fill them with the following content.

city.ts

Open the /ClientApp/src/app/cities/city.ts file and add the following:

```
export interface City {
  id: number;
  name: string;
  lat: string;
  lon: string;
}
```

This small file contains our *city* interface, which we'll be using in our CitiesComponent class file. Since we're eventually going to use it in other Components as well, it's better to create it within a separate file and decorate it with the `export` statement so that we'll be able to use it there as well when the time comes.

cities.component.ts

Open the /ClientApp/src/app/cities/cities.component.ts file and add the following:

```
import { Component, Inject } from '@angular/core';
import { HttpClient } from '@angular/common/http';

import { City } from './city';

@Component({
  selector: 'app-cities',
  templateUrl: './cities.component.html',
  styleUrls: ['./cities.component.css']
})
export class CitiesComponent {
  public cities: City[];

  constructor(
    private http: HttpClient,
    @Inject('BASE_URL') private baseUrl: string) {
  }

  ngOnInit() {
    http.get<City[]>(baseUrl + 'api/Cities')
      .subscribe(result => {
        this.cities = result;
      }, error => console.error(error));
  }
}
```

As we can see, we added an `import` reference to the `City` interface we created a short while ago. We also used the `ngOnInit()` life cycle hook method to perform the HTTP request that will retrieve the cities, just like we did in [Chapter 3, Front-end and Back-end Interactions](#), for our previous `HealthCheck` app.

cities.component.html

Open the `/ClientApp/src/app/cities/cities.component.html` file and add the following:

```
<h1>Cities</h1>

<p>Here's a list of cities: feel free to play with it.</p>

<p *ngIf="!cities"><em>Loading...</em></p>

<table class='table table-striped' aria-labelledby="tableLabel"
[hidden]="!cities">
  <thead>
    <tr>
      <th>ID</th>
      <th>Name</th>
      <th>Lat</th>
      <th>Lon</th>
    </tr>
  </thead>
  <tbody>
    <tr *ngFor="let city of cities">
      <td>{{ city.id }}</td>
      <td>{{ city.name }}</td>
      <td>{{ city.lat }}</td>
      <td>{{ city.lon }}</td>
    </tr>
  </tbody>
</table>
```

The [hidden] attribute

If we take a close look at the preceding HTML code, we will see that the `<table>` element features a strange `[hidden]` attribute. Why is it there, and why is it between squared brackets?

As a matter of fact, the `hidden` attribute is an HTML5-valid content attribute that can be legitimately set on any HTML element. The role it's supposed to play is very similar to the CSS `display: none` setting: it indicates to the browser that the element and all of its descendants should be not visible or perceivable to any user. In other words, it's just another way to hide some content from the user.

For additional information regarding the `hidden` attribute, check out the following URL:



HTML Living Standard (last updated on November 26, 2019):

<https://html.spec.whatwg.org/multipage/interaction.html#the-hidden-attribute>.

As for the square brackets, that's just the Angular syntax to define a property binding, that is, an HTML property or attribute within the Component template (our `.html` file) that gets its value from a variable, property, or expression defined within the Component class (our `.ts` file). It's worth noting that such a binding flows in one direction: from the Component class (the source) to the HTML element within the Component template (the target).

As a direct consequence of what we have just said, every time the source value evaluates to `true`, the HTML property (or attribute) between squared brackets will be set to `true` as well (and vice versa); this is a great way to deal with a lot of HTML attributes that work with Boolean values because we can dynamically set them through the whole Component's life cycle. That's precisely what we do with the `<table>` element in the preceding code block: its `hidden` attribute will evaluate to `false` until the `cities` Component variable is filled by the actual `cities` fetched from the server, which will only happen when the `HttpClient` module finishes its request/response task. Not bad, right?

Wait a minute: isn't that the same behavior of the `*ngIf` structural directive that we already know from Chapter 3, *Front-end and Back-end Interactions*? Why are we using this `[hidden]` attribute instead?

This is a very good question that gives us the chance to clarify the difference between these two similar – yet not identical – approaches:

- The `*ngIf` structural directive adds or removes the element from the DOM based on its corresponding condition or expression; this means that the element will be initialized and/or disposed of (together with all its children, events, and so on) every time its status changes.

- The `hidden` attribute, much like the `display: none` CSS setting, will only instruct the browser to show or hide the element to the user; this means that the element will still be there, thus being fully available and reachable (for example, by JavaScript or other DOM-manipulating actions).

As we can see by looking at the preceding HTML code, we're using both of them: the `*ngIf` structural directive adds or removes the `loading` `<p>` element, while the `[hidden]` *attribute binding* shows or hides the main `<table>`. We have chosen to do that for a reason: the `<p>` element won't have children or events depending on it, while that `<table>` will soon become a complex object with a lot of features to initialize and preserve within the DOM.

cities.component.css

Here's the code for the `/ClientApp/src/app/cities/cities.component.ts` file:

```
table {  
  width: 100%;  
}
```

That's it, at least for now: since we're using the bootstrap client framework, our Component's CSS files will often be very small.

app.module.ts

As we already know, this Component can only be loaded – and can only be reached by Angular client-side routing – if we add it to the `app.module.ts` file in the following way (new lines are highlighted):

```
import { BrowserModule } from '@angular/platform-browser';  
import { NgModule } from '@angular/core';  
import { FormsModule } from '@angular/forms';  
import { HttpClientModule, HTTP_INTERCEPTORS } from  
  '@angular/common/http';  
import { RouterModule } from '@angular/router';  
  
import { AppComponent } from './app.component';  
import { NavMenuComponent } from './nav-menu/nav-menu.component';  
import { HomeComponent } from './home/home.component';  
import { CitiesComponent } from './cities/cities.component';  
  
@NgModule({  
  declarations: [
```

```
    AppComponent,
    NavMenuComponent,
    HomeComponent,
    CitiesComponent
  ],
  imports: [
    BrowserModule.withServerTransition({ appId: 'ng-cli-universal' }),
    HttpClientModule,
    FormsModule,
    RouterModule.forRoot([
      { path: '', component: HomeComponent, pathMatch: 'full' },
      { path: 'cities', component: CitiesComponent }
    ])
  ],
  providers: [],
  bootstrap: [AppComponent]
})
export class AppModule { }
```

Here we go.

nav-component.html

Last but not least, we need to add a reference to the new Component route within the app navigator Component; otherwise, the browser clients won't be able to see (and thus reach) it using the UI.

To do that, open the `nav-component.html` file and add the following (highlighted) lines:

```
// ...existing code...

<ul class="navbar-nav flex-grow">
  <li
    class="nav-item"
    [routerLinkActive]=["link-active"]
    [routerLinkActiveOptions]={ exact: true }>
  <a class="nav-link text-dark" [routerLink]=[ '/' ]>Home</a>
  </li>
  <li class="nav-item" [routerLinkActive]=["link-active"]>
    <a class="nav-link text-dark" [routerLink]=[ '/cities' ]>
      Cities</a>
  </li>
```

```
</li>
</ul>

// ...existing code...
```

That's it. Now, we *could* hit *F5* to launch our app, click to the **Cities** link that will appear near the top-right part of the screen, and experience the following outcome:

The screenshot shows a web application titled "WorldCities". In the top right corner, there are navigation links: "Home", "Cities", and "Countries". The main content area has a title "Cities" and a subtitle "Here's a list of cities: feel free to play with it.". Below this is a table with four columns: "ID", "Name", "Lat", and "Lon". The table contains 8 rows of data. The rows alternate in background color between white and light gray. The data is as follows:

ID	Name	Lat	Lon
1	Malishevë	42.4822	20.7458
2	Prizren	42.2139	20.7397
3	Zubin Potok	42.9144	20.6897
4	Kamenicë	42.5781	21.5803
5	Viti	42.3214	21.3583
6	Shtërpcë	42.2394	21.0272
7	Shtime	42.4331	21.0397
8	Vushtrri	42.8231	20.9675

As we can see by looking at the vertical scrollbar to the right, we would be overwhelmed by a huge HTML table consisting of 12,959 (or so) rows!

That's another huge performance stress for both .NET Core and Angular – which should pass with flying colors on any average development machine since both frameworks can deal well with their respective tasks.

However, such a UI outcome is definitely a no-go in terms of user experience: we can't reasonably expect our end users to be happy if we force them to navigate through a 13k-row HTML table with a browser. They would go mad trying to find the city they're looking for!

To fix these major usability issues, we need to implement a couple of important features that are frequently used to deal with fat HTML tables: **paging**, **sorting**, and **filtering**.

Serving data with Angular Material

To implement a table with paging, sorting, and filtering features, we're going to use **Angular Material**, a UI Component library that implements Material Design in Angular. As we most likely already know, Material Design is a UI design language that Google developed in 2014, which focuses on using grid-based layouts, responsive animations, transitions, padding, and depth effects such as lighting and shadows.

Material Design was introduced by the Google designer Matías Duarte on June 25, 2014, at the 2014 Google I/O conference. To make UI designers familiarize themselves with its core concepts, he explained that: *"unlike real paper, our digital material can expand and reform intelligently. Material has physical surfaces and edges. Seams and shadows provide meaning about what you can touch."*



The main purpose of Material Design is to create a new UI language combining principles of good design with technical and scientific innovation in order to provide a consistent user experience not only across all Google platforms and applications, but also any other web applications seeking to adopt such concepts. The language was revamped in 2018, providing more flexibility and advanced customization features based on themes.

As of 2019, Material Design is used on almost all Google web applications and tools – including Gmail, YouTube, Google Drive, Google Docs, Sheets, Slides, Google Maps, and all of the Google Play-branded applications, as well as most Android and Google OS UI elements. Such wide adoption also includes Angular, which has been provided with a dedicated npm package that can be added to any Angular-based project to implement Material Design into any Angular app; this package is called `@angular/material` and includes the native UI elements, the **Component Dev Kit (CDK)**, a set of animations, and other useful stuff.

To install Angular Material, do the following:

1. Open Command Prompt.
2. Navigate to our project's /ClientApp/ folder.
3. Type the following command:

```
> ng add @angular/material
```

Doing this will trigger the Angular Material command-line setup wizard, which will install the following npm packages:

- @angular/material
- @angular/cdk (prerequisite)

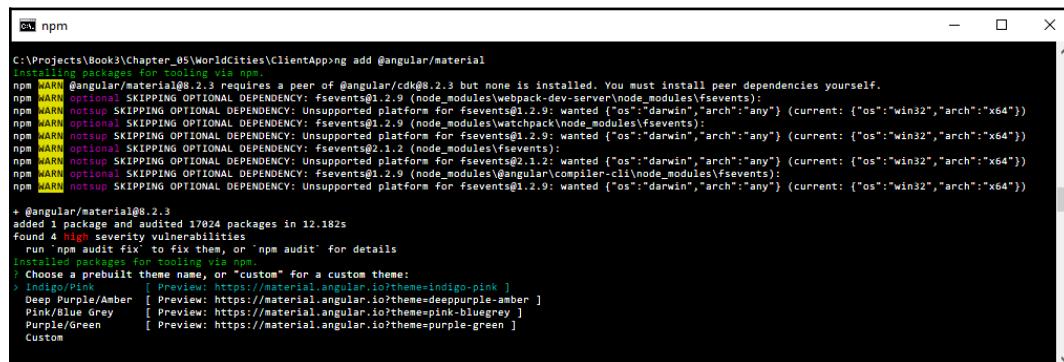
Important: Be sure to install the same @angular/material version specified in the package.json of the GitHub project released with this book - 9.0.0 at the time of writing. Those who want to change or update the Angular version should pay special attention to updating the @angular/material package as well and/or manually fixing the potential breaking changes between the various versions.



For additional information about Angular Material, check out the following URLs:

<https://material.angular.io/>
<https://github.com/angular/components>

During the installation process, the preceding command will ask us what prebuilt theme we would like to install, as shown in the following screenshot:



```
C:\Projects\Book3\Chapter_05Worldcities\ClientApp>ng add @angular/material
Installing packages for tooling via npm...
npm WARN @angular/material@8.2.3 requires a peer of @angular/cdk@8.2.3 but none is installed. You must install peer dependencies yourself.
npm WARN optional SKIPPING OPTIONAL DEPENDENCY: fsevents@1.2.9 (node_modules\webpack-dev-server\node_modules\fsevents):
npm WARN notsup SKIPPING OPTIONAL DEPENDENCY: Unsupported platform for fsevents@1.2.9: wanted {"os":"darwin","arch":"any"} (current: {"os":"win32","arch":"x64"})
npm WARN optional SKIPPING OPTIONAL DEPENDENCY: fsevents@1.2.9 (node_modules\watchpack\node_modules\fsevents):
npm WARN notsup SKIPPING OPTIONAL DEPENDENCY: Unsupported platform for fsevents@1.2.9: wanted {"os":"darwin","arch":"any"} (current: {"os":"win32","arch":"x64"})
npm WARN optional SKIPPING OPTIONAL DEPENDENCY: fsevents@1.2.9 (node_modules\@angular\compiler-cli\node_modules\fsevents):
npm WARN notsup SKIPPING OPTIONAL DEPENDENCY: Unsupported platform for fsevents@1.2.9: wanted {"os":"darwin","arch":"any"} (current: {"os":"win32","arch":"x64"})
npm WARN optional SKIPPING OPTIONAL DEPENDENCY: fsevents@1.2.9 (node_modules\@angular\compiler-cli\node_modules\fsevents):
npm WARN notsup SKIPPING OPTIONAL DEPENDENCY: Unsupported platform for fsevents@1.2.9: wanted {"os":"darwin","arch":"any"} (current: {"os":"win32","arch":"x64"})
+ @angular/material@8.2.3
added 1 package and audited 17024 packages in 12.182s
Found 4 high severity vulnerabilities
  run `npm audit fix` to fix them, or `npm audit` for details
Installed packages for tooling via npm...
? Choose a prebuilt theme. Enter "custom" for a custom theme:
  Indigo/Pink [ Preview: https://material.angular.io?theme=indigo-pink ]
  Deep Purple/Amber [ Preview: https://material.angular.io?theme=deeppurple-amber ]
  Pink/Blue Grey [ Preview: https://material.angular.io?theme=pink-bluegrey ]
  Purple/Green [ Preview: https://material.angular.io?theme=purple-green ]
  Custom
```

For the purpose of this chapter, we're going to pick Indigo/Pink, but we're free to choose any other theme we like. If we want to take a look at them before making our choice, we can visit the preview URIs listed in the preceding screenshot.

The setup wizard will also ask us if we would like to set up **HammerJS** for gesture recognition – which could be very useful if we plan to release our app for mobile devices – and add **animation** support: for the purpose of this book, we're going to choose Y for both of these features.

Once done, the setup process will update the following files:

- package.json
- /src/main.ts
- /src/app/app.module.ts
- angular.json
- src/index.html
- src/styles.css

Now, we can proceed with the revamp of our cities table.

MatTableModule

The Angular component we're going to use is `MatTableModule`, which provides a Material Design styled HTML table that can be used to display rows of data. Let's see how we can implement it in our existing Angular app.

From **Solution Explorer**, navigate to the `/ClientApp/src/app/` folder, create a new `angular-material.module.ts` file, and fill it with the following content:

```
import { NgModule } from '@angular/core';
import { MatTableModule } from '@angular/material/table';

@NgModule({
  imports: [
    MatTableModule
  ],
  exports: [
    MatTableModule
  ]
})

export class AngularMaterialModule { }
```

This is a brand new module that we're going to use for all the Angular Material modules we'll want to implement within our app; putting them here instead of using the `app.module.ts` file will keep that file smaller, which is great for project manageability.

Needless to say, for this *module container* to properly work, we need to add it within our existing `app.module.ts` file. Open it and add the following (highlighted) lines:

```
import { BrowserModule } from '@angular/platform-browser';
import { NgModule } from '@angular/core';
import { FormsModule } from '@angular/forms';
import { HttpClientModule, HTTP_INTERCEPTORS } from
  '@angular/common/http';
import { RouterModule } from '@angular/router';

import { AppComponent } from './app.component';
import { NavMenuComponent } from './nav-menu/nav-menu.component';
import { HomeComponent } from './home/home.component';
import { CitiesComponent } from './cities/cities.component';
import { BrowserAnimationsModule } from '@angular/platform-
  browser/animations';
import { AngularMaterialModule } from './angular-material.module';

@NgModule({
  declarations: [
    AppComponent,
    NavMenuComponent,
    HomeComponent,
    CitiesComponent
  ],
  imports: [
    BrowserModule.withServerTransition({ appId: 'ng-cli-universal' }),
    HttpClientModule,
    FormsModule,
    RouterModule.forRoot([
      { path: '', component: HomeComponent, pathMatch: 'full' },
      { path: 'cities', component: CitiesComponent }
    ]),
    BrowserAnimationsModule,
    AngularMaterialModule
  ],
  providers: [],
  bootstrap: [AppComponent]
})
export class AppModule { }
```

Here we go: now, everything we're going to put in the `angular-material.module.ts` file will be also referenced within our app.

Once we have done that, we can finally open our `/ClientApp/src/app/cities/cities.component.ts` file and add the following (highlighted) lines:

```
// ...existing code...

export class CitiesComponent {
  public displayedColumns: string[] = ['id', 'name', 'lat', 'lon'];
  public cities: City[];

  constructor(
    private http: HttpClient,
    @Inject('BASE_URL') private baseUrl: string) {
  }
}

// ...existing code...
```

Right after that, open the `/ClientApp/src/app/cities/cities.component.html` file and replace our previous table implementation with the new MatTableModule in the following way (updated code is highlighted):

```
<h1>Cities</h1>

<p>Here's a list of cities: feel free to play with it.</p>

<p *ngIf="!cities"><em>Loading...</em></p>

<table mat-table [dataSource]="cities" class="mat-elevation-z8"
[hidden]="!cities">
  <!-- Id Column -->
  <ng-container matColumnDef="id">
    <th mat-header-cell *matHeaderCellDef>ID</th>
    <td mat-cell *matCellDef="let city">{{city.id}}</td>
  </ng-container>

  <!-- Name Column -->
  <ng-container matColumnDef="name">
    <th mat-header-cell *matHeaderCellDef>Name</th>
    <td mat-cell *matCellDef="let city">{{city.name}}</td>
  </ng-container>

  <!-- Lat Column -->
```

```
<ng-container matColumnDef="lat">
  <th mat-header-cell *matHeaderCellDef>Latitude</th>
  <td mat-cell *matCellDef="let city">{{city.lat}}</td>
</ng-container>

<!-- Lon Column -->
<ng-container matColumnDef="lon">
  <th mat-header-cell *matHeaderCellDef>Longitude</th>
  <td mat-cell *matCellDef="let city">{{city.lon}}</td>
</ng-container>

<tr mat-header-row *matHeaderRowDef="displayedColumns"></tr>
<tr mat-row *matRowDef="let row; columns: displayedColumns;"></tr>
</table>
```

As we can see, MatTableModule kind of mimics the behavior of a standard HTML table, but with a template-based approach for each column; the template features a series of auxiliary structural directives (applied using the *`<directiveName>` syntax) that can be used to mark certain template sections and define their template section's actual role. As we can see, all these directives end with the `Def` postfix.

Here are the most relevant ones among those used in the preceding code:

- The `[hidden]` attribute binding is not a surprise as it was already present in the previous table for the exact same purpose: keeping the table hidden until the *cities* have been loaded.
- The `matColumnDef` directive identifies a given column with a unique key.
- The `matHeaderCellDef` directive defines how to display the header for each column.
- The `matCellDef` directive defines how to display the data cells for each column.
- The `matHeaderRowDef` directive, which can be found near the end of the preceding code, identifies a configuration element for the table header row and the display order of the header columns. As we can see, we had this directive expression pointing to a Component variable called `displayedColumns`, which we defined in the `cities.component.ts` file early on; this variable hosts an array containing all the column keys we want to show, which need to be identical to the names specified via the various `matColumnDef` directives.

Let's hit *F5* and navigate to the **Cities** view to see what our brand new table looks like. This can be seen in the following screenshot:

The screenshot shows a table titled "Cities" with 14 rows of data. The table has four columns: "ID", "Name", "Latitude", and "Longitude". The data is as follows:

ID	Name	Latitude	Longitude
1	Malishevë	42.4822	20.7458
2	Prizren	42.2139	20.7397
3	Zubin Potok	42.9144	20.6897
4	Kamenicë	42.5781	21.5803
5	Viti	42.3214	21.3583
6	Shtërpcë	42.2394	21.0272
7	Shtime	42.4331	21.0397
8	Vushtrri	42.8231	20.9675
9	Dragash	42.0265	20.6533
10	Podujevë	42.9111	21.1899
11	Fushë Kosovë	42.6639	21.0961
12	Kaçanik	42.2319	21.2594
13	Klinë	42.6217	20.5778
14	Leposaviq	43.1039	20.8028

OK, the Material Design is indeed there, but the table has the same UI/UX problems as before! For one, it's still very long; let's fix that by implementing the **paging** feature.

MatPaginatorModule

Now that we are using Angular Material, implementing pagination is a rather easy task. The first thing we need to do is import the `MatPaginatorModule` service into the `angular-material.module.ts` file we created a short while ago.

Client-side paging

Here's how we can do that (new lines are highlighted):

```
import { NgModule } from '@angular/core';
import { MatTableModule } from '@angular/material/table';
import { MatPaginatorModule } from '@angular/material/paginator';

@NgModule({
  imports: [
    MatTableModule,
    MatPaginatorModule
  ],
  exports: [
    MatTableModule,
    MatPaginatorModule
  ]
})
export class AngularMaterialModule { }
```

Right after that, we need to open the `cities.component.ts` file and import the `MatPaginator`, the `MatTableDataSource`, and the `ViewChild` services:

```
import { Component, Inject, ViewChild } from '@angular/core';
import { HttpClient } from '@angular/common/http';
import { MatTableDataSource } from '@angular/material/table';
import { MatPaginator } from '@angular/material/paginator';

import { City } from './city';

@Component({
  selector: 'app-cities',
  templateUrl: './cities.component.html',
  styleUrls: ['./cities.component.css']
})
export class CitiesComponent {
  public cities: City[];
  constructor(

---


```

```
    private http: HttpClient,
    @Inject('BASE_URL') private baseUrl: string) {
}

ngOnInit() {
  http.get<City[]>(baseUrl + 'api/Cities')
    .subscribe(result => {
      this.cities = result;
    }, error => console.error(error));
}
}
```

Last but not least, we need to add the following pagination directive within the `cities.component.html` file, right after the `</table>` closing tag:

```
// ...existing code...

<tr mat-header-row *matHeaderRowDef="displayedColumns"></tr>
<tr mat-row *matRowDef="let row; columns: displayedColumns;"></tr>
</table>

<!-- Pagination directive -->
<mat-paginator [hidden]="!cities"
  [pageSize]="10"
  [pageSizeOptions]="[10, 20, 50]"
  showFirstLastButtons></mat-paginator>
```

As we can see, we used the `[hidden]` attribute binding again to keep the paginator hidden until the `cities` were loaded. The other properties that we can see on the `<mat-paginator>` element configure some of the MatPaginatorModule UI options, such as the default page size and an array of all the page size options that we want to make available to the users.

Now, we can hit *F5* and take a look at our efforts. Look at the following screenshot:

ID	Name	Latitude	Longitude
1	Malishevë	42.4822	20.7458
2	Prizren	42.2139	20.7397
3	Zubin Potok	42.9144	20.6897
4	Kamenicë	42.5781	21.5803
5	Viti	42.3214	21.3583
6	Shtërpcë	42.2394	21.0272
7	Shtime	42.4331	21.0397
8	Vushtrri	42.8231	20.9675
9	Dragash	42.0265	20.6533
10	Podujevë	42.9111	21.1899

Items per page: 1 – 10 of 12959 | < < > >|

Now, our table only shows the first 10 cities. It has also got a neat paginator at its bottom-right corner that can be used to navigate through the various pages using arrows. Our end user can even choose how many items per page to display using a neat drop-down list (10, 20, or 50 cities per page). It definitely seems like we did it!

However, if we think about it, we can easily acknowledge how we're not quite there yet. Sure, now our users can browse the table nicely without having to scroll up and down for ages, but it doesn't take a genius to understand that all those rows are still there on the page: we never told the server to actually support a paginated request, so we still fetch all of the cities from our Data Provider (and through the .NET Core API Controller) just like before: as a matter of fact, they're just being hidden by the *front-end*.

This basically means that we still have the same identical performance impact that we had before, both on the server side (huge SQL query result, massive JSON) and on the client side (lots of HTML rows to show/hide on each paginator action, leading to a page change).

In order to mitigate the aforementioned issues, we need to move from client-side paging to server-side paging – which is precisely what we'll do in the next section.

Server-side paging

Implementing server-side paging is a bit more complex than its client-side counterpart. Here's what we need to do:

- Change our `CitiesController` .NET Core class to make it support paged HTTP GET requests.
- Create a new `ApiResult` .NET class that we can use to improve the JSON response of our .NET Core *Controllers*.
- Change our `cities.controller.ts` Angular Component – and the current `MatPaginatorModule` configuration – to make it able to issue the new GET request and deal with the new JSON response.

Let's do this!

CitiesController

The `GetCities` method of our `CitiesController` returns a JSON array of all the ~13,000 cities in our database by default; that's definitely a no-go in terms of server-side performance, so we need to change it. Ideally, we would like to only return a small number of `Cities`, which is something we can easily pull off by adding some (required) variables in the method signature, such as `pageIndex` and `pageSize`.

Here's how we could change that to enforce such behavior (updated lines highlighted):

```
// ...existing code...

[HttpGet]
public async Task<ActionResult<IEnumerable<City>>> GetCities(
    int pageIndex = 0,
    int pageSize = 10)
{
    return await _context.Cities
        .Skip(pageIndex * pageSize)
        .Take(pageSize)
        .ToListAsync();
}

// ...existing code...
```

That's it; we also specified some reasonable default values for those variables in order to avoid huge JSON responses *by default*.

Let's quickly test what we just did: hit *F5* and type the following URL in the browser's address bar: <https://localhost:44334/api/Cities/?pageIndex=0pageSize=10>.

Here's what we should get:

```
[  
  {  
    "id": 1,  
    "name": "Malishevë",  
    "name_ASCII": "Malisheve",  
    "lat": 42.4822,  
    "lon": 20.7458,  
    "countryId": 1,  
    "country": null  
  },  
  {  
    "id": 2,  
    "name": "Prizren",  
    "name_ASCII": "Prizren",  
    "lat": 42.2139,  
    "lon": 20.7397,  
    "countryId": 1,  
    "country": null  
  },  
  {  
    "id": 3,  
    "name": "Zubin Potok",  
    "name_ASCII": "Zubin Potok",  
    "lat": 42.9144,  
    "lon": 20.6897,  
    "countryId": 1,  
    "country": null  
  },  
  {  
    "id": 4,  
    "name": "Kamenicë",  
    "name_ASCII": "Kamenice",  
    "lat": 42.5781,  
    "lon": 21.5803,  
    "countryId": 1,  
    "country": null  
  },  
  {  
    "id": 5,  
    "name": "Viti",  
  }]
```

It definitely seems that our plan is working!

However, there is a major issue we have to deal with: if we just return a JSON array of 10 cities, there will be no way for our Angular app to actually know how many cities are present in our database. Without that information, there is little chance that the paginator would reasonably work the way it did when we implemented the client-side pagination early on.

Long story short, we need to find a way to tell our Angular app some additional information, such as the following:

- The total number of pages (and/or records) available
- The current page
- The number of records on each page

Truth be told, the only required information is the first one as the Angular client would then be able to keep track of the other two; however, since we need to implement that one, we might as well return them all, thus making our *front-end* life a lot easier.

In order to do that, the best thing we can do is create a dedicated *response-type* class – which we're going to use a lot from now on.

ApiResult

From the **Solution Explorer**, right-click the `Data` folder and add a new `ApiResult.cs` C# class file. Then, fill it up with the following content:

```
using Microsoft.EntityFrameworkCore;
using System;
using System.Collections.Generic;
using System.Linq;
using System.Threading.Tasks;

namespace WorldCities.Data
{
    public class ApiResult<T>
    {
        /// <summary>
        /// Private constructor called by the CreateAsync method.
        /// </summary>
        private ApiResult(
            List<T> data,
            int count,
            int pageIndex,
            int pageSize)
        {
            Data = data;
           PageIndex = pageIndex;
           PageSize = pageSize;
           TotalCount = count;
           TotalPages = (int)Math.Ceiling(count / (double)pageSize);
        }
    }
}
```

```
#region Methods
/// <summary>
/// Pages a IQueryable source.
/// </summary>
/// <param name="source">An IQueryable source of generic
/// type</param>
/// <param name="pageIndex">Zero-based current page index
/// (0 = first page)</param>
/// <param name="pageSize">The actual size of each
/// page</param>
/// <returns>
/// A object containing the paged result
/// and all the relevant paging navigation info.
/// </returns>
public static async Task<ApiResult<T>> CreateAsync(
    IQueryable<T> source,
    int pageIndex,
    int pageSize)
{
    var count = await source.CountAsync();
    source = await source
        .Skip(pageIndex * pageSize)
        .Take(pageSize);

    var data = await source.ToListAsync();

    return new ApiResult<T>(
        data,
        count,
        pageIndex,
        pageSize);
}
#endregion

#region Properties
/// <summary>
/// The data result.
/// </summary>
public List<T> Data { get; private set; }

/// <summary>
/// Zero-based index of current page.
/// </summary>
public int PageIndex { get; private set; }

/// <summary>
/// Number of items contained in each page.
/// </summary>
```

```
    public int PageSize { get; private set; }

    /// <summary>
    /// Total items count
    /// </summary>
    public int TotalCount { get; private set; }

    /// <summary>
    /// Total pages count
    /// </summary>
    public int TotalPages { get; private set; }

    /// <summary>
    /// TRUE if the current page has a previous page,
    /// FALSE otherwise.
    /// </summary>
    public bool HasPreviousPage
    {
        get
        {
            return (PageIndex > 0);
        }
    }

    /// <summary>
    /// TRUE if the current page has a next page, FALSE otherwise.
    /// </summary>
    public bool HasNextPage
    {
        get
        {
            return ((PageIndex +1) < TotalPages);
        }
    }
    #endregion
}
```

This `async` class contains some really interesting stuff. Let's try to summarize the most relevant things:

- `Data`: A property of the `List<T>` type that will be used to contain the paged data (it will be translated to a JSON array)
- `PageIndex`: Returns the zero-based index of the current page (0 for the first page, 1 for the second, and so on)

- `PageSize`: Returns the total page size (`TotalCount / PageSize`)
- `TotalCount`: Returns the total `Item` count number
- `TotalPages`: Returns the total number of pages taking into account the total `Items` count (`TotalCount / PageSize`)
- `HasPreviousPage`: Returns `True` if the current page has a previous page, `False` otherwise
- `HasNextPage`: Returns `True` if the current page has a next page, `False` otherwise

Those properties are precisely what we were looking for; the underlying logic to calculate their values should be quite easy to understand by looking at the preceding code.

Other than that, the class basically revolves around the static method `CreateAsync<T>(IQueryable<T> source, int pageIndex, int pageSize)`, which can be used to paginate an Entity Framework `IQueryable` object.



It's worth noting that the `ApiResult` class cannot be instantiated from the outside since its constructor has been marked as `private`; the only way to create it is by using the static `CreateAsync` factory method. There are good reasons to do that: since it is not possible to define an `async` constructor, we have resorted to using a static `async` method that returns a class instance; the constructor has been set to `private` to prevent developers from directly using it instead of the factory method since it's the only reasonable way to instantiate this class.

Here's how we can make use of our brand new `ApiResult` class in the `GetCities` method of our `CitiesController`:

```
// ...existing code...

// GET: api/Cities
// GET: api/Cities/?pageIndex=0&pageSize=10
[HttpGet]
public async Task<ActionResult<ApiResult<City>>> GetCities(
    int pageIndex = 0,
    int pageSize = 10)
{
    return await ApiResult<City>.CreateAsync(
        _context.Cities,
        pageIndex,
```

```
    pageSize  
);  
}  
  
// ...existing code...
```

Here we go! Now, we should have our 10 cities and all the information we were looking for.

Let's hit *F5* and navigate to the same URL as before to see what's changed: <https://localhost:44334/api/Cities/?pageIndex=0&pageSize=10>.

Here's the updated JSON response:

```
        "id": 9,  
        "name": "Dragash",  
        "name_ASCII": "Dragash",  
        "lat": 42.0265,  
        "lon": 20.6533,  
        "countryId": 1,  
        "country": null  
    },  
    {  
        "id": 10,  
        "name": "Podujevë",  
        "name_ASCII": "Podujeve",  
        "lat": 42.9111,  
        "lon": 21.1899,  
        "countryId": 1,  
        "country": null  
    }  
],  
"pageIndex": 0,  
"pageSize": 10,  
"totalCount": 12959,  
"totalPages": 1296,  
"hasPreviousPage": false,  
"hasNextPage": true  
}
```

If we scroll down to the bottom of the page, we will see that our much-needed properties are all there.

The only downside of this implementation is that the URL we need to call to get such a result is rather ugly; before moving on to Angular, it could be useful to spend some time to see if there's a way to make it sleeker.

Theoretically speaking, we could do better than what we did by implementing a dedicated route in the `CitiesController.cs` file in the following way (updated lines are highlighted, but *do not perform such a change on your code* – just have a look):

```
// ...existing code...

// GET: api/Cities
// GET: api/Cities/?pageIndex=0&pageSize=10
// GET: api/Cities/0/10
[HttpGet]
[Route("{pageIndex?}/{pageSize?}")]
public async Task<ActionResult<ApiResult<City>>> GetCities(
    int pageIndex = 0,
    int pageSize = 10)
{
    return await ApiResult<City>.CreateAsync(
        _context.Cities,
        pageIndex,
        pageSize
    );
}

// ...existing code...
```

By implementing that route, we could call the `GetCities` action method with this new URL: <https://localhost:44334/api/Cities/0/10>.

This is arguably better than the following URL: <https://localhost:44334/api/Cities/?pageIndex=0&pageSize=10>.

However, *let's not do that*, at least for now: performing this change would mean becoming unable to add additional parameters, which could be a huge loss in terms of customization options – as we'll see in a short while.

Let's now move to our Angular's `CitiesComponent` and update it to use this new, optimized way of fetching our cities from the server.

CitiesComponent

The only Angular files we need to change are the following:

- The `CitiesComponent` TypeScript file, which is where we put all the data-retrieval logic that we now need to update

- The `CitiesComponent` HTML file, to bind a specific event to our `MatPaginator` element

Let's do this.

Open the `cities.component.ts` file and perform the following changes (new/updated lines are highlighted):

```
import { Component, Inject, ViewChild } from '@angular/core';
import { HttpClient, HttpParams } from '@angular/common/http';
import { MatTableDataSource } from '@angular/material/table';
import { MatPaginator, PageEvent } from '@angular/material/paginator';

import { City } from './city';

@Component({
  selector: 'app-cities',
  templateUrl: './cities.component.html',
  styleUrls: ['./cities.component.css']
})
export class CitiesComponent {
  public displayedColumns: string[] = ['id', 'name', 'lat', 'lon'];
  public cities: MatTableDataSource<City>;

  @ViewChild(MatPaginator) paginator: MatPaginator;

  constructor(
    private http: HttpClient,
    @Inject('BASE_URL') private baseUrl: string) {
  }

  ngOnInit() {
    var pageEvent = new PageEvent();
    pageEvent.pageIndex = 0;
    pageEvent.pageSize = 10;
    this.getData(pageEvent);
  }

  getData(event: PageEvent) {
    var url = this.baseUrl + 'api/Cities';
    var url = this.baseUrl + 'api/Cities';
    var params = new HttpParams()
      .set("pageIndex", event.pageIndex.toString())
      .set("pageSize", event.pageSize.toString());
    this.http.get<any>(url, { params })
      .subscribe(result => {
        this.paginator.length = result.totalCount;
```

```
        this.paginator.pageIndex = result.pageIndex;
        this.paginator.pageSize = result.pageSize;
        this.cities = new MatTableDataSource<City>(result.data);
    }, error => console.error(error));
}
}
```

Let's try to summarize what we did here:

- We used the `@ViewChild` decorator to set a static view query and store its result to the `paginator` variable; this allows us to access and manipulate the `MatPaginator` instance that we previously set up in our Component's template from within the Component class.
- We removed the `HttpClient` from the `ngOnInit()` life cycle hook method and placed the whole data-retrieval logic in a separate `getData()` method. In order to do this, we had to define a couple of internal class variables to host the `HttpClient` and the `baseUrl` to persist them so that we'll be able to use them multiple times (that is, on multiple `getData()` calls).
- We changed the data-retrieval logic to match our new JSON response object.
- We modified our `paginator` configuration strategy to manually set the values we get from the server side instead of having it figuring them out automatically; doing that is required, otherwise it would just take into account (and *paginate*) the small portion of cities we retrieve upon each HTTP requests instead of the full batch.

Among the various new stuff we've implemented with the preceding code, the `@ViewChild` decorator deserves a couple more words: in a nutshell, it can be used to get a reference of a DOM template element from within the Angular Component, thus being a very useful feature whenever we need to manipulate the element's properties.

As we can see from the preceding code, the `@ViewChild` decorator is defined using a *selector* parameter, which is required to access the DOM element: this *selector* can be a class name (if the class has either the `@Component` or `@Directive` decorator), a template reference variable, a provider defined in the child Component tree, and so on. In our specific scenario, we've used the `MatPaginator` class name, since it does have the `@Component` decorator.

While we're at it, it can be useful to know that the `@ViewChild` decorator also accepts a second parameter, which was required until Angular 8 and became optional in Angular 9: a static flag, which can be either `true` or `false` (in Angular 9, it defaults to `false`). If this flag is explicitly set to `true`, the `@ViewChild` is retrieved from the template before the *Change Detection* phase runs (that is, even before the `ngOnInit()` life cycle); conversely, the Component/element retrieval task is resolved either after the Change Detection phase if the element is inside a nested view (for example, a view with a `*ngIf` conditional display directive), or before Change Detection if it isn't.



Since we've used the `[hidden]` attribute binding in the template instead of the `*ngIf` directive, our `MatPaginator` won't run into initialization issues, even without having to set that flag to `true`.

For additional information about the `@ViewChild` decorator, we suggest you take a look at the Angular docs:

<https://angular.io/api/core/ViewChild>.

As for the `cities.component.html` file, we just need to add a single line to the `<mat-paginator>` directive to bind the `getData()` event upon each paging event. Here's how to do that (the new line is highlighted):

```
// ...existing code

<!-- Pagination directive -->
<mat-paginator [hidden]="!cities"
  (page)="pageEvent = getData($event)"
  [pageSize]="10"
  [pageSizeOptions]="[10, 20, 50]"
  showFirstLastButtons></mat-paginator>
```

This simple binding plays a very important role: it ensures that the `getData()` event is called every time the user interacts with the `paginator` element to perform a page change, asking for previous/next page, first/last page, changing the number of items to display, and so on. As we can easily understand, such a call is required for server-side pagination since we need to fetch the updated data from the server every time we have to display different rows.

Once done, let's try the new magic by hitting *F5* and then navigating to the **Cities** view. If we did everything properly, we should get the same UI that we could see before:

The screenshot shows a web application interface titled "WorldCities". At the top right, there are navigation links: "Home", "Cities", and "Countries". The main title is "Cities", with a subtitle "Here's a list of cities: feel free to play with it.". Below this is a table with 10 rows of city data. The columns are labeled "ID", "Name", "Latitude", and "Longitude". The data is as follows:

ID	Name	Latitude	Longitude
1	Malishevë	42.4822	20.7458
2	Prizren	42.2139	20.7397
3	Zubin Potok	42.9144	20.6897
4	Kamenicë	42.5781	21.5803
5	Viti	42.3214	21.3583
6	Shtërpçë	42.2394	21.0272
7	Shtime	42.4331	21.0397
8	Vushtrri	42.8231	20.9675
9	Dragash	42.0265	20.6533
10	Podujevë	42.9111	21.1899

At the bottom, there is a pagination control: "Items per page: 10" with a dropdown arrow, "1 – 10 of 12959", and navigation icons: |<, <, >, >|.

However, this time, we should experience better overall performance and faster response times. That's because we're not dealing with thousands of JSON items and HTML table rows under the hood; we're fetching only a few of them at a time (that is, those we get to see) using our improved server-side logic.

Since we're done with paging, we can finally deal with **sorting**.

MatSortModule

In order to implement sorting, we're going to use `MatSortModule`, which can be implemented just like we did with the `PaginatorModule`.

This time, we won't make client-side sorting experiments as we did with paging early on; we're going for the server-side pattern right from the start.

Extending ApiResult

Let's start with the .NET Core *back-end* part.

Do you remember the `ApiResult` class we created earlier? It's time to improve its source code to add sorting support.

From **Solution Explorer**, open the `/Data/ApiResult.cs` file and update its content accordingly (new/updated lines are highlighted):

```
using Microsoft.EntityFrameworkCore;
using System;
using System.Collections.Generic;
using System.Linq;
using System.Threading.Tasks;
using System.Linq.Dynamic.Core;
using System.Reflection;

namespace WorldCities.Data
{
    public class ApiResult<T>
    {
        /// <summary>
        /// Private constructor called by the CreateAsync method.
        /// </summary>
        private ApiResult(
            List<T> data,
            int count,
            int pageIndex,
            int pageSize,
            string sortColumn,
            string sortOrder)
        {
            Data = data;
           PageIndex = pageIndex;
            PageSize = pageSize;
            TotalCount = count;
            TotalPages = (int)Math.Ceiling(count / (double)pageSize);
            SortColumn = sortColumn;
            SortOrder = sortOrder;
        }

        #region Methods
        /// <summary>
        /// Pages and/or sorts a IQueryble source.
        /// </summary>
        /// <param name="source">An IQueryble source of generic
        /// type</param>
    }
}
```

```
/// <param name="pageIndex">Zero-based current page index
/// (0 = first page)</param>
/// <param name="pageSize">The actual size of each
/// page</param>
/// <param name="sortColumn">The sorting column name</param>
/// <param name="sortOrder">The sorting order ("ASC" or
/// "DESC")</param>
/// <returns>
/// A object containing the IQueryable paged/sorted result
/// and all the relevant paging/sorting navigation info.
/// </returns>
public static async Task<ApiResult<T>> CreateAsync(
    IQueryable<T> source,
    int pageIndex,
    int pageSize,
    string sortColumn = null,
    string sortOrder = null)
{
    var count = await source.CountAsync();

    if (!String.IsNullOrEmpty(sortColumn)
        && IsValidProperty(sortColumn))
    {
        sortOrder = !String.IsNullOrEmpty(sortOrder)
            && sortOrder.ToUpper() == "ASC"
            ? "ASC"
            : "DESC";
        source = source.OrderBy(
            String.Format(
                "{0} {1}",
                sortColumn,
                sortOrder)
        );
    }

    source = source
        .Skip(pageIndex * pageSize)
        .Take(pageSize);
    var data = await source.ToListAsync();
    return new ApiResult<T>(
        data,
        count,
        pageIndex,
        pageSize,
        sortColumn,
        sortOrder);
}
#endregion
```

```
#region Methods
/// <summary>
/// Checks if the given property name exists
/// to protect against SQL injection attacks
/// </summary>
public static bool IsValidProperty(
    string propertyName,
    bool throwExceptionIfNotFound = true)
{
    var prop = typeof(T).GetProperty(
        propertyName,
        BindingFlags.IgnoreCase |
        BindingFlags.Public |
        BindingFlags.Instance);
    if (prop == null && throwExceptionIfNotFound)
        throw new NotSupportedException(
            String.Format(
                "ERROR: Property '{0}' does not exist.",
                propertyName));
    return prop != null;
}
#endregion

#region Properties
/// <summary>
/// The data result.
/// </summary>
public List<T> Data { get; private set; }

/// <summary>
/// Zero-based index of current page.
/// </summary>
public int PageIndex { get; private set; }

/// <summary>
/// Number of items contained in each page.
/// </summary>
public int PageSize { get; private set; }

/// <summary>
/// Total items count
/// </summary>
public int TotalCount { get; private set; }

/// <summary>
/// Total pages count
/// </summary>
```

```
public int TotalPages { get; private set; }

/// <summary>
/// TRUE if the current page has a previous page,
/// FALSE otherwise.
/// </summary>
public bool HasPreviousPage
{
    get
    {
        return (PageIndex > 0);
    }
}

/// <summary>
/// TRUE if the current page has a next page, FALSE otherwise.
/// </summary>
public bool HasNextPage
{
    get
    {
        return ((PageIndex +1) < TotalPages);
    }
}

/// <summary>
/// Sorting Column name (or null if none set)
/// </summary>
public string SortColumn { get; set; }

/// <summary>
/// Sorting Order ("ASC", "DESC" or null if none set)
/// </summary>
public string SortOrder { get; set; }
#endregion
}
```

What we did was basically add two new `sortColumn` and `sortOrder` attributes to the main class static method and implement them through the code; while we were there, we also took the chance to define two new properties with the same name (in uppercase) so that the sorting details will be part of the JSON response, just like the paging ones.

It's worth noting that, since we're now assembling our **Language-Integrated Query (LINQ)**-to-SQL queries with literal data coming from the client, we also added a new `IsValidProperty()` method that will check that the `sortColumn` specified does actually exist as a typed property of the generic `<T>` entity we're dealing with; as the method comment clearly says, that's actually a security countermeasure against SQL injection attempts. That's a very important security issue that we'll be talking about in a short while.

If we try to build our project right after these changes, we'll be most likely greeted by some compiler errors, such as the following one:

```
Error CS0246: The type or namespace name System.Linq.Dynamic could not
be found (are you missing a using directive or an assembly
reference?) .
```

Don't worry, it's perfectly normal: we just need to add a new NuGet package to our project.

Installing `System.Linq.Dynamic.Core`

The `IQueryable<T>.OrderBy()` extension method that we used in the improved `ApiResult` source code to programmatically apply the column sorting is part of the `System.Linq.Dynamic.Core` namespace; thanks to this library, it's possible to write Dynamic LINQ queries (string-based) on an `IQueryable`, which is just like what we did in the preceding code.

Unfortunately, `System.Linq.Dynamic.Core` is not part of the .NET Core stock binaries; therefore, in order to use these features, we need to add it via NuGet.

The fastest way to do that is to open Visual Studio's **Package Manager Console** and issue the following command:

```
> Install-Package System.Linq.Dynamic.Core
```

IMPORTANT: Be sure to install `System.Linq.Dynamic.Core` and not `System.Linq.Dynamic`, which is its .NET Framework 4.0 counterpart; the latter won't work with our .NET Core web application project.

At the time of writing, the most recent version of the `System.Linq.Dynamic.Core` package is 1.0.19, which works absolutely fine for our purposes.



For those who want to retrieve additional information regarding this great package, we suggest you take a look at the following resources:

NuGet website:

<https://www.nuget.org/packages/System.Linq.Dynamic.Core/>.

GitHub project:

<https://github.com/StefH/System.Linq.Dynamic.Core>.

What is LINQ?

Before moving forward, let's spend a couple of minutes talking about LINQ in the unlikely case you have never heard anything about it.

Also known as Language-Integrated Query, LINQ is the codename of a Microsoft .NET Framework set of technologies that adds data query capabilities to .NET languages such as C# and VB.NET. LINQ was first released in 2007 and was one of the major new features of .NET Framework 3.5.

The main purpose of LINQ is to make the developer able to express structured queries against data using a first-class language construct, without having to learn different query languages for each type of data source (collection types, SQL, XML, CSV, and so on). For each of these *major* data source types, there's a LINQ implementation that provides the same query experience for objects (*LINQ to Objects*), Entity Framework entities (*LINQ to Entities*), relational databases (*LINQ to SQL*), XML (*LINQ to XML*), and so on.

LINQ structured queries can be expressed using two alternative – yet also complementary – approaches:

- **Lambda expressions**, such as the following:

```
var city = _context.Cities.Where(c => c.Name == "New York").First();
```

- **Query expressions**, such as the following:

```
var city = (from c in _context.Cities where c.Name == "New  
York" select c).First();
```

Both yield the same result with the same performance since query expressions are translated into their lambda expression equivalent before they're compiled.

For additional information about LINQ, lambda expressions, and query expressions, check out the following links:

LINQ:

<https://docs.microsoft.com/en-us/dotnet/csharp/linq/>.



LINQ lambda expressions (C# Programming Guide):

<https://docs.microsoft.com/en-us/dotnet/csharp/programming-guide/statements-expressions-operators/lambda-expressions>.

LINQ query expression basics:

<https://docs.microsoft.com/en-us/dotnet/csharp/linq/query-expression-basics>.

Linq.Dynamic.Core pros and cons

Now, since LINQ has been built-in with .NET Framework since v3.5 and it's shipped with .NET Core as well, what does the `System.Linq.Dynamic.Core` package actually do and why are we using it?

As we can see from the two preceding examples, both lambda expressions and query expressions work with a strongly typed approach: whenever we *query* an object of any type using LINQ, the source type – together with all the properties we want our query to check for – must be known by the compiler. This means that we would be unable to use these techniques with generic objects (`object`) or types (`<T>`). That's where `Linq.Dynamic` comes to the rescue, allowing the developer to write lambda expressions and query expressions with literal strings and translating them into their strongly typed equivalent using **reflection**.

Here's the same query as before written using `System.Linq.Dynamic.Core`:

```
var city = _context.Cities.Where("Name = @1", "New York").First();
```

We can immediately see the difference – and also the tremendous advantage we can get by using such an approach: we will be able to build our queries dynamically, regardless of whether we're dealing with strongly typed objects or generic types, just like we did within the source code of `ApiResult` a short while ago.

However, such an approach will also have a major downside: our code will be less testable and way too error-prone, for at least two important reasons:

- We'll be just *a literal string away* from query errors that will almost always lead to major crashes
- The risk of unwanted queries (including SQL injection attacks) could increase exponentially, depending on how we build those queries and/or where we get our *dynamic* strings from

Those who don't know what SQL injections are and/or why they are dangerous should definitely take a look at the following guide, written by Tim Sammut and Mike Schiffman from the Cisco Security Intelligence team:



Understanding SQL Injections:

https://tools.cisco.com/security/center/resources/sql_injection.

The former issue is bad, but the latter is even worse: being open to SQL injection attacks could be devastating and therefore is something we should avoid at any cost – including getting rid of the `System.Linq.Dynamic.Core` package.

Preventing SQL injections

Luckily enough, we don't need to do that: although we're getting *two* potentially harmful variable strings coming from the client – `sortColumn` and `sortOrder` – we have already put in place effective countermeasures for both of them in the preceding source code of `ApiResult`.

Here's what we did for `sortOrder`:

```
//... existing code...

sortOrder = !String.IsNullOrEmpty(sortOrder)
    && sortOrder.ToUpper() == "ASC"
    ? "ASC"
```

```
: "DESC";  
//... existing code...
```

As we can see, we'll convert it into either "ASC" or "DESC" before using it anywhere, thus leaving no openings to SQL injections.

The `sortColumn` parameter is way more complex to handle because it can theoretically contain any possible column name mapped to any of our entities: `id`, `name`, `lat`, `lon`, `iso2`, `iso3`... If we were to check them all, we would need a very long conditional block! Not to mention the fact that it would also be very hard to maintain whenever we add new entities and/or properties to our project.

For that very reason, we chose a completely different – and arguably better – approach, which relies upon the following `IsValidProperty` method:

```
// ...existing code...  
  
public static bool IsValidProperty(  
    string propertyName,  
    bool throwExceptionIfNotFound = true)  
{  
    var prop = typeof(T).GetProperty(  
        propertyName,  
        BindingFlags.IgnoreCase |  
        BindingFlags.Public |  
        BindingFlags.Instance);  
    if (prop == null && throwExceptionIfNotFound)  
        throw new NotSupportedException(  
            String.Format(  
                "ERROR: Property '{0}' does not exist.",  
                propertyName)  
        );  
    return prop != null;  
}  
  
// ...existing code...
```

As we can see, this method checks that the given `propertyName` corresponds to an existing typed `Property` within our `<T>` generic entity class: if it does, it returns `True`; otherwise, it throws a `NotSupportedException` (or returns `False`, depending on how we call it). This is a great way to shield our code against SQL injection because there's absolutely no way that a harmful string would match one of our entity's properties.

The property name check has been implemented through `System.Reflection`, a technique that's used to inspect and/or retrieve metadata on types at runtime. To work with reflection, we need to include the `System.Reflection` namespace in our class – which is precisely what we did at the beginning of the source code of our improved `ApiResult`.



For additional information about `System.Reflection`, check out the following guide:

<https://docs.microsoft.com/en-us/dotnet/csharp/programming-guide/concepts/reflection>.

As we can see by looking back at the `ApiResult` source code, such a method is being called in the following way:

```
if (!String.IsNullOrEmpty(sortColumn)
    && IsValidProperty(sortColumn))
{
    /// if we are here, sortColumn is safe to use
}
```

Those curly brackets define our SQL injection safety zone: as long as we deal with `sortColumn` within them, we have nothing to worry about.



Truth be told, even after implementing this *defensive* approach, there's still a minor threat we could be exposed to: if we have some *reserved* columns/properties that we don't want the client to interact with (system columns, for example), the preceding countermeasure won't block it from doing that, although being unable to acknowledge their existence or to read their data, an experienced user could still be able to "order" the table results by them – providing it knows their precise *name* somehow.

If we want to prevent this remote – yet theoretically possible – leak, we can set these properties to `private` (since we told our `IsValidProperty` method to the only check for `public` properties) and/or rethink the whole method logic so that it better suits our security needs.

Updating CitiesController

Now that we have improved our `ApiResult` class, we can implement it within our `CitiesController`.

Open the `/Controllers/CitiesController.cs` file and change its contents accordingly (updated lines are highlighted):

```
// ..existing code...

// GET: api/Cities
// GET: api/Cities/?pageIndex=0&pageSize=10
// GET: api/Cities/?pageIndex=0&pageSize=10&sortColumn=name&
// sortOrder=asc
[HttpGet]
public async Task<ActionResult<ApiResult<City>>> GetCities(
    int pageIndex = 0,
    int pageSize = 10,
    string sortColumn = null,
    string sortOrder = null)
{
    return await ApiResult<City>.CreateAsync(
        _context.Cities,
        pageIndex,
        pageSize,
        sortColumn,
        sortOrder);
}

// ..existing code...
```

We're done with the *back-end* part; let's move to the *front-end*.

Updating the Angular app

As always, we need to change three files:

- The `angular-material.module.ts` file, where we need to add the new `@angular/material` module
- The `cities.component.ts` file, to implement the sorting business logic
- The `cities.component.html` file, to bind the new variables, methods, and references defined in the `.ts` file within the UI template

angular-material.module.ts

Open the `/ClientApp/src/app/angular-material.module.ts` file and change it in the following way (updated lines are highlighted):

```
import { NgModule } from '@angular/core';
import { MatTableModule } from '@angular/material/table';
import { MatPaginatorModule } from '@angular/material/paginator';
import { MatSortModule } from '@angular/material/sort';

@NgModule({
  imports: [
    MatTableModule,
    MatPaginatorModule,
    MatSortModule
  ],
  exports: [
    MatTableModule,
    MatPaginatorModule,
    MatSortModule
  ]
})

export class AngularMaterialModule { }
```

From now on, we'll be able to import the `MatSortModule`-related classes in any Angular Component.

cities.component.ts

Once done, open the `cities.component.ts` file and make the following modifications (updated lines are highlighted):

```
import { Component, Inject, ViewChild } from '@angular/core';
import { HttpClient, HttpParams } from '@angular/common/http';
import { MatTableDataSource } from '@angular/material/table';
import { MatPaginator, PageEvent } from '@angular/material/paginator';
import { MatSort } from '@angular/material/sort';

import { City } from './city';

@Component({
  selector: 'app-cities',
  templateUrl: './cities.component.html',
  styleUrls: ['./cities.component.css']
})
export class CitiesComponent { }
```

```
public displayedColumns: string[] = ['id', 'name', 'lat', 'lon'];
public cities: MatTableDataSource<City>;
```

```
defaultPageIndex: number = 0;
defaultPageSize: number = 10;
public defaultSortColumn: string = "name";
public defaultSortOrder: string = "asc";
```

```
@ViewChild(MatPaginator) paginator: MatPaginator;
@ViewChild(MatSort) sort: MatSort;
```

```
constructor(
  private http: HttpClient,
  @Inject('BASE_URL') private baseUrl: string) {
}
```

```
ngOnInit() {
  this.loadData();
}
```

```
loadData() {
  var pageEvent = new PageEvent();
  pageEvent.pageIndex = this.defaultPageIndex;
  pageEvent.pageSize = this.defaultPageSize;
  this.getData(pageEvent);
}
```

```
getData(event: PageEvent) {
  var url = this.baseUrl + 'api/Cities';
  var params = new HttpParams()
    .set("pageIndex", event.pageIndex.toString())
    .set("pageSize", event.pageSize.toString())
    .set("sortColumn", (this.sort)
      ? this.sort.active
      : this.defaultSortColumn)
    .set("sortOrder", (this.sort)
      ? this.sort.direction
      : this.defaultSortOrder);
  this.http.get<any>(url, { params })
    .subscribe(result => {
      console.log(result);
      this.paginator.length = result.totalCount;
      this.paginator.pageIndex = result.pageIndex;
      this.paginator.pageSize = result.pageSize;
      this.cities = new MatTableDataSource<City>(result.data);
    }, error => console.error(error));
}
```

Here's a breakdown of the most relevant changes:

- We imported the `MatSort` reference from the `@angular/material` package.
- We added four new class variables to set the paging and sorting default values: `defaultPageIndex`, `defaultPageSize`, `defaultSortColumn`, and `defaultSortOrder`. Two of them have been defined as `public` because we need to use them from the HTML template via two-way data binding.
- We moved the initial `getData()` call from the class constructor to a new centralized `loadData()` function so that we can bind it to the table (as we'll see in a short while).
- We added the `sortColumn` and `sortOrder` HTTP GET parameters to our `HttpParams` object so that we can send the sorting information to the server side.

`cities.component.html`

Right after that, open the `cities.component.html` file and make the following modifications (updated lines are highlighted):

```
// ...existing code

<table mat-table [dataSource]="cities" class="mat-elevation-z8"
[hidden]="!cities"
  matSort (matSortChange)="loadData()"
  matSortActive="{{defaultSortColumn}}"
  matSortDirection="{{defaultSortOrder}}>

  <!-- Id Column -->
  <ng-container matColumnDef="id">
    <th mat-header-cell *matHeaderCellDef mat-sort-headermat-sort-header>Name</th>
    <td mat-cell *matCellDef="let city"> {{city.name}} </td>
  </ng-container>

  <!-- Lat Column -->
  <ng-container matColumnDef="lat">
    <th mat-header-cell *matHeaderCellDef mat-sort-header>Latitude
```

```
</th>
<td mat-cell *matCellDef="let city"> {{city.lat}} </td>
</ng-container>

<!-- Lon Column -->
<ng-container matColumnDef="lon">
  <th mat-header-cell *matHeaderCellDef mat-sort-header>Longitude
  </th>
  <td mat-cell *matCellDef="let city"> {{city.lon}} </td>
</ng-container>

<tr mat-header-row *matHeaderRowDef="displayedColumns"></tr>
<tr mat-row *matRowDef="let row; columns: displayedColumns;"></tr>
</table>

// ...existing code...
```

Here's what we did in a nutshell:

- We added the following attributes to the `<table mat-table>` element:
 - `matSort`: A reference to the `matSort` local variable we added to the `cities.component.ts` file early on
 - `(matSortChange)`: An event binding that will execute the `sortData()` method (also defined in the `.ts` file earlier) upon each sorting attempt by the user
 - `matSortActive` and `matSortDirection`: Two data bindings to the `defaultSortColumn` and `defaultSortOrder` variables that we defined in the `.ts` file early on
- We added the `mat-sort-header` attribute to each `<th mat-header-cell>` element (one for each table column).



Now we can see why we didn't use the *sleek* URL we defined early on in our `.NET Core CitiesController` and opted for the standard GET parameters instead: this approach allows us to programmatically add an indefinite amount of HTTP GET parameters to our request thanks to the `HttpParams` class from the `@angular/common/http` package.

Let's quickly test it out by hitting *F5* and navigating to the **Cities** view. Here's what we should be able to see:

WorldCities		Home Cities Countries			
<h2>Cities</h2>					
Here's a list of cities: feel free to play with it.					
ID	Name ↑	Latitude	Longitude		
7835	'Ajlūn	32.3333	35.7528		
3954	'Ajmān	25.4056	55.4618		
51	'Amrān	15.6594	43.9439		
4172	25 de Mayo	-37.8	-67.6833		
4092	28 de Noviembre	-51.65	-72.3		
6377	Aalborg	57.0337	9.9166		
5579	Aarau	47.3896	8.0524		
5607	Aarau	47.39	8.034		
7096	Aasiaat	68.7167	-52.8667		
1378	Aba	5.1004	7.35		
Items per page: <input type="text" value="10"/> ▾		1 – 10 of 12959 < < > >			

As we can see, the cities are now sorted alphabetically in ascending order. If we click on the various column headers, we can change their order as we please: the first click will sort the content in ascending order, while the second will do the opposite.



It's worth noting how the paging and sorting features are able to coexist without issues; needless to say, whenever we try to change the table sorting, the paging will just roll back to the first page.

Now that the sorting has been implemented, there's only one missing feature left: **filtering**.

Adding filtering

If we think that we'll be able to get away with another Component, this time, we're going to be disappointed: Angular Material does not provide a specific module to be used for filtering purposes. This means that we cannot rely on a standard approach to adding filtering to our table; we have to figure out a reasonable approach by ourselves.

In general terms, the best thing to do whenever we need to code a feature by ourselves is starting to visualize what we want it to look like: for example, we can imagine a **Search** input field lying on top of our table that would trigger our `CitiesComponent` to reload the cities data from the server – through its `getData()` method – whenever we type something in it. How does that sound?

Let's try to lay down an action plan:

1. As always, we would need to extend our `ApiResult` class to programmatically handle the filtering task on the server side.
2. We'll also need to change the signature of the `GetCities()` action method of our .NET `CitiesController` so we can get the additional information from the client.
3. Right after that, we'll have to implement the filtering logic within our Angular `CitiesComponent`.
4. Last but not least, we need to add the input textbox in the `CitiesComponent` HTML template file and bind an event to it to trigger the data retrieval process upon typing something.

Now that we have made it, let's do our best to put that plan into action.

Extending `ApiResult` (again)

It seems like we need to perform another upgrade to our beloved `ApiResult` class to add filtering support to the already existing paging and sorting logic.

Truth be told, we're not forced to do everything within the `ApiResult` class: we could entirely skip that part and just add the following to our existing `CitiesController`:

```
// ...existing code...

[HttpGet]
public async Task<ActionResult<ApiResult<City>>> GetCities(
```

```
        int pageIndex = 0,
        int pageSize = 10,
        string sortColumn = null,
        string sortOrder = null,
        string filterColumn = null,
        string filterQuery = null)
    {
        // first we perform the filtering...
        var cities = _context.Cities;
        if (!String.IsNullOrEmpty(filterColumn)
            && !String.IsNullOrEmpty(filterQuery))
        {
            cities= cities.Where(c => c.Name.Contains(filterQuery));
        }

        // ... and then we call the ApiResult
        return await ApiResult<City>.CreateAsync(
            cities,
            pageIndex,
            pageSize,
            sortColumn,
            sortOrder);
    }

    // ...existing code...
}
```

That's definitely a viable approach. As a matter of fact, if we weren't using the `System.Linq.Dynamic.Core` package library, this would most likely be the only possible approach: we would have no way to programmatically set a column filter using an external class that works with generic `IQueryable<T>` objects, thus being unaware of the entity type and property names.

Luckily enough, we do have that package, so we can avoid performing the preceding changes (or roll them back, if we have already done that) and modify our `/Data/ApiResult.cs` class file in the following way instead:

```
using Microsoft.EntityFrameworkCore;
using System;
using System.Collections.Generic;
using System.Linq;
using System.Threading.Tasks;
using System.Linq.Dynamic.Core;

namespace WorldCities.Data
{
    public class ApiResult<T>
```

```
{  
    /// <summary>  
    /// Private constructor called by the CreateAsync method.  
    /// </summary>  
    public ApiResult(  
        List<T> data,  
        int count,  
        int pageIndex,  
        int pageSize,  
        string sortColumn,  
        string sortOrder,  
        string filterColumn,  
        string filterQuery)  
    {  
        Data = data;  
       PageIndex = pageIndex;  
       PageSize = pageSize;  
       TotalCount = count;  
       TotalPages = (int)Math.Ceiling(count / (double)pageSize);  
       SortColumn = sortColumn;  
       SortOrder = sortOrder;  
        FilterColumn = filterColumn;  
        FilterQuery = filterQuery;  
    }  
  
    #region Methods  
    /// <summary>  
    /// Pages, sorts and/or filters a IQueryable source.  
    /// </summary>  
    /// <param name="source">An IQueryable source of generic  
    /// type</param>  
    /// <param name="pageIndex">Zero-based current page index  
    /// (0 = first page)</param>  
    /// <param name="pageSize">The actual size of  
    /// each page</param>  
    /// <param name="sortColumn">The sorting colum name</param>  
    /// <param name="sortOrder">The sorting order ("ASC" or  
    /// "DESC")</param>  
    /// <param name="filterColumn">The filtering column  
name</param>  
    /// <param name="filterQuery">The filtering query (value to  
    /// lookup)</param>  
    /// <returns>  
    /// A object containing the IQueryable paged/sorted/filtered  
    /// result  
    /// and all the relevant paging/sorting/filtering navigation  
    /// info.  
    /// </returns>
```

```
public static async Task<ApiResult<T>> CreateAsync(
    IQueryable<T> source,
    int pageIndex,
    int pageSize,
    string sortColumn = null,
    string sortOrder = null,
    string filterColumn = null,
    string filterQuery = null)
{
    if (!String.IsNullOrEmpty(filterColumn)
        && !String.IsNullOrEmpty(filterQuery)
        && IsValidProperty(filterColumn))
    {
        source = source.Where(
            String.Format("{0}.Contains(@0)",
            filterColumn),
            filterQuery);
    }

    var count = await source.CountAsync();

    if (!String.IsNullOrEmpty(sortColumn)
        && IsValidProperty(sortColumn))
    {
        sortOrder = !String.IsNullOrEmpty(sortOrder)
            && sortOrder.ToUpper() == "ASC"
            ? "ASC"
            : "DESC";
        source = source.OrderBy(
            String.Format(
                "{0} {1}",
                sortColumn,
                sortOrder)
        );
    }

    source = source
        .Skip(pageIndex * pageSize)
        .Take(pageSize);

    var data = await source.ToListAsync();
    return new ApiResult<T>(
        data,
        count,
        pageIndex,
        pageSize,
        sortColumn,
        sortOrder,
```

```
        filterColumn,
        filterQuery);
    }
#endregion

#region Methods
/// <summary>
/// Checks if the given property name exists
/// to protect against SQL injection attacks
/// </summary>
public static bool IsValidProperty(
    string propertyName,
    bool throwExceptionIfNotFound = true)
{
    var prop = typeof(T).GetProperty(
        propertyName,
        BindingFlags.IgnoreCase |
        BindingFlags.Public |
        BindingFlags.Instance);
    if (prop == null && throwExceptionIfNotFound)
        throw new NotSupportedException(
            String.Format(
                "ERROR: Property '{0}' does not exist.",
                propertyName));
    return prop != null;
}
#endregion

#region Properties
/// <summary>
/// The data result.
/// </summary>
public List<T> Data { get; private set; }

/// <summary>
/// Zero-based index of current page.
/// </summary>
public int PageIndex { get; private set; }

/// <summary>
/// Number of items contained in each page.
/// </summary>
public int PageSize { get; private set; }

/// <summary>
/// Total items count
/// </summary>
```

```
public int TotalCount { get; private set; }

/// <summary>
/// Total pages count
/// </summary>
public int TotalPages { get; private set; }

/// <summary>
/// TRUE if the current page has a previous page,
/// FALSE otherwise.
/// </summary>
public bool HasPreviousPage
{
    get
    {
        return (PageIndex > 0);
    }
}

/// <summary>
/// TRUE if the current page has a next page, FALSE otherwise.
/// </summary>
public bool HasNextPage
{
    get
    {
        return ((PageIndex +1) < TotalPages);
    }
}

/// <summary>
/// Sorting Column name (or null if none set)
/// </summary>
public string SortColumn { get; set; }

/// <summary>
/// Sorting Order ("ASC", "DESC" or null if none set)
/// </summary>
public string SortOrder { get; set; }

/// <summary>
/// Filter Column name (or null if none set)
/// </summary>
public string FilterColumn { get; set; }

/// <summary>
/// Filter Query string
/// (to be used within the given FilterColumn)
```

```
    /// </summary>
    public string FilterQuery { get; set; }
    #endregion
}
}
```

And that's it. As we can see, we were able to programmatically implement the `IQueryable<T>.Where()` method – which actually performs the filtering task – thanks to another useful extension method provided by the `System.Linq.Dynamic.Core` package.

Needless to say, we took the chance to use our `IsValidProperty` method again to shield our code against possible SQL injection attempts: the filtering-related logic (and dynamic LINQ query) will be only executed if it returns `True`, that is, if the `filterColumn` parameter value matches with an existing entity public property.

While we were there, we also added two additional properties (`FilterColumn` and `FilterQuery`) so that we'll have them on the JSON response object, and modified the constructor method signature accordingly.

CitiesController

Now, we can open our `/Controllers/CitiesController.cs` file and make the following changes:

```
[HttpGet]
public async Task<ActionResult<ApiResult<City>>> GetCities(
    int pageIndex = 0,
    int pageSize = 10,
    string sortColumn = null,
    string sortOrder = null,
    string filterColumn = null,
    string filterQuery = null)
{
    return await ApiResult<City>.CreateAsync(
        _context.Cities,
        pageIndex,
        pageSize,
        sortColumn,
        sortOrder,
        filterColumn,
        filterQuery);
}
```

The preceding code is very similar to the alternative implementation that we assumed in the previous section: as we mentioned earlier, both approaches are viable, depending on our tastes. However, since we're going to use this same implementation for the *countries* in a short while, making good use of `System.Linq.Dynamic.Core` and centralizing all the `IQueryable` logic is arguably a better approach since it keeps our source code as DRY as possible.



Don't Repeat Yourself (DRY) is a widely achieved principle of software development. Whenever we violate it, we fall into a **WET** approach, which could mean **Write Everything Twice, We Enjoy Typing, or Waste Everyone's Time**, depending on what we like the most.

The .NET part is done; let's move on to Angular.

CitiesComponent

Open the `/ClientApp/src/app/cities/cities.component.ts` file and update its content in the following way (modified lines are highlighted):

```
import { Component, Inject, ViewChild } from '@angular/core';
import { HttpClient, HttpParams } from '@angular/common/http';
import { MatTableDataSource } from '@angular/material/table';
import { MatPaginator, PageEvent } from '@angular/material/paginator';
import { MatSort } from '@angular/material/sort';

import { City } from './city';

@Component({
  selector: 'app-cities',
  templateUrl: './cities.component.html',
  styleUrls: ['./cities.component.css']
})
export class CitiesComponent {
  public displayedColumns: string[] = ['id', 'name', 'lat', 'lon'];
  public cities: MatTableDataSource<City>

  defaultPageIndex: number = 0;
  defaultPageSize: number = 10;
  public defaultSortColumn: string = "name";
  public defaultSortOrder: string = "asc";

  defaultFilterColumn: string = "name";
  filterQuery: string = null;
```

```
@ViewChild(MatPaginator) paginator: MatPaginator;
@ViewChild(MatSort) sort: MatSort;

constructor(
    private http: HttpClient,
    @Inject('BASE_URL') private baseUrl: string) {
}

ngOnInit() {
    this.loadData(null);
}

loadData(query: string = null) {
    var pageEvent = new PageEvent();
    pageEvent.pageIndex = this.defaultPageIndex;
    pageEvent.pageSize = this.defaultPageSize;
    if (query) {
        this.filterQuery = query;
    }
    this.getData(pageEvent);
}

getData(event: PageEvent) {
    var url = this.baseUrl + 'api/Cities';
    var params = new HttpParams()
        .set("pageIndex", event.pageIndex.toString())
        .set("pageSize", event.pageSize.toString())
        .set("sortColumn", (this.sort)
            ? this.sort.active
            : this.defaultSortColumn)
        .set("sortOrder", (this.sort)
            ? this.sort.direction
            : this.defaultSortOrder);

    if (this.filterQuery) {
        params = params
            .set("filterColumn", this.defaultFilterColumn)
            .set("filterQuery", this.filterQuery);
    }

    this.http.get<any>(url, { params })
        .subscribe(result => {
            this.paginator.length = result.totalCount;
            this.paginator.pageIndex = result.pageIndex;
            this.paginator.pageSize = result.pageSize;
            this.cities = new MatTableDataSource<City>(result.data);
        });
}
```

```
    }, error => console.error(error));
}
}
```

This time, the new code only consists of a few additional lines; we've just changed the signature of the `loadData()` method (with a `null` default value, so that we won't break anything) and conditionally added a couple of parameters to our HTTP request – that's it.

CitiesComponent template (HTML) file

Let's see what we need to add in the

`/ClientApp/src/app/cities/cities.component.html` template file:

```
<h1>Cities</h1>

<p>Here's a list of cities: feel free to play with it.</p>

<p *ngIf="!cities"><em>Loading...</em></p>

<mat-form-field [hidden]="!cities">
  <input matInput (keyup)="loadData($event.target.value)"
        placeholder="Filter by name (or part of it)...">
</mat-form-field>

<table mat-table [dataSource]="cities" class="mat-elevation-z8"
[hidden]="!cities"
  matSort (matSortChange)="loadData()"
  matSortActive="{{defaultSortColumn}}"
  matSortDirection="{{defaultSortOrder}}">

  // ...existing code...
```

As we can see, we just added a `<mat-form-field>` element with the usual `[hidden]` attribute binding (to make it appear only after our cities have been loaded) and a `(keyup)` event binding that will trigger the `loadData()` method upon each key press; this call will also contain the input value, which will be handled by our Component class by the means we just implemented there.

CitiesComponent style (CSS) file

Before testing it out, we need to make a minor change to the /ClientApp/src/app/cities/cities.component.css file as well:

```
table {  
    width: 100%;  
}  
  
.mat-form-field {  
    font-size: 14px;  
    width: 100%;  
}
```

This is required to make our new MatInputModule span through the entire available space (it's limited to 180px by default).

AngularMaterialModule

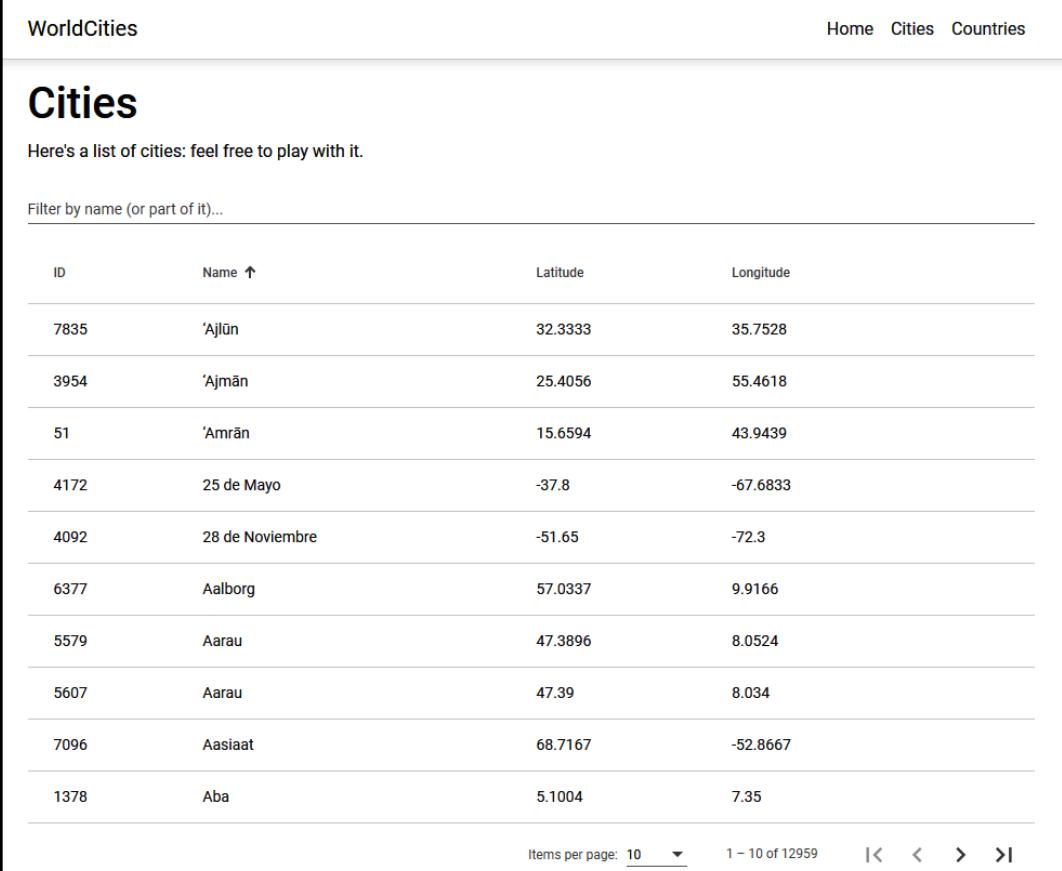
Wait a minute: didn't we just say MatInputModule? That's correct: as a matter of fact, it seems like we have actually used an Angular Material module after all – and for good reason, since it looks much better than a vanilla HTML input textbox!

However, since we did that, we need to reference it within our AngularMaterialModule container or we'll get a compiler error. To do that, open the /ClientApp/src/app/angular-material.module.ts file and add the following lines:

```
import { NgModule } from '@angular/core';  
import { MatTableModule } from '@angular/material/table';  
import { MatPaginatorModule } from '@angular/material/paginator';  
import { MatSortModule } from '@angular/material/sort';  
import { MatInputModule } from '@angular/material/input';  
  
@NgModule({  
    imports: [  
        MatTableModule,  
        MatPaginatorModule,  
        MatSortModule,  
        MatInputModule  
    ],  
    exports: [  
        MatTableModule,  
        MatPaginatorModule,  
        MatSortModule,
```

```
    MatInputModule  
]  
})  
  
export class AngularMaterialModule { }
```

That's it: now, we can hit *F5* and navigate to the `Cities` view to test the new filtering feature. If we did everything properly, we should be able to see something similar to the following screenshot:



The screenshot shows a web application interface titled "WorldCities". At the top right, there are navigation links for "Home", "Cities", and "Countries". The main title "Cities" is displayed prominently. Below the title, a sub-instruction reads "Here's a list of cities: feel free to play with it.". A search bar labeled "Filter by name (or part of it)..." is present. The main content area displays a table of city data with columns for "ID", "Name ↑", "Latitude", and "Longitude". The table lists 10 entries from a total of 12,959. The entries include: ID 7835, Name 'Ajlūn', Latitude 32.3333, Longitude 35.7528; ID 3954, Name 'Ajmān', Latitude 25.4056, Longitude 55.4618; ID 51, Name 'Amrān', Latitude 15.6594, Longitude 43.9439; ID 4172, Name '25 de Mayo', Latitude -37.8, Longitude -67.6833; ID 4092, Name '28 de Noviembre', Latitude -51.65, Longitude -72.3; ID 6377, Name 'Aalborg', Latitude 57.0337, Longitude 9.9166; ID 5579, Name 'Aarau', Latitude 47.3896, Longitude 8.0524; ID 5607, Name 'Aarau', Latitude 47.39, Longitude 8.034; ID 7096, Name 'Aasiaat', Latitude 68.7167, Longitude -52.8667; ID 1378, Name 'Aba', Latitude 5.1004, Longitude 7.35. At the bottom of the table, there are pagination controls: "Items per page: 10 ▾", "1 – 10 of 12959", and navigation arrows (<, >, <<, >>).

Looks pretty good, right?

If we try to type something into the filter textbox, we should see the table and the paginator update accordingly in real-time. Look at what happens if we type New York:

ID	Name ↑	Latitude	Longitude
9793	New York	40.6943	-73.9249
8771	West New York	40.7856	-74.0093

Items per page: 10 | < < > >|

That's definitely a good real-time filtering feature.

Adding the countries to the loop

Before moving on, how about getting the countries up to speed? Yeah, it would mean redoing everything that we just did a second time; however, now that we know how to do this, we'll arguably be able to do that in a flash...

... or maybe not.

Nonetheless, we definitely should spend some reasonable time doing that now, because that would be a great way to plant everything we have learned so far in our muscle memory.

Let's just do this so that we can move on to trying something else. To avoid wasting pages, we'll just focus on the most relevant steps here, leaving everything else to what we just did with the cities – and to our GitHub repository, which hosts the full source code of what we need to do.

.NET Core

Let's start with the .NET Core part.

CountriesController

We should already have our `CountriesController` ready from Chapter 4, *Data Model with Entity Framework Core*, right? Open that file and replace the `GetCountries()` default action method with the following code:

```
// ...existing code...

[HttpGet]
public async Task<ActionResult<ApiResult<Country>>> GetCountries(
    int pageIndex = 0,
    int pageSize = 10,
    string sortColumn = null,
    string sortOrder = null,
    string filterColumn = null,
    string filterQuery = null)
{
    return await ApiResult<Country>.CreateAsync(
        _context.Countries,
        pageIndex,
        pageSize,
        sortColumn,
        sortOrder,
        filterColumn,
        filterQuery);
}

// ...existing code...
```

Luckily enough, our `ApiResult` class is type-agnostic; therefore, we can use it there with no issues. Also, since we have centralized all the hard work there, the .NET server-side part is already done.

An odd JSON naming issue

Before moving on, let's quickly test the Component: hit `F5` and type the following URL into the browser's address bar: `https://localhost:44334/api/Countries/?pageIndex=0pageSize=2`.

As soon as we hit *Enter*, we should be able to see the following interface:

```
{  
  "items": [  
    {  
      "id": 1,  
      "name": "Kosovo",  
      "is02": "XK",  
      "is03": "XKS",  
      "cities": null  
    },  
    {  
      "id": 2,  
      "name": "Svalbard",  
      "is02": "XR",  
      "is03": "XSV",  
      "cities": null  
    }  
  ],  
  "pageIndex": 0,  
  "pageSize": 2,  
  "totalCount": 235,  
  "totalPages": 118,  
  "hasPreviousPage": false,  
  "hasNextPage": true,  
  "sortColumn": null,  
  "sortOrder": null,  
  "filterColumn": null,  
  "filterQuery": null  
}
```

It seems like it's all g... Hey, wait a minute: what's up with those `is02` and `is03` property names? They shouldn't be capitalized like that!

In order to understand what happened there, we need to take a step back and acknowledge something we might have underestimated so far: the camelCase conversion that the brand new `System.Text.Json` API (introduced with .NET Core 3) automatically does when serializing all our .NET classes to JSON. We already talked about this issue early on in this chapter, when we saw the `.NET CitiesController` JSON output for the first time, and we said that it wasn't a big deal since Angular is also camelCase-oriented – we would just have to define the various interfaces using camelCase as well.

Unfortunately, such automatic camelCase conversion might cause unwanted side effects when dealing with all-uppercase properties such as those two; whenever this happens, we need to adapt our source code to properly deal with that:

- The most obvious thing to do would be to just define them in our Angular interface in the exact same way, that is, using that exact casing; however, this would mean dealing with those `iso2` and `iso3` variable names throughout our whole Angular code, which is rather ugly and might also be quite misleading.
- If we don't want to adopt those hideous property names, there is an alternative – and arguably better – workaround we can use: we can decorate our offending properties with the `[JsonPropertyName]` Data Annotation, which allows us to force a JSON property name, regardless of the default casing convention (be it camelCase or PascalCase) specified within the `Startup` class.

The `[JsonPropertyName]` workaround seems the most reasonable fix we can apply to our specific scenario; let's just go with it and get rid of such a problem for good!

Open the `/Data/Country.cs` file and add the following lines to the existing code (new lines are highlighted):

```
// ...existing code...

/// <summary>
/// Country code (in ISO 3166-1 ALPHA-2 format)
/// </summary>
[JsonPropertyName("iso2")]
public string ISO2 { get; set; }

/// <summary>
/// Country code (in ISO 3166-1 ALPHA-3 format)
/// </summary>
[JsonPropertyName("iso3")]
public string ISO3 { get; set; }

// ...existing code...
```

Now, we can see whether those properties will respect this behavior by hitting *F5* and typing the same URL as before into the browser's address bar: `https://localhost:44334/api/Countries/?pageIndex=0pageSize=2`:

```
{  
  "items": [  
    {  
      "id": 1,  
      "name": "Kosovo",  
      "iso2": "XK",  
      "iso3": "XKS",  
      "cities": null  
    },  
    {  
      "id": 2,  
      "name": "Svalbard",  
      "iso2": "XR",  
      "iso3": "XSV",  
      "cities": null  
    }  
  ],  
  "pageIndex": 0,  
  "pageSize": 2,  
  "totalCount": 235,  
  "totalPages": 118,  
  "hasPreviousPage": false,  
  "hasNextPage": true,  
  "sortColumn": null,  
  "sortOrder": null,  
  "filterColumn": null,  
  "filterQuery": null  
}
```

It definitely seems like they do; thanks to this unexpected issue, we had the chance to add a new powerful weapon to our .NET Core arsenal.

Now, we just need to create and configure the Angular Component.

Angular

The Angular implementation will be less trivial than the .NET Core one since we'll have to deal with multiple aspects:

- Adding the `CountriesComponent` TS, HTML, and CSS files and implementing the `Countries` table, as well as the paging, sorting, and filtering features as we did with the cities

- Configuring the `AppModule` to properly reference it and add the corresponding route
- Updating the `NavComponent` to add the navigation link

Let's do this! From the **Solution Explorer**, do the following:

1. Navigate to the `/ClientApp/src/app/` folder.
2. Create a new `/countries/` folder.
3. Within that folder, create the following new files:
 - `country.ts`
 - `countries.component.ts`
 - `countries.component.html`
 - `countries.component.css`

Once done, fill them with the following content.

country.ts

Here's the source code for the `/ClientApp/src/app/countries/country.ts` interface file:

```
export interface Country {  
    id: number;  
    name: string;  
    iso2: string;  
    iso3: string;  
}
```

Nothing new here – the code is very similar to what we did when we created the `city.ts` interface file.

countries.component.ts

Here's the source code for
the `/ClientApp/src/app/countries/countries.component.ts` file:

```
import { Component, Inject, ViewChild } from '@angular/core';  
import { HttpClient, HttpParams } from '@angular/common/http';  
import { MatTableDataSource } from '@angular/material/table';  
import { MatPaginator, PageEvent } from '@angular/material/paginator';  
import { MatSort } from '@angular/material/sort';
```

```
import { Country } from './country';

@Component({
  selector: 'app-countries',
  templateUrl: './countries.component.html',
  styleUrls: ['./countries.component.css']
})
export class CountriesComponent {
  public displayedColumns: string[] = ['id', 'name', 'iso2', 'iso3'];
  public countries: MatTableDataSource<Country>;

  defaultPageIndex: number = 0;
  defaultPageSize: number = 10;
  public defaultSortColumn: string = "name";
  public defaultSortOrder: string = "asc";

  defaultFilterColumn: string = "name";
  filterQuery: string = null;

  @ViewChild(MatPaginator) paginator: MatPaginator;
  @ViewChild(MatSort) sort: MatSort;

  constructor(
    private http: HttpClient,
    @Inject('BASE_URL') private baseUrl: string) {
  }

  ngOnInit() {
    this.loadData(null);
  }

  loadData(query: string = null) {
    var pageEvent = new PageEvent();
    pageEvent.pageIndex = this.defaultPageIndex;
    pageEvent.pageSize = this.defaultPageSize;
    if (query) {
      this.filterQuery = query;
    }
    this.getData(pageEvent);
  }

  getData(event: PageEvent) {
    var url = this.baseUrl + 'api/Countries';
    var params = new HttpParams()
      .set("pageIndex", event.pageIndex.toString())
      .set("pageSize", event.pageSize.toString())
      .set("sortColumn", (this.sort)
        ? this.sort.active
```

```
    : this.defaultSortColumn)
.set("sortOrder", (this.sort)
? this.sort.direction
: this.defaultSortOrder);

if (this.filterQuery) {
  params = params
    .set("filterColumn", this.defaultFilterColumn)
    .set("filterQuery", this.filterQuery);
}

this.http.get<any>(url, { params })
.subscribe(result => {
  this.paginator.length = result.totalCount;
  this.paginator.pageIndex = result.pageIndex;
  this.paginator.pageSize = result.pageSize;
  this.countries = new MatTableDataSource<Country>(result.data);
}, error => console.error(error));
}
}
```

Again, this is basically a mirror of the `cities.component.ts` file.

countries.component.html

Here's the source code for

the `/ClientApp/src/app/countries/countries.component.html` file:

```
<h1>Countries</h1>

<p>Here's a list of countries: feel free to play with it.</p>

<p *ngIf="!countries"><em>Loading...</em></p>

<mat-form-field [hidden]="!countries">
  <input matInput (keyup)="loadData($event.target.value)"
    placeholder="Filter by name (or part of it)...">
</mat-form-field>

<table mat-table [dataSource]="countries" class="mat-elevation-z8"
[hidden]="!countries"
  matSort (matSortChange)="loadData()"
  matSortActive="{{defaultSortColumn}}"
  matSortDirection="{{defaultSortOrder}}>

  <!-- Id Column -->
  <ng-container matColumnDef="id">
```

```
<th mat-header-cell *matHeaderCellDef mat-sort-header>ID</th>
<td mat-cell *matCellDef="let country"> {{country.id}} </td>
</ng-container>

<!-- Name Column -->
<ng-container matColumnDef="name">
  <th mat-header-cell *matHeaderCellDef mat-sort-header>Name</th>
  <td mat-cell *matCellDef="let country"> {{country.name}} </td>
</ng-container>

<!-- Lat Column -->
<ng-container matColumnDef="iso2">
  <th mat-header-cell *matHeaderCellDef mat-sort-header>ISO 2</th>
  <td mat-cell *matCellDef="let country"> {{country.iso2}} </td>
</ng-container>

<!-- Lon Column -->
<ng-container matColumnDef="iso3">
  <th mat-header-cell *matHeaderCellDef mat-sort-header>ISO 3</th>
  <td mat-cell *matCellDef="let country"> {{country.iso3}} </td>
</ng-container>

<tr mat-header-row *matHeaderRowDef="displayedColumns"></tr>
<tr mat-row *matRowDef="let row; columns: displayedColumns;"></tr>
</table>

<!-- Pagination directive -->
<mat-paginator [hidden]="!countries"
  (page)="pageEvent = getData($event)"
  [pageSize]="10"
  [pageSizeOptions]="[10, 20, 50]"
  showFirstLastButtons></mat-paginator>
```

The template, just as expected, is almost identical to the `cities.component.html` template file.

countries.component.css

Here's the source code for the `/ClientApp/src/app/countries/countries.component.css` file:

```
table {
  width: 100%;
}

.mat-form-field {
```

```
    font-size: 14px;
    width: 100%;
}
```

The preceding file is so similar to the `cities.components.css` file that we could even reference it instead of creating a new one; however, dealing with separate files is almost always a better choice, considering that we might need to apply different changes to the `Cities` and `Countries` tables later on.

AppModule

Now let's register our new Component to the `AppModule` configuration file.

Open the `/ClientApp/src/app/app.module.ts` file and add the following highlighted lines:

```
import { BrowserModule } from '@angular/platform-browser';
import { NgModule } from '@angular/core';
import { FormsModule } from '@angular/forms';
import { HttpClientModule, HTTP_INTERCEPTORS } from
  '@angular/common/http';
import { RouterModule } from '@angular/router';

import { AppComponent } from './app.component';
import { NavMenuComponent } from './nav-menu/nav-menu.component';
import { HomeComponent } from './home/home.component';
import { CitiesComponent } from './cities/cities.component';
import { CountriesComponent } from './countries/countries.component';
import { BrowserAnimationsModule } from '@angular/platform-
browser/animations';
import { AngularMaterialModule } from './angular-material.module';

@NgModule({
  declarations: [
    AppComponent,
    NavMenuComponent,
    HomeComponent,
    CitiesComponent,
    CountriesComponent
  ],
  imports: [
    BrowserModule.withServerTransition({ appId: 'ng-cli-universal' }),
    HttpClientModule,
    FormsModule,
    RouterModule.forRoot([
      { path: '', component: HomeComponent, pathMatch: 'full' },

```

```
        { path: 'cities', component: CitiesComponent },
        { path: 'countries', component: CountriesComponent }
    ]),
    BrowserModule,
    AngularMaterialModule
],
providers: [],
bootstrap: [AppComponent]
})
export class AppModule {}
```

The preceding `RouterModule` configuration will make our new `CountriesComponent` get served by Angular when the client browser points to the `/countries` dedicated route. However, our users won't know that such a route exists if we don't add a visible link to it within our `NavComponent` menu; that's precisely why we're going to add it.

NavComponent

Open the `/ClientApp/src/app/nav-menu/nav-menu.component.html` file and add the following highlighted lines to the existing code:

```
// ...existing code...

<ul class="navbar-nav flex-grow">
  <li
    class="nav-item"
    [routerLinkActive]=["link-active"]
    [routerLinkActiveOptions]={ exact: true }>
    <a class="nav-link text-dark" [routerLink]=["'/'"]>Home</a>
  </li>
  <li class="nav-item" [routerLinkActive]=["link-active"]>
    <a class="nav-link text-dark" [routerLink]=["'/cities']>
      Cities</a>
  </li>
  <li class="nav-item" [routerLinkActive]=["link-active"]>
    <a class="nav-link text-dark" [routerLink]=["'/countries']>
      Countries</a>
  </li>
</ul>

// ...existing code...
```

... and that's it!

Our `CountriesComponent` is done, and – if we didn't make mistakes – it should work in about the same way as our beloved `CitiesComponent` that took so much time to finalize.

Testing CountriesComponent

It's time to see the results of our hard work: hit `F5`, navigate to the `Countries` view, and expect to see the following:

WorldCities		Home Cities Countries																																													
<h2>Countries</h2>																																															
Here's a list of countries: feel free to play with it.																																															
Filter by name (or part of it)...																																															
<table><thead><tr><th>ID</th><th>Name ↑</th><th>Latitude</th><th>Longitude</th></tr></thead><tbody><tr><td>120</td><td>Afghanistan</td><td>AF</td><td>AFG</td></tr><tr><td>123</td><td>Albania</td><td>AL</td><td>ALB</td></tr><tr><td>173</td><td>Algeria</td><td>DZ</td><td>DZA</td></tr><tr><td>232</td><td>American Samoa</td><td>AS</td><td>ASM</td></tr><tr><td>118</td><td>Andorra</td><td>AD</td><td>AND</td></tr><tr><td>125</td><td>Angola</td><td>AO</td><td>AGO</td></tr><tr><td>122</td><td>Anguilla</td><td>AI</td><td>AIA</td></tr><tr><td>121</td><td>Antigua And Barbuda</td><td>AG</td><td>ATG</td></tr><tr><td>126</td><td>Argentina</td><td>AR</td><td>ARG</td></tr><tr><td>124</td><td>Armenia</td><td>AM</td><td>ARM</td></tr></tbody></table>				ID	Name ↑	Latitude	Longitude	120	Afghanistan	AF	AFG	123	Albania	AL	ALB	173	Algeria	DZ	DZA	232	American Samoa	AS	ASM	118	Andorra	AD	AND	125	Angola	AO	AGO	122	Anguilla	AI	AIA	121	Antigua And Barbuda	AG	ATG	126	Argentina	AR	ARG	124	Armenia	AM	ARM
ID	Name ↑	Latitude	Longitude																																												
120	Afghanistan	AF	AFG																																												
123	Albania	AL	ALB																																												
173	Algeria	DZ	DZA																																												
232	American Samoa	AS	ASM																																												
118	Andorra	AD	AND																																												
125	Angola	AO	AGO																																												
122	Anguilla	AI	AIA																																												
121	Antigua And Barbuda	AG	ATG																																												
126	Argentina	AR	ARG																																												
124	Armenia	AM	ARM																																												

Items per page: 10 ▾ 1 – 10 of 235 |< < > >|

If we are able to get this same output on our first attempt, it definitely means that we have learned our lesson; if we didn't, don't worry: we'll just have to check out what we did wrong and fix that. Practice makes perfect.



The browser's console log can be a very useful tool for debugging the server-side and client-side errors: most Angular errors come with well-documented exception text and a contextual link to the corresponding file and source code line, thus making it quite easy for the developer to understand what happens under the hood.

Summary

This chapter was all about reading data from the .NET Core *back-end* and finding a way to properly show it to the browser with the Angular *front-end*.

We started by using our existing `CitiesController` to fetch a large number of cities with Angular Components; although both frameworks are perfectly able to deal with massive data, we quickly understood that we need to improve the whole data request, response, and render flow process to grant our users a decent user experience.

For this very reason, we chose to adopt the `System.Linq.Dynamic.Core` .NET package to revamp our server-side business logic and the Angular Material npm package to greatly improve our client-side UI: by combining the powerful features of these two packages, we managed to pull off a bunch of interesting features: paging, sorting, and filtering. During our development journey, we also took the chance to identify, address, and mitigate some important security issues, such as a harmful SQL injection risk.

Right after finishing our work with `Cities`, we moved on to `Countries`, taking the chance to retrace our steps and cement what we just learned into our muscle memory.

After all our hard work, we can definitely say that we did a great job and fulfilled our goal: being able to read our data from the .NET Core *back-end* and gracefully present it through the *front-end* with Angular, thus making the end users fully able to see and interact with it.

We're now ready to add another layer of complexity to our application: give our users the chance to modify the existing data and/or add new data using HTML forms; these features are a must-have for most interactive web applications such as CMS, forums, social networks, chat rooms, and the like. In the next chapter, we'll see how we can deal with such tasks using reactive forms, a pivotal Angular module that provides a model-driven approach to handling form inputs whose values change over time.

Suggested topics

JSON, RESTful conventions, HTTP verbs, HTTP status, life cycle hooks, client-side paging, server-side paging, sorting, filtering, Dependency Injection, SQL injection

.NET Core

System.Linq, System.Linq.Dynamic.Core, IQueryble, Entity Framework Core

Angular

Components, Routing, Modules, AppModule, HttpClient, ngIf, hidden, Data Binding, Property Binding, Attribute Binding, ngFor, Directives, Structural Directives, interpolations, templates

References

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- *System.Linq.Dynamic.Core project page on GitHub:* <https://github.com/StefH/System.Linq.Dynamic.Core>

- *LINQ Overview:* <https://docs.microsoft.com/en-us/dotnet/csharp/linq/>
- *LINQ (Language Integrated Query):* <https://docs.microsoft.com/en-us/dotnet/csharp/programming-guide/concepts/linq/>
- *LINQ Lambda Expressions (C# Programming Guide):* <https://docs.microsoft.com/en-us/dotnet/csharp/programming-guide/statements-expressions-operators/lambda-expressions>
- *LINQ Query expression basics:* <https://docs.microsoft.com/en-us/dotnet/csharp/linq/query-expression-basics>
- *Reflection (C#):* <https://docs.microsoft.com/en-us/dotnet/csharp/programming-guide/concepts/reflection>
- *.NET Core and Entity Framework: set IQueryble<T> Column Names programmatically with Dynamic LINQ:* <https://www.ryadel.com/en/asp-net-core-set-column-name-programmatically-dynamic-linq-where-iqueryable/>
- *Understanding SQL Injections:* https://tools.cisco.com/security-center/resources/sql_injection

6

Forms and Data Validation

In this chapter, we'll mostly deal with forms, data input, and validation techniques. As we already know, HTML forms are one of the most important and delicate aspects of any business application. Nowadays, forms are used to fulfill almost any task involving user-submitted data, such as registering or logging in to a website, issuing a payment, reserving a hotel room, ordering a product, performing and retrieving search results, and more.

If we were asked to define a form from a developer's perspective, we would come out with the statement that "*A form is a UI-based interface that allows authorized users to enter data that will be sent to a server for processing*". The moment we accept this definition, two additional considerations should come into mind:

- Each form should provide a data entry experience good enough to efficiently guide our users through the expected workflow; otherwise, they won't be able to use it properly.
- Each form, as long as it brings potentially insecure data to the server, can have a major security impact in terms of data integrity, data security, and system security, unless the developer possesses the required *know-how* to adopt and implement the appropriate countermeasures.

These two phrases provide a good summary of what we'll do in this chapter; we'll do our best to guide our users into submitting the data in the most appropriate way, and we'll also learn how to check these input values properly to prevent, avoid, and/or minimize a wide spectrum of integrity and security threats. It's also important to understand that these two topics are frequently intertwined with each other; hence, we'll often deal with them at the same time.

In this chapter, we'll cover the following topics:

- **Angular forms**, where we'll deal with Template-Driven Forms as well as **Reactive Forms**, all while understanding the pros and cons of both approaches and looking at which is the most suited for use in various common scenarios
- **Data validation**, where we'll learn how to double-check our users' input data in the *front-end* and also from the *back-end*, as well as the various techniques to give visual feedback when they send incorrect or invalid values
- **Form builder**, where we'll implement another Reactive Form using some factory methods instead of manually instantiating the various form model elements

At the end of each task, we'll also take some time to verify the result of our work using our web browser.

Technical requirements

In this chapter, we're going to need all the technical requirements that we mentioned in the previous chapters, plus the following external libraries:

- **System.Linq.Dynamics.Core** (optional)

As always, it's advisable to avoid installing these straight away. We're going to bring them in during this chapter so that we can contextualize their purpose within our project.

The code files for this chapter can be found at https://github.com/PacktPublishing/ASP.NET-Core-3-and-Angular-9-Third-Edition/tree/master/Chapter_06/

Exploring Angular forms

If we take a look at our current .NET Core with Angular projects, we will see how none of them allow our users to *interact* with the data:

- For the `HealthCheck` app, this is expected since there's simply no data to deal with: this is a monitor app that doesn't store anything and requires no input from the user.
- The `WorldCities` app, however, tells a whole different story: we do have a database that we use to return results to our users, who could – at least theoretically – be allowed to make changes.

It goes without saying that the `WorldCities` app would be our best candidate for implementing our forms. In the following sections, we'll do just that, starting with the Angular *front-end* and then moving to the .NET Core *back-end*.

Forms in Angular

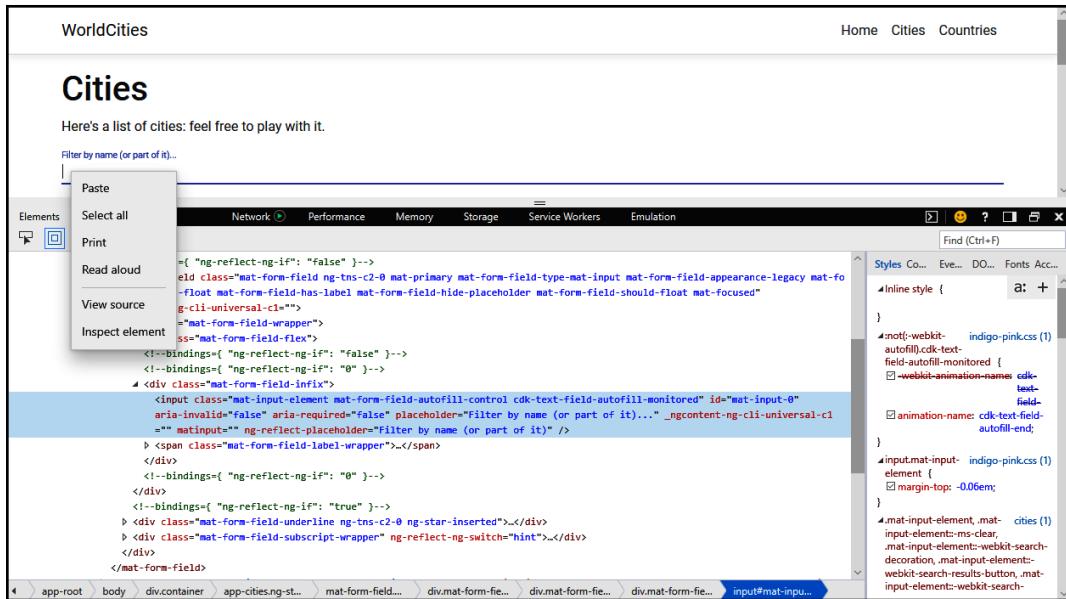
Let's take a minute to briefly review our `WorldCities` app in the state we left it in at the end of Chapter 5, *Fetching and Displaying Data*. If we take a look at the `CitiesComponent` and `CountriesComponent` templates, we will see that we actually already have a data input element of some sort: we're clearly talking about `<mat-form-field>`, which is the *selector* of Angular Material's `MatInputModule`, which we added to the loop during Chapter 5, *Fetching and Displaying Data*, to let our users filter the `cities` and `countries` by their name.

Here's the relevant code snippet:

```
<mat-form-field [hidden]="!cities">
  <input matInput (keyup)="loadData($event.target.value)"
        placeholder="Filter by name (or part of it)...">
</mat-form-field>
```

This means that we are already accepting some kind of user action – consisting of a single input string – and reacting to it accordingly: such an action + reaction chain is the basis of an interaction between the user and the app, which is basically what the vast majority of forms are all about.

However, if we look at the generated HTML code, we can clearly see that we do not have any actual `<form>` element. We can test it by right-clicking that view's input element from our browser window and selecting **Inspect element**, as shown in the following screenshot:



As we can see, there is no main form, only a single `input` field that perfectly handles the task we've assigned to it. The absence of the form is not missed because we're not submitting anything using FORM DATA: we're performing our data fetching using the Angular `HttpClient` module, which technically does this using an asynchronous **XMLHttpRequest (XHR)** through JavaScript – in one word, **AJAX**.

Such an approach does not require a `<form>` container element to handle the data encoding and transmission tasks using the following supported methods:

- `application/x-www-form-urlencoded`
- `multipart/form-data`
- `text/plain`

It only needs the actual input elements to get the user's input.

For further details regarding the encoding method supported by the HTML `<form>` element, take a look at the following specifications:

URL Living Standard, – URL-encoded Form Data: <https://url.spec.whatwg.org/#concept-urlencoded>.



HTML Living Standard, section 4.10.21.7 – Multipart Form

Data: <https://html.spec.whatwg.org/multipage/form-control-infrastructure.html#multipart-form-data>.

HTML Living Standard, section 4.10.21.8 – Plain Text Form

Data: <https://html.spec.whatwg.org/multipage/form-control-infrastructure.html#plain-text-form-data>.

Although not required, a `form` element – or any HTML container for our input elements – might be very useful for a number of important tasks that don't fall into the data encoding and transmission subjects. Let's see what they are and why we may need them.

Reasons to use forms

Let's try to summarize the most blatant shortages of our current formless approach:

- We cannot keep track of the global form state since there's no way we can tell whether the input text is valid or not.
- We have no easy way to display an error message to the users to let them know what they have to do to make the form valid.
- We don't verify the input data in any way; we just collect and toss it to the server without thinking twice.

That's absolutely fine in our specific scenario since we're only dealing with a single text string and we don't care too much about its length, the input text, and so on. However, if we have to deal with multiple input elements and several value types, such limitations could seriously hinder our work – in terms of either data flow control, data validation, and user experience.

Sure, we could easily work around most of the aforementioned issues by implementing some custom methods within our form-based *Components*; we could throw some errors such as `isValid()`, `isNumber()`, and so on here and there, and then hook them up to our template syntax and show/hide the validation messages with the help of structural directives such as `*ngIf`, `*ngFor`, and the like. However, it will definitely be a horrible way to address our problem; we didn't choose a feature-rich client-side framework such as Angular to work that way.

Luckily enough, we have no reason to do that since Angular provides us with a couple of alternative strategies to deal with these common form-related scenarios:

- **Template-Driven Forms**
- **Model-Driven Forms**, also known as **Reactive Forms**

Both of them are highly coupled with the framework and thus extremely viable; they both belong to the `@angular/forms` library and also share a common set of form control classes. However, they also have their own specific sets of features, along with their pros and cons, which can ultimately lead us to choosing one of them.

Let's try to quickly summarize these differences.

Template-Driven Forms

If you've come from AngularJS, there's a high chance that the Template-Driven approach will ring a bell or two. As the name implies, Template-Driven Forms host most of the logic in the template code; working with a Template-Driven Form means to build the form in the `.html` template file, bind data to the various input fields using an `ngModel` instance, and use a dedicated `ngForm` object related to the whole form and containing all the inputs, with each being accessible through their name, to perform the required validity checks.

To understand this, here's what a Template-Driven Form looks like:

```
<form novalidate autocomplete="off" #form="ngForm"
      (ngSubmit)="onSubmit(form)">
  <input type="text" name="name" value="" required
         placeholder="Insert the city name..." 
         [(ngModel)]="city.Name" #title="ngModel"
  />

  <span *ngIf="(name.touched || name.dirty) &&
    name.errors?.required">
    Name is a required field: please enter a valid city name.
  </span>
</form>
```

```
</span>

<button type="submit" name="btnSubmit"
[disabled]="form.invalid">
  Submit
</button>

</form>
```

As we can see, we can access any element, including the form itself, with some convenient aliases – the attributes with the # sign – and check for their current states to create our own validation workflow. These states are provided by the framework and will change in real-time, depending on various things: `touched`, for example, becomes `True` when the control has been visited at least once; `dirty`, which is the opposite of `pristine`, means that the control value has changed, and so on. We used both of them in the preceding example because we want our validation message to only be shown if the user moves their focus to the `<input name="name">` and then goes away, leaving it blank by either deleting its value or not setting it.

These are Template-Driven Forms in a nutshell; now that we've had an overall look at them, let's try to summarize the pros and cons of this approach.

The pros

Here are the main advantages of Template-Driven Forms:

- **Template-Driven Forms are very easy to write.** We can recycle most of our HTML knowledge (assuming that we have any). On top of that, if we came from AngularJS, we already know how well we can make them work once we've mastered the technique.
- **They are rather easy to read and understand,** at least from an HTML point of view; we have a plain, understandable HTML structure containing all the input fields and validators, one after another. Each element will have a name, a two-way binding with the underlying `ngModel`, and (possibly) Template-Driven logic built upon aliases that have been hooked to other elements that we can also see, or to the form itself.

The cons

Here are their weaknesses:

- **Template-Driven Forms require a lot of HTML code**, which can be rather difficult to maintain and is generally more error-prone than pure TypeScript.
- For the same reason, **these forms cannot be unit tested**. We have no way to test their validators or to ensure that the logic we implemented will work, other than running an end-to-end test with our browser, which is hardly ideal for complex forms.
- **Their readability will quickly drop** as we add more and more validators and input tags. Keeping all their logic within the template might be fine for small forms, but it doesn't scale well when dealing with complex data items.

Ultimately, we can say that Template-Driven Forms might be the way to go when we need to build small forms with simple data validation rules, where we can benefit more from their simplicity. On top of that, they are quite similar to the typical HTML code we're already used to (assuming that we do have a plain HTML development background): we just need to learn how to decorate the standard `<form>` and `<input>` elements with aliases and throw in some validators handled by structural directives such as the ones we've already seen, and we'll be set in (almost) no time.



For additional information on Template-Driven Forms, we highly recommend that you read the official Angular documentation at <https://angular.io/guide/forms>.

That being said, the lack of unit testing, the HTML code bloat that they will eventually produce, and the scaling difficulties will eventually lead us toward an alternative approach for any non-trivial form.

Model-Driven/Reactive Forms

The Model-Driven approach was specifically added in Angular 2+ to address the known limitations of Template-Driven Forms. The forms that are implemented with this alternative method are known as **Model-Driven Forms** or Reactive Forms, which are the exact same thing.

The main difference here is that (almost) nothing happens in the template, which acts as a mere reference to a more complex TypeScript object that gets defined, instantiated, and configured programmatically within the Component class: the form **model**.

To understand the overall concept, let's try to rewrite the previous form in a Model-Driven/Reactive way (the relevant parts are highlighted). The outcome of doing this is as follows:

```
<form [formGroup]="form" (ngSubmit)="onSubmit()">

    <input formControlName="name" required />

    <span *ngIf="(form.get('name').touched || form.get('name').dirty)
      && form.get('name').errors?.required">
        Name is a required field: please enter a valid city name.
    </span>

    <button type="submit" name="btnSubmit"
      [disabled]="form.invalid">
        Submit
    </button>

</form>
```

As we can see, the amount of required code is much lower.

Here's the underlying form model that we will define in the Component class file (the relevant parts are highlighted in the following code):

```
import { FormGroup, FormControl } from '@angular/forms';

class ModelFormComponent implements OnInit {
    form: FormGroup;

    ngOnInit() {
        this.form = new FormGroup({
            title: new FormControl()
        });
    }
}
```

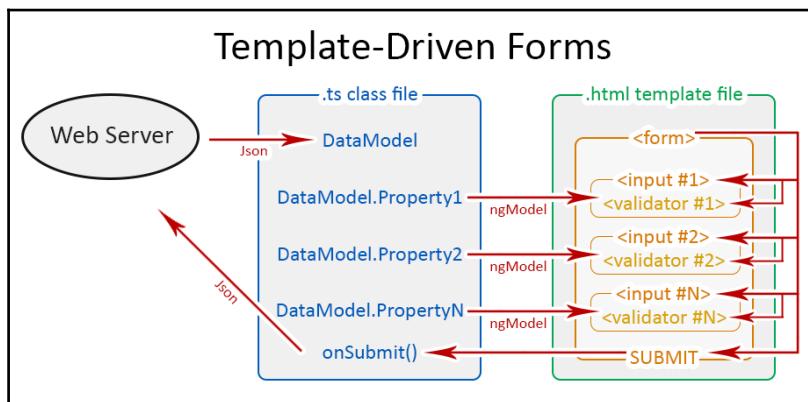
Let's try to understand what's happening here:

- The `form` property is an instance of `FormGroup` and represents the form itself.
- `FormGroup`, as the name suggests, is a container of form controls sharing the same purpose. As we can see, the `form` itself acts as a `FormGroup`, which means that we can nest `FormGroup` objects inside other `FormGroup`s (we didn't do that in our sample, though).
- Each data input element in the form template – in the preceding code, `name` – is represented by an instance of `FormControl`.
- Each `FormControl` instance encapsulates the related control's current state, such as `valid`, `invalid`, `touched`, and `dirty`, including its actual value.
- Each `FormGroup` instance encapsulates the state of each child control, meaning that it will only be valid if/when all its children are also valid.

Also, note that we have no way of accessing the `FormControls` directly, like we were doing in Template-Driven Forms; we have to retrieve them using the `.get()` method of the main `FormGroup`, which is the `form` itself.

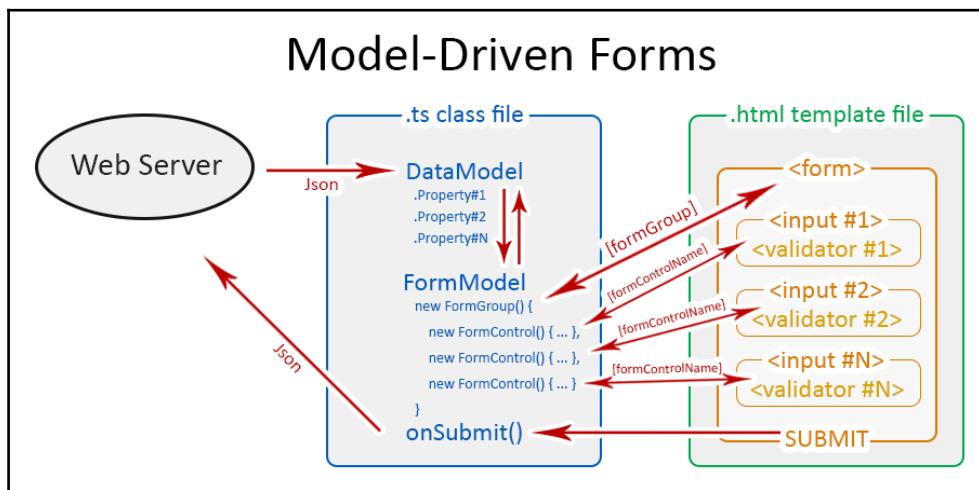
At first glance, the Model-Driven template doesn't seem too different from the Template-Driven one; we still have a `<form>` element, an `<input>` element hooked to a `` validator, and a `submit` button; on top of that, checking the state of the input elements takes a bigger amount of source code since they have no aliases we can use. What's the real deal, then?

To help us visualize the difference, let's look at the following diagrams; here's a schema depicting how **Template-Driven Forms** work:



By looking at the arrows, we can easily see that, in **Template-Driven Forms**, everything happens in the template; the HTML form elements are directly bound to the **DataModel** Component represented by a property filled with an asynchronous HTML request to the **Web Server**, much like we did with our cities and country table. That **DataModel** will be updated as soon as the user changes something, that is, unless a validator prevents them from doing that. If we think about it, we can easily understand how there isn't a single part of the whole workflow that happens to be under our control; Angular handles everything by itself using the information in the data bindings defined within our template. This is what *Template-Driven* actually means: the template is calling the shots.

Now, let's take a look at the **Model-Driven Forms** (or Reactive Forms) approach:



As we can see, the arrows depicting the **Model-Driven Forms** workflow tell a whole different story. They show how the data flows between the **DataModel** Component – which we get from the **Web Server** – and a UI-oriented form model that retains the states and the values of the HTML form (and its children input elements) that are presented to the user. This means that we'll be able to get in between the data and the form control objects and perform a number of tasks firsthand: push and pull data, detect and react to user changes, implement our own validation logic, perform unit tests, and so on.

Instead of being superseded by a template that's not under our control, we can track and influence the workflow programmatically since the form model that calls the shots is also a TypeScript class; that's what Model-Driven Forms are about. This also explains why they are also called **Reactive Forms** – an explicit reference to the Reactive programming style that favors explicit data handling and change management throughout the workflow.



For additional information on Model-Driven/Reactive Forms, we highly recommend reading the official Angular documentation at <https://angular.io/guide/reactive-forms>.

Enough with the theory; it's time to empower our Components with some Reactive Forms.

Building our first Reactive Form

In this section, we'll create our first Reactive Form. More specifically, we're going to build a `CityEditComponent` that will give our users the chance to edit an existing *city* record.

To do that, we'll do the following:

- Add a reference to the `ReactiveFormsModule` to our `AppModule` class.
- Create the `CityEditComponent` TypeScript and template files.

ReactiveFormsModule

The first thing we have to do to start working with Reactive Forms is add a reference to the `ReactiveFormsModule` in the `AppModule` class.

From **Solution Explorer**, open the `/ClientApp/src/app/app.module.ts` file and add the following code (the updated source code is highlighted):

```
import { BrowserModule } from '@angular/platform-browser';
import { NgModule } from '@angular/core';
import { FormsModule } from '@angular/forms';
import { HttpClientModule, HTTP_INTERCEPTORS } from
  '@angular/common/http';
import { RouterModule } from '@angular/router';
```

```
import { AppComponent } from './app.component';
import { NavMenuComponent } from './nav-menu/nav-menu.component';
import { HomeComponent } from './home/home.component';
import { CitiesComponent } from './cities/cities.component';
import { CountriesComponent } from './countries/countries.component';
import { BrowserAnimationsModule } from '@angular/platform-browser/animations';
import { AngularMaterialModule } from './angular-material.module';
import { FormControl, ReactiveFormsModule } from '@angular/forms';

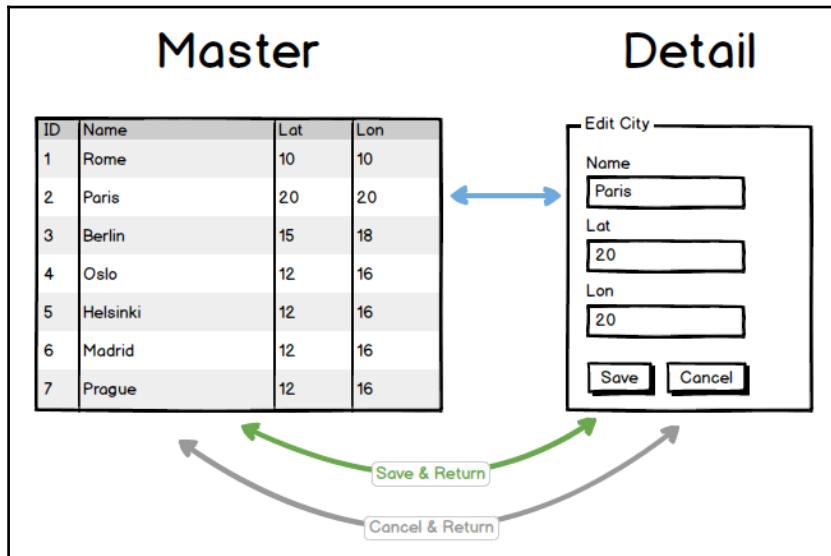
@NgModule({
  declarations: [
    AppComponent,
    NavMenuComponent,
    HomeComponent,
    CitiesComponent,
    CountriesComponent
  ],
  imports: [
    BrowserModule.withServerTransition({ appId: 'ng-cli-universal' }),
    HttpClientModule,
    FormsModule,
    RouterModule.forRoot([
      { path: '', component: HomeComponent, pathMatch: 'full' },
      { path: 'cities', component: CitiesComponent },
      { path: 'countries', component: CountriesComponent }
    ]),
    BrowserAnimationsModule,
    AngularMaterialModule,
    ReactiveFormsModule
  ],
  providers: [],
  bootstrap: [AppComponent]
})
export class AppModule { }
```

Now that we've added a reference to the `ReactiveFormsModule` in our app's `AppModule` file, we can implement the Angular Component that will host the actual form.

CityEditComponent

Since our CityEditComponent is meant to allow our users to modify a city, we'll need to let it know which city it has to fetch from (and send to) the server. The best way to do that is by using a GET parameter, such as the city id.

Therefore, we're going to implement a standard **Master/Detail** UI pattern, much like the following one:



Sounds like a plan: let's do it!

From the **Solution Explorer** of our `WorldCities` project, do the following:

1. Navigate to the `/ClientApp/src/app/cities` folder.
2. Right-click the folder's name and select **Add | New Item** three times to create the following files:
 - `city-edit.component.ts`
 - `city-edit.component.html`
 - `city-edit.component.css`

We know what we're doing here due to what we learned about in Chapter 3, *Front-end and Back-end Interaction*: we're creating a new Angular Component.

city-edit.component.ts

Once you're done, open the three new (and empty) files and fill them with the following code.

The following is the source code for the /ClientApp/src/app/cities/city-edit.component.ts file:

```
import { Component, Inject } from '@angular/core';
import { HttpClient } from '@angular/common/http';
import { ActivatedRoute, Router } from '@angular/router';
import { FormGroup, FormControl } from '@angular/forms';

import { City } from './City';

@Component({
  selector: 'app-city-edit',
  templateUrl: './city-edit.component.html',
  styleUrls: ['./city-edit.component.css']
})
export class CityEditComponent {

  // the view title
  title: string;

  // the form model
  form: FormGroup;

  // the city object to edit
  city: City;

  constructor(
    private activatedRoute: ActivatedRoute,
    private router: Router,
    private http: HttpClient,
    @Inject('BASE_URL') private baseUrl: string) {
  }

  ngOnInit() {
    this.form = new FormGroup({
      name: new FormControl(''),
      lat: new FormControl(''),
      lon: new FormControl('')
    });
  }

  loadData() {
```

```
// retrieve the ID from the 'id' parameter
var id = +this.activatedRoute.snapshot.paramMap.get('id');

// fetch the city from the server
var url = this.baseUrl + "api/cities/" + id;
this.http.get<City>(url).subscribe(result => {
  this.city = result;
  this.title = "Edit - " + this.city.name;

  // update the form with the city value
  this.form.patchValue(this.city);
}, error => console.error(error));
}

onSubmit() {

  var city = this.city;

  city.name = this.form.get("name").value;
  city.lat = +this.form.get("lat").value;
  city.lon = +this.form.get("lon").value;

  var url = this.baseUrl + "api/cities/" + this.city.id;
  this.http
    .put<City>(url, city)
    .subscribe(result => {

      console.log("City " + city.id + " has been updated.");

      // go back to cities view
      this.router.navigate(['/cities']);
    }, error => console.log(error));
}
}
```

This is a fair amount of source code: luckily enough, there are a lot of comments that should help us understand the purpose of each relevant step.

Let's try to summarize what we did here:

- We added some `import` references to the modules we're about to use within this class: among them, we can see a couple of new kids on the block: `@angular/router` and `@angular/form`. The former is required to define some internal routing patterns, while the latter contains the `FormGroup` and `FormControl` classes that we need in order to build our form.

- Right below the class definition, we created a `FormGroup` instance within a `form` variable: that's our form model.
- The `form` variable instance contains three `FormControl` objects that will store the `city` values we want to allow our users to change: `name`, `lat`, and `lon`. We don't want to make them change the `Id` or the `CountryId` – at least, not for now.
- Right below the `form` variable, we defined a `city` variable that will host the actual city when we retrieve it from the database.
- The city retrieval task is handled by the `loadData()` method, which is rather similar to the one we implemented in the `cities.component.ts` file: a standard data-fetching task handled by a `HttpClient` module that's injected (as usual) by the `constructor()`. The most relevant difference here is that the method, right after the HTTP request/response cycle, proactively loads the retrieved city data within the form model (by using the form's `patchValue()` method) instead of relying to the Angular data-binding feature: that's hardly a surprise since we're using the Model-Driven/Reactive approach and not the Template-Driven one.
- The `onSubmit()` method is where the update magic takes place: `HttpClient` plays a major role here as well by issuing a PUT request to the server sending the `city` variable properly. Once the `Observable` subscription has been processed, we use the `router` instance to redirect the user back to the `CitiesComponent` (the *Master* view).



The `patchValue()` method that we used previously is one of a few more words. The `@angular/forms` package gives us two ways to update a Reactive Form's model: the `setValue()` method, which sets a new value for each individual control, and the `patchValue()` method, which will replace any properties that have been defined in the object that have changed in the form model. The main difference between them is that `setValue()` performs a strict check of the source object and will throw errors if it doesn't fully adhere to the model structure (including all nested `FormControl` elements), while `patchValue()` will silently fail on those errors. Therefore, we can say that the former method might be a better choice for complex forms and/or whenever we need to catch nesting errors, while the latter is the way to go when things are simple enough – like in our current samples.

The `@angular/router` package deserves a special mention because it's the first time we have seen it in a Component TypeScript file: we've only used it twice before:

- In the `app.module.ts` file, to define our client-side routing rules
- In the `nav.component.html` file, to implement the aforementioned routing rules and make them appear as navigation links within the web application's main menu

This time, we had to import it because we needed a way to retrieve the `City id` parameter from the URL. To do this, we used the `ActivatedRoute` interface, which allows us to retrieve information about the currently active route, as well as the `GET` parameter we were looking for.

city-edit.component.html

Here's the content for the `/ClientApp/src/app/cities/city-edit.component.html` template file:

```
<div class="city-edit">
  <h1>{{title}}</h1>

  <p *ngIf="!city"><em>Loading...</em></p>

  <div class="form" [formGroup]="form" (ngSubmit)="onSubmit()">

    <div class="form-group">
      <!--
        <div class="form-group" [ngClass]="{{ 'has-error has-
          feedback' : hasError('name') }}>
      -->

      <label for="name">City name:</label>
      <br />
      <input type="text" id="name"
        formControlName="name" required
        placeholder="City name..." 
        class="form-control" />
      <!--
        <span *ngIf="hasError('name')"
          class="glyphicon glyphicon-remove form-control-
          feedback"
          aria-hidden="true"></span>
      -->
      <div *ngIf="hasError('name')"
        class="help-block">
        Name is a required field: please insert a valid name.
      </div>
    </div>
  </div>
```

```
        </div>
      -->
    </div>

    <div class="form-group">
      <!--
        <div class="form-group" [ngClass]="{{ 'has-error has-
          feedback' : hasError('name') }}">
      -->

        <label for="lat">City latitude:</label>
        <br />
        <input type="text" id="lat"
          formControlName="lat" required
          placeholder="Latitude..." 
          class="form-control" />
      <!--
        <span *ngIf="hasError('lat')"
          class="glyphicon glyphicon-remove form-control-
          feedback"
          aria-hidden="true"></span>
      <div *ngIf="hasError('lat')"
          class="help-block">
          Latitude is a required field: please insert a valid
          latitude value.
        </div>
      -->
    </div>

    <div class="form-group">
      <!--
        <div class="form-group" [ngClass]="{{ 'has-error has-
          feedback' : hasError('name') }}">
      -->

        <label for="lon">City longitude:</label>
        <br />
        <input type="text" id="lon"
          formControlName="lon" required
          placeholder="Latitude..." 
          class="form-control" />
      <!--
        <span *ngIf="hasError('lon')"
          class="glyphicon glyphicon-remove form-control-
          feedback"
          aria-hidden="true"></span>
      <div *ngIf="hasError('lon')"
```

```
        class="help-block">
          Longitude is a required field: please insert a valid
          longitude value.
      </div>
    -->
</div>

<div class="form-group commands">
  <button type="submit"
    (click)="onSubmit()"
    class="btn btn-success">
    Create City
  </button>
  <button type="submit"
    [routerLink]=["'/countries']"
    class="btn btn-default">
    Cancel
  </button>
</div>
</div>
</div>
```

Wait a minute: where's our `<form>` HTML element? Didn't we say that we were working with form-based approaches because they are way better than placing a bunch of separate `<input>` fields here and there?

As a matter of fact, we **do** have a form: we just used a `<div>` rather than the classic `<form>` element. As you may have guessed at this point, forms in Angular don't necessarily have to be created using the `<form>` HTML element, since we won't be using its distinctive features: for that very reason, we are free to define them using `<div>`, `<p>`, or any HTML block-level element that could reasonably contain `<input>` fields.

city-edit.component.css

Last but not least, here's our `/ClientApp/src/app/cities/city-edit.component.css` content:

```
/* empty */
```

Yeah, that's it: we don't need a specific style at the moment, so we'll just leave it empty.

Adding the navigation link

Now that our `CityEditComponent` is ready, we need to enforce our master/detail pattern by adding a navigation link that would allow our users to navigate from our city listing (master) to the city edit form (detail).

To do that, we need to perform two tasks:

- Create a new route within the `app.module.ts` file.
- Implement the preceding route in the template code of `CitiesComponent`.

Let's do this!

app.module.ts

Open the `/ClientApp/src/app/app.module.ts` file and define a new route with the following source code (the new lines are highlighted):

```
import { BrowserModule } from '@angular/platform-browser';
import { NgModule } from '@angular/core';
import { FormsModule } from '@angular/forms';
import { HttpClientModule, HTTP_INTERCEPTORS } from
  '@angular/common/http';
import { RouterModule } from '@angular/router';

import { AppComponent } from './app.component';
import { NavMenuComponent } from './nav-menu/nav-menu.component';
import { HomeComponent } from './home/home.component';
import { CitiesComponent } from './cities/cities.component';
import { CityEditComponent } from './cities/city-edit.component';
import { CountriesComponent } from './countries/countries.component';
import { BrowserAnimationsModule } from '@angular/platform-
browser/animations';
import { AngularMaterialModule } from './angular-material.module';
import { FormControl, ReactiveFormsModule } from '@angular/forms';

@NgModule({
  declarations: [
    AppComponent,
    NavMenuComponent,
    HomeComponent,
    CitiesComponent,
    CityEditComponent,
    CountriesComponent
  ],
  imports: [
    BrowserModule,
    BrowserAnimationsModule,
    HttpClientModule,
    FormsModule,
    ReactiveFormsModule
  ],
  providers: [
    { provide: HTTP_INTERCEPTORS, useClass: JwtInterceptor, multi: true },
    { provide: HTTP_INTERCEPTORS, useClass: ErrorInterceptor, multi: true }
  ]
})
```

```
imports: [
  BrowserModule.withServerTransition({ appId: 'ng-cli-universal' }),
  HttpClientModule,
  FormsModule,
  RouterModule.forRoot([
    { path: '', component: HomeComponent, pathMatch: 'full' },
    { path: 'cities', component: CitiesComponent },
    { path: 'city/:id', component: CityEditComponent },
    { path: 'countries', component: CountriesComponent },
  ]),
  BrowserAnimationsModule,
  AngularMaterialModule,
  ReactiveFormsModule
],
providers: [],
bootstrap: [AppComponent]
})
export class AppModule { }
```

As we can see, we imported the `CityEditComponent`, added it to the `@NgModule` declarations list, and – last but not least – defined a new `city/:id` corresponding to the route. The syntax we used will route any URL composed by `city` and a parameter that will be registered with the `id` name.

cities.component.html

Now that we have the navigation route, we need to implement it within the *Master* view so that the *Detail* view can be reached.

Open the `/ClientApp/src/app/cities/cities.component.html` file and change the HTML template code for the city's Name column in the following way:

```
<!-- ...existing code... -->

<!-- Name Column -->
<ng-container matColumnDef="name">
  <th mat-header-cell *matHeaderCellDef mat-sort-header>Name</th>
  <td mat-cell *matCellDef="let city">
    <a [routerLink]=["'/city', city.id]">{{city.name}}</a>
  </td>
</ng-container>

<!-- ...existing code... -->
```

Once you're done, test it out by hitting *F5* and navigating to the **Cities** view. As shown in the following screenshot, the city names are now clickable links:

ID	Name ↑	Latitude	Longitude
7835	'Ajlūn	32.3333	35.7528
3954	'Ajmān	25.4056	55.4618
51	'Amrān	15.6594	43.9439
4172	25 de Mayo	-37.8	-67.6833
4092	28 de Noviembre	-51.65	-72.3
6377	Aalborg	57.0337	9.9166
5579	Aarau	47.3896	8.0524
5607	Aarau	47.39	8.034
7096	Aasiaat	68.7167	-52.8667
1378	Aba	5.1004	7.35

Items per page: 1 – 10 of 12959 | |

From there, filter the table for `Paris` and click on the first result to access the `CityEditComponent`, which we'll finally be able to see (as shown in the following screenshot):

The screenshot shows a web page titled "WorldCities" with a navigation bar at the top right labeled "Home", "Cities", and "Countries". Below the title, the heading "Edit - Paris" is displayed. The form contains three input fields: "City name:" with the value "Paris", "City latitude:" with the value "48.8667", and "City longitude:" with the value "2.3333". At the bottom of the form are two buttons: a green "Save" button and a white "Cancel" button.

As we can see, everything is much like we would expect it to be. We have three textboxes, a **Save** button, and a **Cancel** button, both of which are ready to perform the task they have been assigned. The former will send the modified text to the server for the update and then redirect the user to the *Master* view, while the latter will redirect the user without performing any change.

That's definitely a good start! However, we're far from done: we still have to add validators, implement error handling, and write a couple of unit tests for the client-side and the server-side. Let's get started.

Adding a new city

Before going any further, let's spend a couple more minutes adding a very useful feature to our `CityEditComponent`: the chance to add a brand-new `City`. This is a rather classic requirement of a *Detail* view with editing capabilities, which can be handled with the same Component – as long as we perform some small modifications to handle the two possible scenarios.

To do that, we'll have to perform the following steps:

1. Extend our **CityEditComponent's functionalities** to make it able to add new cities, as well as edit existing ones.
2. Add a new **Add City button** to our Component's template file and bind it to a new client-side route.
3. Implement the required functionalities to **select a country** for the newly added city, which will also be useful in edit mode (it will allow users to change the country for existing cities).

Let's get to work!

Extending the CityEditComponent

Open the `/ClientApp/src/app/cities/city-edit.component.ts` file and add the following code (the new/updated lines are highlighted):

```
import { Component, Inject } from '@angular/core';
import { HttpClient } from '@angular/common/http';
import { ActivatedRoute, Router } from '@angular/router';
import { FormGroup, FormControl } from '@angular/forms';

import { City } from './City';

@Component({
  selector: 'app-city-edit',
  templateUrl: './city-edit.component.html',
  styleUrls: ['./city-edit.component.css']
})
export class CityEditComponent {

  // the view title
  title: string;

  // the form model
  form: FormGroup;

  // the city object to edit or create
  city: City;

  // the city object id, as fetched from the active route:
  // It's NULL when we're adding a new city,
  // and not NULL when we're editing an existing one.
  id?: number;
```

```
constructor(
  private activatedRoute: ActivatedRoute,
  private router: Router,
  private http: HttpClient,
  @Inject('BASE_URL') private baseUrl: string) {
}

ngOnInit() {
  this.form = new FormGroup({
    name: new FormControl(''),
    lat: new FormControl(''),
    lon: new FormControl('')
  });

  this.loadData();
}

loadData() {

  // retrieve the ID from the 'id'
  this.id = +this.activatedRoute.snapshot.paramMap.get('id');
  if (this.id) {
    // EDIT MODE

    // fetch the city from the server
    var url = this.baseUrl + "api/cities/" + this.id;
    this.http.get<City>(url).subscribe(result => {
      this.city = result;
      this.title = "Edit - " + this.city.name;

      // update the form with the city value
      this.form.patchValue(this.city);
    }, error => console.error(error));
  }
  else {
    // ADD NEW MODE

    this.title = "Create a new City";
  }
}

onSubmit() {

  var city = (this.id) ? this.city : <City>{};

  city.name = this.form.get("name").value;
  city.lat = +this.form.get("lat").value;
```

```
city.lon = +this.form.get("lon").value;

if (this.id) {
    // EDIT mode

    var url = this.baseUrl + "api/cities/" + this.city.id;
    this.http
        .put<City>(url, city)
        .subscribe(result => {

            console.log("City " + city.id + " has been updated.");

            // go back to cities view
            this.router.navigate(['/cities']);
        }, error => console.log(error));
}

else {
    // ADD NEW mode
    var url = this.baseUrl + "api/cities";
    this.http
        .post<City>(url, city)
        .subscribe(result => {

            console.log("City " + result.id + " has been created.");

            // go back to cities view
            this.router.navigate(['/cities']);
        }, error => console.log(error));
}
}
```

The HTML template file may also perform a minor update to notify the user of the new feature.

Open the `/ClientApp/src/app/cities/cities.component.html` file and modify it in the following way (the new/updated lines are highlighted).

Add the following highlighted code near the beginning of the file:

```
<!-- ... existing code ... -->

<p *ngIf="this.id && !city"><em>Loading...</em></p>

<!-- ... existing code ... -->
```

With such an improvement, we'll ensure that the "Loading..." message won't appear when we're adding a new city since the `city` variable will be empty.

Also, add the following highlighted code toward the end of the file:

```
<!-- ... existing code ... -->

<div class="form-group commands">
  <button *ngIf="id" type="submit"
    (click)="onSubmit()"
    class="btn btn-success">
    Save
  </button>
  <button *ngIf="!id" type="submit"
    (click)="onSubmit()"
    class="btn btn-success">
    Create
  </button>
  <button type="submit"
    [routerLink]=["'/cities']"
    class="btn btn-default">
    Cancel
  </button>
</div>

<!-- ... existing code ... -->
```

This minor yet useful addition will let us know if the form is working as expected: whenever we add a new city, we will see a more appropriate **Create** button instead of the **Save** one, which will still be visible in edit mode.

Now, we need to do two things:

1. Find a nice way to let our users know that they can add new cities as well as modify the existing ones.
2. Make them able to access this new feature.

A simple **Add a new City** button will fix both these issues at once: let's add it to our `CitiesComponent`.

Adding the "Add a new City" button

Open the `/ClientApp/src/app/cities.component.html` file and add the following code:

```
<!-- ... existing code ... -->

<h1>Cities</h1>
```

```
<p>Here's a list of cities: feel free to play with it.</p>

<p *ngIf="!cities"><em>Loading...</em></p>

<div class="commands text-right" *ngIf="cities">
  <button type="button"
    [routerLink]="/city"
    class="btn btn-success">
    Add a new City
  </button>
</div>

<!-- ... existing code ... -->
```

Here we go. There's nothing new here; we've added the usual *route-based* button within a container and a `*ngIf` *structural directive* to make it appear after the `cities` array becomes available.

Adding a new route

Now, we need to define the new route that we referenced for the **Add a new City** button.

To do that, open the `/ClientApp/src/app/app.module.ts` file and update the code, as follows:

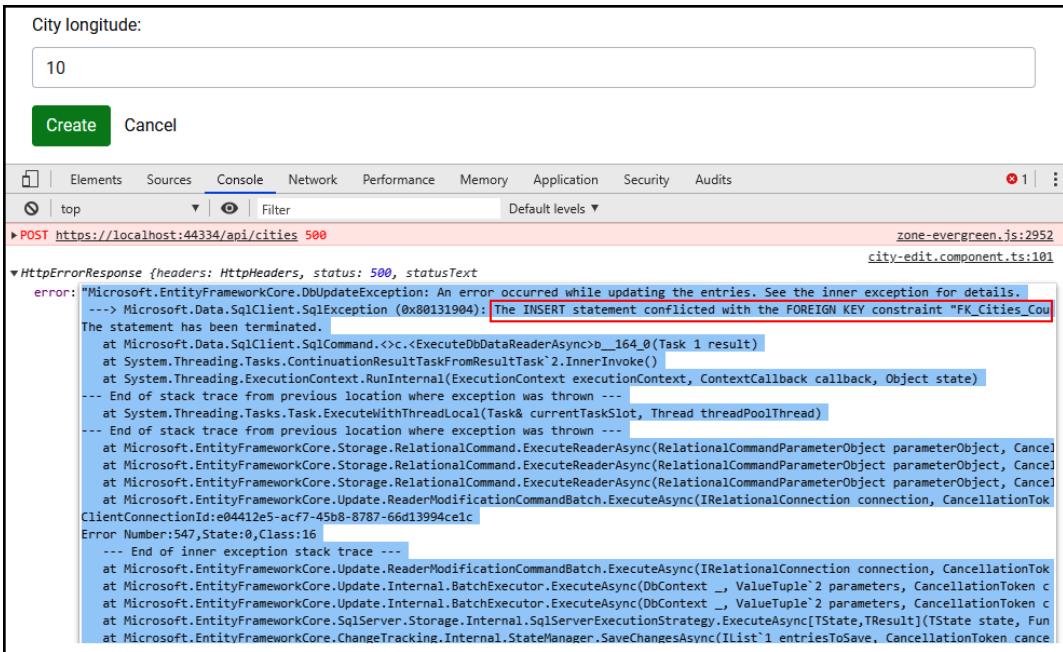
```
// ...existing code...

RouterModule.forRoot([
  { path: '', component: HomeComponent, pathMatch: 'full' },
  { path: 'cities', component: CitiesComponent },
  { path: 'city/:id', component: CityEditComponent },
  { path: 'city', component: CityEditComponent },
  { path: 'countries', component: CountriesComponent },
]),

// ...existing code...
```

As we can see, the (new) route to add a new city and the (existing) route to edit an existing city are very similar since they both redirect the user to the same Component: the only difference is that the latter doesn't have the `id` parameter, which is the technique we used to make our Component aware of which task it has been called for. If the `id` is present, the user is editing an existing city; otherwise, they're adding a new one.

We are doing well... but we're not quite there yet. If we were to test what we've done so far by hitting **F5** and trying to add a new city, our `HttpClient` module would be greeted by an **HTTP 500 - Internal Server Error** from the server, similar to the one shown in the following screenshot:



Here's the full error text (with the relevant parts highlighted):

```
---> Microsoft.Data.SqlClient.SqlException (0x80131904): The INSERT statement conflicted with the FOREIGN KEY constraint "FK_Cities_Countries_CountryId". The conflict occurred in database "WorldCities", table "dbo.Countries", column 'Id'.
The statement has been terminated.
```

It definitely seems like we forgot the `CountryId` property of the `City` entity: we did that on purpose when we had to define the Angular city interface because we didn't need it at that time. We didn't suffer from its absence when we implemented the city edit mode because that property was *silently* fetched from the server and then stored within our Angular local variable, which we were sending back to the server while the HTTP `PUT` request was performing the update. However, now that we do want to create a new city from scratch, such a missing property will eventually take its toll.

To fix this, we need to add the `CountryId` property to the `/ClientApp/src/app/cities/city.ts` file in the following way (the new lines are highlighted):

```
export interface City {  
    id: number;  
    name: string;  
    lat: number;  
    lon: number;  
    countryId: number;  
}
```

However, this won't be enough: we also need to give our users the chance to assign a specific `Country` to the new city; otherwise, the `countryId` property will never see an actual value – unless we define it programmatically with a fixed value, which would be a rather ugly workaround (to say the least).

Let's fix this in a decent way by adding a list of countries to `CityEditComponent` so that the user will be able to select one before hitting the `Create` button. Such a new feature will be very useful – even when the Component runs in edit mode – since it will allow our users to change the country for existing cities.

HTML select

The easiest way to allow our users to pick a country from a list of countries would be to use a `<select>` element and populate it by fetching our data from the .NET *backend* via the `CountriesController`'s `GetCountries()` method. Let's do that now.

Open the `/ClientApp/src/app/cities/city-edit.component.ts` file and add the following code (the new lines are highlighted):

```
import { Component, Inject } from '@angular/core';  
import { HttpClient, HttpParams } from '@angular/common/http';  
import { ActivatedRoute, Router } from '@angular/router';  
import { FormGroup, FormControl } from '@angular/forms';  
  
import { City } from './City';  
import { Country } from '../../countries/Country';  
  
@Component({  
    selector: 'app-city-edit',  
    templateUrl: './city-edit.component.html',  
    styleUrls: ['./city-edit.component.css']  
})
```

```
export class CityEditComponent {

    // the view title
    title: string;

    // the form model
    form: FormGroup;

    // the city object to edit or create
    city: City;

    // the city object id, as fetched from the active route:
    // It's NULL when we're adding a new city,
    // and not NULL when we're editing an existing one.
    id?: number;

    // the countries array for the select
    countries: Country[];

    constructor(
        private activatedRoute: ActivatedRoute,
        private router: Router,
        private http: HttpClient,
        @Inject('BASE_URL') private baseUrl: string) {
    }

    ngOnInit() {
        this.form = new FormGroup({
            name: new FormControl(''),
            lat: new FormControl(''),
            lon: new FormControl(''),
            countryId: new FormControl('')
        });
        this.loadData();
    }

    loadData() {

        // load countries
        this.loadCountries();

        // retrieve the ID from the 'id'
        this.id = +this.activatedRoute.snapshot.paramMap.get('id');
        if (this.id) {
            // EDIT MODE

            // fetch the city from the server
        }
    }
}
```

```
var url = this.baseUrl + "api/cities/" + this.id;
this.http.get<City>(url).subscribe(result => {
    this.city = result;
    this.title = "Edit - " + this.city.name;

    // update the form with the city value
    this.form.patchValue(this.city);
}, error => console.error(error));
}

else {
    // ADD NEW MODE

    this.title = "Create a new City";
}
}

loadCountries() {
    // fetch all the countries from the server
    var url = this.baseUrl + "api/countries";
    var params = new HttpParams()
        .set("pageSize", "9999")
        .set("sortColumn", "name");

    this.http.get<any>(url, { params }).subscribe(result => {
        this.countries = result.data;
    }, error => console.error(error));
}

onSubmit() {

    var city = (this.id) ? this.city : <City>{};

    city.name = this.form.get("name").value;
    city.lat = +this.form.get("lat").value;
    city.lon = +this.form.get("lon").value;
    city.countryId = +this.form.get("countryId").value;

    if (this.id) {
        // EDIT mode

        var url = this.baseUrl + "api/cities/" + this.city.id;
        this.http
            .put<City>(url, city)
            .subscribe(result => {

                console.log("City " + city.id + " has been updated.");
                // go back to cities view
            });
    }
}
```

```
        this.router.navigate(['/cities']);
    }, error => console.log(error));
}
else {
    // ADD NEW mode
    var url = this.baseUrl + "api/cities";
    this.http
        .post<City>(url, city)
        .subscribe(result => {

            console.log("City " + result.id + " has been created.");

            // go back to cities view
            this.router.navigate(['/cities']);
        }, error => console.log(error));
}
}
```

What did we do here?

- We added the `HttpParams` module to the `import` list of `@angular/common/http`.
- We added a reference to our `Country` interface since we need to handle countries as well.
- We added a `countries` variable to store our countries.
- We added a `countryId` form control (with a required validator, since it's a required value) to our form.
- We added a `loadCountries()` method to fetch the countries from the server.
- We added a call to the `loadCountries()` method from the `loadData()` method so that we'll asynchronously fetch the countries while we do the rest of the `loadData()` stuff (such as loading the city and/or setting up the form).
- We updated the city's `countryId` so that it matches the one that's selected in the form in the `onSubmit()` method so that it will be sent to the server for the insert or update task.



It's worth noting how, in the `loadCountries()` method, we had to set up some GET parameters for the `/api/countries` URL to comply with the strict default values that we set in Chapter 5, *Fetching and Displaying Data*: we don't need paging here since we need to fetch the entire countries list to populate our select list. More specifically, we set a `pageSize` of `9999` to ensure that we get all our countries, as well as an appropriate `sortColumn` to have them ordered by their name.

Now, we can use our brand-new `countries` variable on our HTML template.

Open the `/ClientApp/src/app/cities/city-edit.component.html` file and add the following code (the new lines are highlighted):

```
<!-- ...existing code... -->

<div class="form-group">
  <label for="lon">City longitude:</label>
  <br />
  <input type="text" id="lon"
    formControlName="lon" required
    placeholder="Latitude..." 
    class="form-control" />
</div>

<div class="form-group" *ngIf="countries">
  <label for="lon">Country:</label>
  <br />
  <select id="countryId" class="form-control"
    formControlName="countryId">
    <option value=""--- Select a country ---</option>
    <option *ngFor="let country of countries" [value]="country.id">
      {{country.name}}
    </option>
  </select>
</div>

<!-- ...existing code... -->
```

If we press *F5* to test our code and navigate to the **Add a new City or Edit City** view, we'll see the following output:

The screenshot shows a web application interface titled "WorldCities". At the top right, there are navigation links: "Home", "Cities", and "Countries". The main content area has a title "Create a new City". Below the title are four input fields with labels: "City name:", "City latitude:", "City longitude:", and "Country:". The "Country:" field is a dropdown menu with the placeholder "-- Select a country --". At the bottom of the form are two buttons: a green "Create" button and a white "Cancel" button.

Now, by clicking the **-- Select a country --** select list, our users will be able to pick a country from the ones that are available. That's not bad, right?

However, we can do even better: we can improve the user experience of our view by replacing our standard HTML `select` with a more powerful Component from the **Angular Material** package library: `MatSelectModule`.

Angular material select (`MatSelectModule`)

Since we've never used `MatSelectModule` before, we need to add it to the `/ClientApp/src/app/angular-material.component.ts` file, just like we did for `MatPaginatorModule`, `MatSortModule`, and `MatInputModule` back in [Chapter 5, *Fetching and Displaying Data*](#).

Here's how to do that (the new lines are highlighted):

```
import { NgModule } from '@angular/core';
import { MatTableModule } from '@angular/material/table';
```

```
import { MatPaginatorModule } from '@angular/material/paginator';
import { MatSortModule } from '@angular/material/sort';
import { MatInputModule } from '@angular/material/input';
import { MatSelectModule } from '@angular/material/select';

@NgModule({
  imports: [
    MatTableModule,
    MatPaginatorModule,
    MatSortModule,
    MatInputModule,
    MatSelectModule
  ],
  exports: [
    MatTableModule,
    MatPaginatorModule,
    MatSortModule,
    MatInputModule,
    MatSelectModule
  ]
})
export class AngularMaterialModule {}
```

Right after that, we can replace the <select> HTML element we added to the /ClientApp/src/app/cities/city-edit.component.ts file a short while ago in the following way (the updated lines are highlighted):

```
<!-- ...existing code... -->

<div class="form-group">
  <label for="lon">Country:</label>
  <br />
  <mat-form-field *ngIf="countries">
    <mat-label>Select a Country...</mat-label>
    <mat-select id="countryId" formControlName="countryId">
      <mat-option *ngFor="let country of countries"
        [value]="country.id">
        {{country.name}}
      </mat-option>
    </mat-select>
  </mat-form-field>
</div>

<!-- ...existing code... -->
```

And that's it! We can see the updated result by hitting *F5* (see the following screenshot for the output):

The screenshot shows a web page titled "WorldCities" with a navigation bar at the top. The main content area has a title "Create a new City". It contains four input fields: "City name:" with a placeholder "City name...", "City latitude:" with a placeholder "Latitude...", "City longitude:" with a placeholder "Latitude...", and a dropdown menu for "Country" with the option "Select a Country...". At the bottom are two buttons: a green "Create" button and a "Cancel" button.

The MatSelectModule is definitely prettier than the stock `<select>` HTML element, all while retaining the same features: we don't even need to change the underlying Component class file since it uses the same binding interface.

Now, we can add our brand-new city to our database. Let's do this using the following data:

- **Name:** New Tokyo
- **Latitude:** 35.685
- **Longitude:** 139.7514
- **Country:** Japan

Fill in our Create a new City form with these values and click the **Create** button. If everything went well, we should be brought back to the **Cities** view, where we'll be able to find our New Tokyo city using the filter (see the following screenshot):

The screenshot shows a web application interface for managing cities. At the top, there's a navigation bar with the title "WorldCities" and links for "Home", "Cities", and "Countries". Below the navigation, the main title "Cities" is displayed in large, bold letters. A sub-instruction "Here's a list of cities: feel free to play with it." is present. On the right side of the page is a green button labeled "Add a new City". Below the button is a search input field with the placeholder "Filter by name (or part of it)...". The search term "New Tokyo" is typed into this field. A horizontal line separates the search area from the table below. The table has four columns: "ID", "Name ↑", "Latitude", and "Longitude". There is one data row shown, which corresponds to the search results. The row contains the ID "13461", the name "New Tokyo" (which is also highlighted in blue), the latitude "35.685", and the longitude "139.7514". At the bottom of the table, there are pagination controls: "Items per page: 10" (with a dropdown arrow), "1 - 1 of 1", and navigation arrows (left, right, first, last). The entire application is contained within a light gray box.

Here we go: we successfully added our first city!

Now that our Reactive Form is working properly and we have decent know-how of how it works, we're ready to spend some time tweaking it by adding something that could be very useful in a production scenario: some error-handling capabilities. We'll obtain these by adding some data validators.

Understanding data validation

Adding data validation to a form is hardly an option: it's a required feature to check the user input in terms of accuracy and completeness to improve the overall data quality by validating the data we want – or need – to collect. It's also very useful in terms of user experience because the error-handling capabilities it comes with will make our users able to understand why the form doesn't work and what they can do to fix the issues preventing them from submitting their data.

To understand such a concept, let's take our current `CityEditComponent` Reactive Form: it's working fine if our users fill all the required fields; however, there's no way for them to understand what the required values actually are, or what happens if they forget to fill all of them out... except for a `console.log` error message, which is what our source code is currently doing whenever our PUT and POST requests end up with a *back-end* error of any sort.

In this section, we'll learn how we can validate user input from the *front-end* UI and display useful validation messages using our current Reactive Form. While we're there, we'll also take the chance to create an `Edit Country/Add new Country` form and learn something new in the process.

Template-driven validation

For the sake of simplicity, we've chosen to not mess around with Template-Driven Forms and bring our focus to Model-Driven/Reactive Forms instead. However, it might be wise to spend a couple of minutes understanding how we can add validation to a Template-Driven Form as well.

The good news about this is that we can use the same standard validation attributes that we would normally use to validate a native HTML form: the Angular framework uses directives to match them with validator functions internally and in a fully transparent way. More specifically, every time the value of a form control changes, Angular will run these functions and generate either a list of validation errors, thus resulting in an invalid status, or null, meaning that the form is valid.

The form's state – as well as each form control's state – can be checked/inspected by exporting `ngModel` to a local template variable. Here's an example that can help clarify this:

```
<input id="name" name="name" class="form-control" required  
minlength="4"  
[(ngModel)]="city.name" #name="ngModel">  
  
<div *ngIf="name.invalid && (name.dirty || name.touched)" class="alert  
alert-danger">  
    <div *ngIf="name.errors?.required">Name is required.</div>  
    <div *ngIf="name.errors?.minlength">Name must be at least 4  
        characters long.</div>  
</div>
```

The *data validation directives* are highlighted in bold. As we can see, the preceding form will raise an error – and show a `<div>` element with an alert style to the user – whenever the city's name is not present or its character count is smaller than 4, since this is the minimum allowed length for the name input.

It's worth noting that we're checking two properties that might sound rather odd: `name.dirty` and `name.touched`. Here's a brief explanation of what they mean and why it's wise to check for their status:

- The `dirty` property starts as being false and becomes true whenever the user changes its starting values.
- The `touched` property starts as being false and becomes true whenever the user blurs the form control element, that is, it goes away from it after having it on focus.

Now that we know how these properties work, we should be able to understand why we are checking them: we want our data validator error to only be seen if/when the user went away from the control, leaving it with an invalid value – or no value at all.



That's it for Template-Driven validation, at least for the purpose of this book. Those who need additional information should check out the following guide at <https://angular.io/guide/forms#template-driven-forms>.

Safe Navigation Operator

Before moving on, it could be useful to spend a couple of minutes explaining the meaning of the `? question mark` that we've been using whenever we need to check for the presence of form errors, such as in the following example, which has been taken from the preceding code:

```
name.errors?.required
```

Such a question mark is Angular's Safe Navigation Operator, also known as the **Elvis Operator**, and is very useful for protecting against null and undefined values in property paths. When the Safe Navigation Operator is present, Angular stops evaluating the expression when it hits the first `null` value. In the preceding code, if `name.errors` is `null`, the whole expression would return `false` without checking the `required` property, thus avoiding the following null-reference exception:

TypeError: Cannot read property 'required' of null.

As a matter of fact, the Safe Navigation Operator makes us able to navigate an object path – even when we are not aware of whether such path exists or not – by returning either the value of the object path (if it exists) or null. Such behavior is perfect if we wish to check for the conditional presence of errors in Angular forms, where a null return value has the same meaning as *false* (= no errors). For this very reason, we're going to use it a lot from now on.



For more information about the **safe navigation operator**, check out the following URL at <https://angular.io/guide/template-syntax#safe-navigation-operator>.

Model-Driven validation

When dealing with Reactive Forms, the whole validation approach is rather different. In a nutshell, we could say that most of this job has to be done within the Component class: instead of adding validators using HTML attributes in the template, we'll have to add validator functions directly to the form control model in the Component class so that Angular will be able to call them whenever the value of the control changes.

Since we'll mostly be dealing with functions, we'll also get the option to make them sync or async, thus getting the chance to add synchronous and/or asynchronous validators:

- **Sync validators** immediately return either a set of validation errors or null. They can be set up using the second argument when we instantiate the `FormControl` they need to check (the first one being the default value).
- **Async validators** return a *Promise* or *Observable* that's been configured to emit a set of validation errors or null. They can be set up using the third argument when we instantiate the `FormControl` they need to check.



It's important to know that `async` validators will only be executed/checked after the `sync` validators, and only if all of them successfully pass. Such an architectural choice has been made for performance reasons.

In the upcoming sections, we'll create both of them and add them to our form.

Our first validators

Enough with the theory: let's add our first set of validators in our CityEditComponent's form.

Open the /ClientApp/src/app/cities/city-edit.component.ts file and add the following code:

```
import { Component, Inject } from '@angular/core';
import { HttpClient, HttpParams } from '@angular/common/http';
import { ActivatedRoute, Router } from '@angular/router';
import { FormGroup, FormControl, Validators } from '@angular/forms';

import { City } from './City';
import { Country } from '../../countries/Country';

@Component({
  selector: 'app-city-edit',
  templateUrl: './city-edit.component.html',
  styleUrls: ['./city-edit.component.css']
})
export class CityEditComponent {

  // the view title
  title: string;

  // the form model
  form: FormGroup;

  // the city object to edit or create
  city: City;

  // the city object id, as fetched from the active route:
  // It's NULL when we're adding a new city,
  // and not NULL when we're editing an existing one.
  id?: number;

  // the countries array for the select
  countries: Country[];

  constructor(
    private activatedRoute: ActivatedRoute,
    private router: Router,
    private http: HttpClient,
    @Inject('BASE_URL') private baseUrl: string) {
  }

  ngOnInit() {
```

```
        this.form = new FormGroup({
            name: new FormControl('', Validators.required),
            lat: new FormControl('', Validators.required),
            lon: new FormControl('', Validators.required),
            countryId: new FormControl('', Validators.required)
        }, null, this.isDupeCity());

        this.loadData();
    }

// ...existing code...
```

As we can see, we added the following:

- An import reference to the `Validators` class from the `@angular/forms` package.
- A `Validators.required` to each of our `FormControl` elements. As the name suggests, such a validator expects a non-null value for these fields; otherwise, it will return an `invalid` status.

`Validators.required` is a built-in sync validator among those available from the `Validators` class. Other built-in validators provided by this class include `min`, `max`, `requiredTrue`, `email`, `minLength`, `maxLength`, `pattern`, `nullValidator`, `compose`, and `composeAsync`.



For more information regarding Angular's built-in validators, take a look at the following URL at <https://angular.io/api/forms/Validators>.

Once you're done, open the `/ClientApp/src/app/cities/city-edit.component.html` file and add the following code:

```
<div class="city-edit">
    <h1>{{title}}</h1>

    <p *ngIf="this.id && !city"><em>Loading...</em></p>

    <div class="form" [formGroup]="form" (ngSubmit)="onSubmit()">
        <div class="form-group">
            <label for="name">City name:</label>
            <br />
            <input type="text" id="name"
                formControlName="name" required
                placeholder="City name...">
        </div>
    </div>
</div>
```

```
        class="form-control"
    />

    <div *ngIf="form.get('name').invalid &&
      (form.get('name').dirty || form.get('name').touched)"
      class="invalid-feedback">
      <div *ngIf="form.get('name').errors?.required">
        Name is required.
      </div>
    </div>
</div>

<div class="form-group">
  <label for="lat">City latitude:</label>
  <br />
  <input type="text" id="lat"
    formControlName="lat" required
    placeholder="Latitude..." 
    class="form-control" />

  <div *ngIf="form.get('lat').invalid &&
    (form.get('lat').dirty || form.get('lat').touched)"
    class="invalid-feedback">
    <div *ngIf="form.get('lat').errors?.required">
      Latitude is required.
    </div>
  </div>
</div>

<div class="form-group">
  <label for="lon">City longitude:</label>
  <br />
  <input type="text" id="lon"
    formControlName="lon" required
    placeholder="Latitude..." 
    class="form-control" />

  <div *ngIf="form.get('lon').invalid &&
    (form.get('lon').dirty || form.get('lon').touched)"
    class="invalid-feedback">
    <div *ngIf="form.get('lon').errors?.required">
      Longitude is required.
    </div>
  </div>
</div>

<div class="form-group">
  <label for="lon">Country:</label>
```

```
<br />
<mat-form-field *ngIf="countries">
  <mat-label>Select a Country...</mat-label>
  <mat-select id="countryId" formControlName="countryId">
    <mat-option *ngFor="let country of countries"
      [value]="country.id">
      {{country.name}}
    </mat-option>
  </mat-select>
</mat-form-field>

<div *ngIf="form.get('countryId').invalid &&
  (form.get('countryId').dirty ||
  form.get('countryId').touched)">
  class="invalid-feedback">
  <div *ngIf="form.get('countryId').errors?.required">
    Please select a Country.
  </div>
</div>
</div>

<div class="form-group commands">
  <button *ngIf="id" type="submit"
    (click)="onSubmit()">
    [disabled]="form.invalid"
    class="btn btn-success">
      Save
  </button>
  <button *ngIf="!id" type="submit"
    (click)="onSubmit()">
    [disabled]="form.invalid"
    class="btn btn-success">
      Create
  </button>
  <button type="submit"
    [routerLink]=["'/cities']"
    class="btn btn-default">
    Cancel
  </button>
</div>
</div>
</div>
```

Here, we added four `<div>` elements (one for each input) to check the input value and conditionally return an error. As we can see, these validators are all working in the same way:

- The first `<div>` (the parent) checks if the `FormControl` is valid or not. It only appears if it's invalid and either dirty or touched so that it won't be shown until the user has had the chance to set it.
- The second `<div>` (the child) checks for the required validator.

We used this approach because we could have multiple validators for each `FormControl`. Therefore, it can be useful to have a separate child element for each of them and a single *parent* element that encompasses them all (`invalid` is set to `true` whenever any of the configured validators doesn't pass).

While we're there, we added a `[disabled]` property bound to the `Create` and `Save` buttons to conditionally disable them whenever the form has an invalid state. This is a great way to prevent the user from submitting wrong or invalid values.

Right after that, open the `/ClientApp/src/app/cities/city-edit.component.css` file and add the following code:

```
input.ng-valid {  
    border-left: 5px solid green;  
}  
  
input.ng-invalid.ng-dirty,  
input.ng-invalid.ng-touched {  
    border-left: 5px solid red;  
}  
  
input.ng-valid ~ .valid-feedback,  
input.ng-invalid ~ .invalid-feedback {  
    display: block;  
}
```

These simple yet powerful styles leverage existing Angular and Bootstrap CSS classes so that they decorate our input fields whenever they have a valid or invalid status.

Let's quickly check everything we've done so far: hit `F5`, navigate to the **Cities** view, click on the `Add a new City` button, and play with the form while trying to trigger the validators.

Here's what happens when we cycle through the various input values without typing anything:

The screenshot shows a web application interface for creating a new city. At the top, there is a navigation bar with the title "WorldCities" and links for "Home", "Cities", and "Countries". Below the navigation, the main content area has a heading "Create a new City". The form contains four input fields: "City name", "City latitude", "City longitude", and "Country". Each field has a placeholder text ("City name...", "Latitude...", "Longitude...", and "Select a Country...") and a red error message below it: "Name is required.", "Latitude is required.", "Longitude is required.", and "Country is required.". At the bottom of the form are two buttons: a green "Create" button and a blue "Cancel" button.

Not bad, right? The input errors couldn't be more visible, and the **Create** button will stay disabled until they are all fixed, thus preventing accidental submits. All of these colored warnings should help our users understand what they're doing wrong and fix these issues.

Before ending our journey on data validation, there's still one topic we need to cover: the server-side validation, which can often be the only reasonable way to prevent some complex errors.

Server-side validation

Server-side validation is the process of checking for errors (and handling them accordingly) on the server side, that is, after the data has been sent to the *back-end*. This is a whole different approach to the **client-side validation**, where the data is being checked by the *front-end*, that is, before the data has been sent to the server.

Handling errors on the *client side* has a lot of advantages in terms of speed and performances because the user immediately knows whether the input data is valid or not without having to query the server. However, *server side* validation is a required feature of any decent web application because it prevents against a lot of potentially harmful scenarios, such as the following:

- **Implementation errors** of the *client-side validation* process, which can fail to block badly-formatted data
- **Client-side hacks** performed by experienced users, browser extensions, or plugins that might want to allow the user to send unsupported input values to the *back-end*
- **Request forgery**, that is, false HTTP requests containing incorrect or malicious data

All of these techniques are based upon circumventing the *client-side validators*, which is always possible because we have no way to prevent our users (or hackers) from skipping, altering, or eliminating them; conversely, *server-side validators* cannot be avoided because they will be performed by the same *back-end* that will process the input data.

Therefore, in a nutshell, we could reasonably say that *client-side validation* is an optional and convenient feature, while *server-side validation* is a requirement for any decent web application that cares about the quality of the input data.



To avoid confusion, it is important to understand that *server-side validation*, although being implemented on the *back-end*, also requires a *front-end* implementation, such as calling the *back-end* and then showing the validation results to the user. The main difference between *client-side validation* and *server-side validation* is that the former only exists on the client-side and never calls the *back-end*, while the latter relies upon a *front-end + back-end* coordinated effort, thus being more complex to implement and test.

Moreover, there are some scenarios where server-side validation is the only possible way to check for certain conditions or requirements that cannot be verified by *client-side* validation alone. To explain this concept, let's look at a quick example.

Launch our `WorldCities` app in *debug* mode by hitting `F5`, go to our **Cities** view, and type `paris` into the filter textbox.

You should see the following output:

The screenshot shows a web application interface for managing cities. At the top, there's a navigation bar with links for 'Home', 'Cities', and 'Countries'. The main title is 'WorldCities' and the current section is 'Cities'. Below the title, there's a heading 'Cities' and a sub-instruction 'Here's a list of cities: feel free to play with it.' To the right of the instruction is a green button labeled 'Add a new City'. Below the button is a search input field with the placeholder 'Filter by name (or part of it)...' and the word 'paris' typed into it. A horizontal line separates the search area from the table below. The table has four columns: 'ID', 'Name ↑', 'Latitude', and 'Longitude'. It contains five rows of data, each representing a city with the name 'Paris':

ID	Name ↑	Latitude	Longitude
6736	Paris	48.8667	2.3333
9270	Paris	33.6689	-95.5462
9625	Paris	36.2934	-88.3065
11089	Paris	39.6148	-87.6904
12817	Paris	38.2015	-84.2717

At the bottom of the table, there's a pagination control with the text 'Items per page: 10' followed by a dropdown arrow, the text '1 – 5 of 5', and a set of navigation arrows (less than, greater than, first, last).

The preceding screenshot tells us the following things:

- There are at least *five* cities called `Paris` all over the world. (!)
- Multiple cities can have the same identical name.

That's not surprising: when we created our database using Entity Framework with *code-first*, we didn't make the `name` field *unique* since we knew that there could be a high chance of *homonymous* cities. Luckily enough, this isn't an issue since we can still distinguish them by looking at the `lat`, `lon`, and `country` values.



For example, if we check the first three on **Google Maps**, we will see that the first one is in *France*, the second is in *Texas (US)*, and the third is in *Tennessee (US)*. Same name, different cities.

Now, what about adding a *validator* that could check if the city we are trying to add has the same name, `lat`, and `lon` values as a city already present in our database? Such a feature would block our users from inserting the same identical city multiple times, thus avoiding real duplicates, without blocking the *homonyms* that have different coordinates.

Unfortunately, there's no way to do that on the *client-side* only. To fulfill this task, we would need to create an Angular *custom validator* that could *asynchronously* check these values against the *server* and then return an *OK (valid)* or *KO (invalid)* result: in other words, a *server-side validation* task.

Let's try to do that now.

DupeCityValidator

In this section, we'll create a custom validator that will perform an asynchronous call to our .NET Core *back-end* to ensure that the *city* we're trying to add doesn't have the same name, `lat`, `lon`, and `country` as an existing one.

city-edit.component.ts

The first thing we have to do is create the validator itself and bind it to our Reactive Form. To do that, open the `/ClientApp/src/app/cities/city-edit.component.ts` file and change its contents accordingly (the new/updated lines are highlighted):

```
import { Component, Inject } from '@angular/core';
import { HttpClient, HttpParams } from '@angular/common/http';
import { ActivatedRoute, Router } from '@angular/router';
import { FormGroup, FormControl, Validators, AbstractControl,
  AsyncValidatorFn } from '@angular/forms';
import { Observable } from 'rxjs';
import { map } from 'rxjs/operators';

import { City } from './City';
import { Country } from '../../countries/Country';

// ...existing code...
```

```
ngOnInit() {
    this.form = new FormGroup({
        name: new FormControl('', Validators.required),
        lat: new FormControl('', Validators.required),
        lon: new FormControl('', Validators.required),
        countryId: new FormControl('', Validators.required)
    }, null, this.isDupeCity());

    this.loadData();
}

// ...existing code...

isDupeCity(): AsyncValidatorFn {
    return (control: AbstractControl): Observable<{ [key: string]: any } | null> => {

        var city = <City>{};
        city.id = (this.id) ? this.id : 0;
        city.name = this.form.get("name").value;
        city.lat = +this.form.get("lat").value;
        city.lon = +this.form.get("lon").value;
        city.countryId = +this.form.get("countryId").value;

        var url = this.baseUrl + "api/cities/IsDupeCity";
        return this.http.post<boolean>(url, city).pipe(map(result => {

            return (result ? { isDupeCity: true } : null);
        }));
    }
}
}
```

As we can see, we make some important changes in the preceding code:

- We added some *import* references (`AbstractControl`, `AsyncValidatorFn`, `Observable`, and `map`) that we used to implement our new async custom validator. If you don't get what we need them for, don't worry: we'll be talking about this topic later on.
- We created a new `isDupeCity()` method, which contains the whole implementation of our async custom validator.
- We configured the new validator to be used by the main `FormGroup` (the one related to the whole form).

As for our custom validator, it seems way more complex than it actually is. Let's try to summarize what it does:

- The first thing worth mentioning is that the function is defined as an `AsyncValidatorFn` that returns an `Observable`: this means that we're not returning a value but a *subscriber function instance* that will eventually return a value – which will be either a *key/value* object or `null`. Such a value will only be *emitted* when the `Observable` is executed.
- The *inner function* creates a temporary `city` object, fills it with the real-time form data, calls a `IsDupeCity` *back-end* URL that we don't know yet (but we will soon enough), and eventually returns either `true` or `null`, depending on the result. It's worth noting that we're not *subscribing* to the `HttpClient` this time, like we often did in the past: we're manipulating it using the `pipe` and `map` *ReactJS (RxJS)* operators, which we'll be talking about in a short while.



For more information regarding *custom async validators*, read the following guide at <https://angular.io/guide/form-validation#implementing-custom-async-validator>.

Since our custom validator relies on a HTTP request being sent to our .NET Core *back-end*, we need to implement that method as well.

CitiesController

Open the `/Controllers/CitiesController.cs` file and add the following method at the bottom of the file:

```
// ...existing code...

private bool CityExists(int id)
{
    return _context.Cities.Any(e => e.Id == id);
}

[HttpPost]
[Route("IsDupeCity")]
public bool IsDupeCity(City city)
{
    return _context.Cities.Any(
        e => e.Name == city.Name
        && e.Lat == city.Lat
        && e.Lon == city.Lon
```

```
    && e.CountryId == city.CountryId  
    && e.Id != city.Id  
);  
  
// ...existing code...
```

The .NET method is very straightforward: it checks the data model for a `City` that has the same `Name`, `Lat`, `Lon`, and `CountryId` as the one provided by the *front-end* (as well as a different `Id`) and returns `true` or `false` as the result, respectively. The `Id` check has been added to conditionally disable the *dupe check* when the user is editing an existing city. If that's the case, using the *same* `Name`, `Lat`, `Lon`, and `CountryId` would be allowed since we're basically overwriting the same city and not creating a new one. When the user adds a new city, that `Id` value will always be set to *zero*, preventing the *dupe check* from being disabled.

city-edit.component.html

Now that the *back-end* code is ready, we need to create a suitable error message from the UI. Open the `/ClientApp/src/app/cities/city-edit.component.html` file and update its content in the following way (the new lines are highlighted):

```
<div class="city-edit">  
  <h1>{{title}}</h1>  
  
  <p *ngIf="this.id && !city"><em>Loading...</em></p>  
  
  <div class="form" [formGroup]="form" (ngSubmit)="onSubmit()">  
  
    <div *ngIf="form.invalid && form.errors?.isDupeCity"  
        class="alert alert-danger">  
      <strong>ERROR</strong>:  
      A city with the same <i>name</i>, <i>lat</i>,  
      <i>lon</i> and <i>country</i> already exists.  
    </div>  
  
  <!-- ...existing code... -->
```

As shown in the preceding code, the alert `<div>` we added will only be shown if the form is invalid. There are errors that are strictly related to the form itself and the `isDupeCity` error is returning `true`; all these conditions need to be met, otherwise we risk showing such an alert, even when it doesn't have to be.

Testing it out

Now that the Component HTML template has been set up, we can test the result of our hard work: press *F5*, navigate to the **Cities** view, click the **Add a new City** button, and insert the following values:

- **Name:** New Tokyo
- **Latitude:** 35.685
- **Longitude:** 139.7514
- **Country:** Japan

If you did everything properly, you should be greeted by the following error message:

The screenshot shows a web application interface for creating a new city. At the top, there's a navigation bar with 'WorldCities' on the left and 'Home' (highlighted), 'Cities', and 'Countries' on the right. Below the navigation is a large heading 'Create a new City'. A red error box contains the text 'ERROR: A city with the same name, lat, lon and country already exists.' The form fields are as follows: 'City name:' with 'Tokyo' entered; 'City latitude:' with '35.685' entered; 'City longitude:' with '139.7514' entered; 'Country:' with a dropdown menu showing 'Select a Country...' and 'Japan' selected. At the bottom are two buttons: a green 'Create' button and a grey 'Cancel' button.

That's great! Our custom *async* validator is working fine and triggers both the *front-end* and the *back-end* validation logic.

Observables and RxJS operators

The `async` logic that's used to perform the call makes extensive use of the *Observable/RxJS* pattern: this time, though, instead of relying on the `subscribe()` method we've already used a number of times, we opted for a pipe + map approach. These are two very important RxJS operators that allow us to perform our data manipulation tasks while retaining the *Observable* status of the returned value, while subscriptions will *execute* the *Observable* and return actual data instead.

Such a concept might be quite difficult to understand. Let's try to put it in other words:

- We should use the `subscribe()` method when we want to execute the *Observable* and get its actual result; for example, a JSON structured response. Such a method returns a *Subscription* that can be canceled but **can't be subscribed to** anymore.
- We should use the `map()` operator when we want to transform/manipulate the data events of the *Observable* without executing it so that it can be passed to other `async` actors that will also manipulate (and eventually execute) it. Such a method returns an *Observable* that **can be subscribed to**.

As for the `pipe()`, it's just an RxJS operator that composes/chains other operators (such as `map`, `filter`, and so on).

The most important difference between *Observable* methods and RxJS operators is that the latter always return *Observables*, while the former return a different (and mostly final) object type. Does it ring a bell?

If we think about what we learned back in Chapter 5, *Fetching and Displaying Data*, when dealing with the .NET *Entity Framework*, it should definitely sound familiar. Remember when we were playing around with the `IQueryable<T>` interface? The various `Where`, `OrderBy`, and `CountAsync` `IQueryable` methods that we used when we build our `ApiResult` class are quite similar to what we can do in Angular by chaining multiple `map` functions with the `pipe` operator. Conversely, the `subscribe()` method strictly resembles the various `ToListAsync()`/`ToDictionaryAsync()` that we used in .NET to execute the `IQueryable` and retrieve its result in a usable object.

Performance issues

Before moving on, let's try to answer the following question: *when will this validator be checked?* In other words, can we reasonably expect performance issues, considering the fact it performs a *server-side* API call upon each check?

If we recall what we said earlier, the *asynchronous* validators will only be checked when all the *synchronous* validators return `true`. Since `isDupeCity` is `async`, it won't be called until all the `Validators.required` that we previously set up in all the `FormControl` elements return `true`. That's a piece of great news indeed, since there would be no sense in checking for an existing city with `name`, `lat`, `lon`, and/or `countryId` being `null` or empty.

Based on what we have just said, we can reasonably expect the `isDupeCity` validator to be called once or twice for each form submission, which is perfectly fine in terms of performance impact. Everything is fine, then. Let's move on.

Introducing the FormBuilder

Now that our `CityEditComponent` has been set up, we might be tempted to reuse the same techniques to create a `CountryEditComponent` and get the job done, just like we did in Chapter 5, *Fetching and Displaying Data*, with our `CitiesComponent` and `CountryComponent` files. However, we won't be doing this. Instead, we'll take the chance to introduce a new tool to our shed that can be very useful when dealing with multiple forms: the `FormBuilder` service.

In the following chapters, we'll do the following:

- Create our `CountryEditComponent` with all the required TypeScript, HTML, and CSS files.
- Learn how to use the `FormBuilder` service to generate form controls in a better way.
- Add a new set of `Validators` (including a brand-new `isDupeCountry` custom validator) to the new form implementation.
- Test our new `FormBuilder`-based implementation to check that everything works.

By the end of this section, we'll have a fully-functional `CountryEditComponent` that will work in the same way that `CityEditComponent` does, except it will be based on a slightly different approach.

Creating the CountryEditComponent

Let's start by laying down the files we need. From the **Solution Explorer** of our `WorldCities` project, do the following:

1. Navigate to the `/ClientApp/src/app/countries` folder.
2. Right-click the folder's name and select `Add | New Item` three times to create the following files:
 - `country-edit.component.ts`
 - `country-edit.component.html`
 - `country-edit.component.css`

Once you're done, fill them with the following content.

country-edit.component.ts

Open the `/ClientApp/src/app/countries/country-edit.component.ts` file and fill it with the following code. Watch out for the highlighted parts, which are rather different from the previous `CityEditComponent`; other minor differences, such as `country` instead of `city`, are not highlighted, since they're more than expected:

```
import { Component, Inject } from '@angular/core';
import { HttpClient, HttpParams } from '@angular/common/http';
import { ActivatedRoute, Router } from '@angular/router';
import { FormGroup, FormBuilder, Validators, AbstractControl,
AsyncValidatorFn } from '@angular/forms';
import { map } from 'rxjs/operators';
import { Observable } from 'rxjs';

import { Country } from '../../countries/Country';

@Component({
  selector: 'app-country-edit',
  templateUrl: './country-edit.component.html',
  styleUrls: ['./country-edit.component.css']
})
export class CountryEditComponent {

  // the view title
  title: string;

  // the form model
```

```
form: FormGroup;

// the city object to edit or create
country: Country;

// the city object id, as fetched from the active route:
// It's NULL when we're adding a new country,
// and not NULL when we're editing an existing one.
id?: number;

constructor(
  private fb: FormBuilder,
  private activatedRoute: ActivatedRoute,
  private router: Router,
  private http: HttpClient,
  @Inject('BASE_URL') private baseUrl: string) {
  this.loadData();
}

ngOnInit() {
  this.form = this.fb.group({
    name: ['', Validators.required, this.isDupeField("name")]
  },
  iso2: ['', [
    Validators.required,
    Validators.pattern('[a-zA-Z]{2}')
  ],
  this.isDupeField("iso2")
],
iso3: ['', [
  Validators.required,
  Validators.pattern('[a-zA-Z]{3}')
],
this.isDupeField("iso3")
]);
}

loadData() {
  // retrieve the ID from the 'id'
  this.id = +this.activatedRoute.snapshot.paramMap.get('id');
}
```

```
if (this.id) {
    // EDIT MODE

    // fetch the country from the server
    var url = this.baseUrl + "api/countries/" + this.id;
    this.http.get<Country>(url).subscribe(result => {
        this.country = result;
        this.title = "Edit - " + this.country.name;

        // update the form with the country value
        this.form.patchValue(this.country);
    }, error => console.error(error));
}

else {
    // ADD NEW MODE

    this.title = "Create a new Country";
}

onSubmit() {

    var country = (this.id) ? this.country : <Country>{};

    country.name = this.form.get("name").value;
    country.iso2 = this.form.get("iso2").value;
    country.iso3 = this.form.get("iso3").value;

    if (this.id) {
        // EDIT mode

        var url = this.baseUrl + "api/countries/" + this.country.id;
        this.http
            .put<Country>(url, country)
            .subscribe(result => {

                console.log("Country " + country.id + " has been updated.");

                // go back to cities view
                this.router.navigate(['/countries']);
            }, error => console.log(error));
    }

    else {
        // ADD NEW mode
        var url = this.baseUrl + "api/countries";
        this.http
            .post<Country>(url, country)
            .subscribe(result => {
```

```
        console.log("Country " + result.id + " has been created.");

        // go back to cities view
        this.router.navigate(['/countries']);
    }, error => console.log(error));
}

isDupeField(fieldName: string): AsyncValidatorFn {
    return (control: AbstractControl): Observable<{ [key: string]: any } | null> => {

        var params = new HttpParams()
            .set("countryId", (this.id) ? this.id.toString() : "0")
            .set("fieldName", fieldName)
            .set("fieldValue", control.value);
        var url = this.baseUrl + "api/countries/IsDupeField";
        return this.http.post<boolean>(url, null, { params })
            .pipe(map(result => {
                return (result ? { isDupeField: true } : null);
            }));
    }
}
}
```

As we can see, the Component's source code is quite similar to the `CityEditComponent`, except for some limited yet important differences that we're going to summarize here:

- The `FormBuilder` service has been added to the `@angular/forms` import list, replacing the `FormControl` reference that we don't need anymore. As a matter of fact, we're still creating form controls, but we'll do that via the `FormBuilder` instead of manually instantiating them, which means we don't need to *explicitly reference* them.
- The `form` variable is now instantiated using a different approach that strongly relies upon the new `FormBuilder` service.
- The various `FormControl` elements that get instantiated within the `form` feature some *validators* that we have never seen before.

The `FormBuilder` service gives us three *factory methods* so that we can create our form structure: `control()`, `group()`, and `array()`. Each generates an instance of the corresponding `FormControl`, `FormGroup`, and `FormArray` class. In our example, we're creating a single containing group with three controls, each with their own set of *validators*.

As for the *validators*, we can see two new entries:

- `Validator.pattern`: A built-in *validator* that requires the control's *value* to match a given regular expression (*regex*) pattern. Since our `ISO2` and `ISO3` country fields are defined using a strict format, we're going to use them to ensure that the user will input correct values.
- `isDupeField`: This is a custom `async` validator that we implemented here for the first time. It's similar to the `isDupeCity` validator we created for our `CityEditComponent` but with some key differences that we're going to summarize in the next section.



Those who don't know much about *regular expressions* (or *regex* for short) and want to use the `Validator.pattern` to its full extent should definitely visit the following website, which contains a good amount of resources regarding *regex* and a great online builder and tester with full *JavaScript* and *PHP/PCRE regex* support: <https://regextester.com/>.

isDupeField validator

As we can see by looking at the preceding Component's source code, the `isDupeField` custom validator is not assigned to the main `FormGroup` like `isDupeCity` is; instead, it's set three times: one for each `FormControl` it needs to check. The reason for this is simple: compared to `isDupeCity`, which was meant to check for duplicate cities using a four-fields dupe key, `isDupeField` needs to **individually check** each field it's assigned to. We need to do that because we don't want more than one country having the same `name`, **or** the same `iso2`, **or** the same `iso3`.

This also explains why we need to specify a `fieldName` and a corresponding `fieldValue` instead of passing a `Country` interface: the `isDupeField` *server-side* API will have to perform a different check for each `fieldName` we're going to pass, instead of relying on a single general-purpose check like the `isDupeCity` API does.

As for the `countryId` parameter, it's required to prevent the *dupe-check* from raising a validation error when editing an existing *country*. In the `isDupeCity` validator, it was passed as a property of the `city` class. Now, we need to explicitly add it to the `POST` parameters.

IsDupeField server-side API

Now, we need to implement our custom validator's *back-end* API.

Open the `/Controllers/CountriesController.cs` file and add the following method at the bottom of the file:

```
// ...existing code...

private bool CountryExists(int id)
{
    return _context.Countries.Any(e => e.Id == id);
}

[HttpPost]
[Route("IsDupeField")]
public bool IsDupeField(
    int countryId,
    string fieldName,
    string fieldValue)
{
    case "name":
        return _context.Countries.Any(
            c => c.Name == fieldValue && c.Id != countryId);
    case "iso2":
        return _context.Countries.Any(
            c => c.ISO2 == fieldValue && c.Id != countryId);
    case "iso3":
        return _context.Countries.Any(
            c => c.ISO3 == fieldValue && c.Id != countryId);
    default:
        return false;
}
```

Although the code resembles the `IsDupeCity` *server-side* API, we're switching the `fieldName` parameter and performing a different *dupe-check* depending on its value; such logic is implemented with a standard `switch/case` conditional block with *strongly-typed* LINQ lambda expressions for each field we can reasonably expect. Again, we're also checking that the `countryId` is different so that our users can *edit* an existing country.

If the `fieldName` that's received from the client differs from the three supported values, our API will respond with `false`.

An alternative approach using Linq.Dynamic

Before moving on, we may want to ask ourselves why we've implemented the `IsDupeField` API using *strongly-typed* LAMBDA expressions inside a `switch...case` block instead of relying on the `System.Linq.Dynamic.Core` library.

As a matter of fact, we did that for the sake of simplicity, since the *dynamic* approach would require us having to write additional code to protect our method from *SQL injection* attacks. However, since we already implemented such a task in the `IsValidProperty()` method of our `ApiResult` class, maybe we can use it and shrink the preceding code down: after all, we've made it *public* and *static* so that we can use it anywhere.

Here's an alternative implementation using the aforementioned tools (the old code is commented, while the new code is highlighted):

```
using System.Linq.Dynamic.Core;

// ...existing code...

[HttpPost]
[Route("IsDupeField")]
public bool IsDupeField(
    int countryId,
    string fieldName,
    string fieldValue)
{
    // Default approach (using strongly-typed LAMBA expressions)
    //switch (fieldName)
    //{
    //    case "name":
    //        return _context.Countries.Any(c => c.Name == fieldValue);
    //    case "iso2":
    //        return _context.Countries.Any(c => c.ISO2 == fieldValue);
    //    case "iso3":
    //        return _context.Countries.Any(c => c.ISO3 == fieldValue);
    //    default:
    //        return false;
    //}
}

// Alternative approach (using System.Linq.Dynamic.Core)
return (ApiResult<Country>.IsValidProperty(fieldName, true))
    ? _context.Countries.Any(
        String.Format("{0} == @0 && Id != @1", fieldName),
        fieldValue,
        countryId)
```

```
: false;  
}
```

Not bad, right?

The *alternative dynamic* approach definitely looks more DRY and versatile than the *default* one, all while retaining the same security level against *SQL injection* attacks. The only downside may be due to the additional overhead brought by the `System.Linq.Dynamic.Core` library, which will likely have some minor performance impact. Although this shouldn't be an issue in most scenarios, whenever we want our APIs to respond to HTTP requests as quickly as possible, we should arguably favor the default approach.

country-edit.component.html

It's time to implement the template of our `CountryEditComponent`.

Open the `/ClientApp/src/app/countries/country-edit.component.html` file and fill it with the following code. Once again, pay attention to the highlighted parts, which are rather different from the template of `CityEditComponent`; other minor differences, such as `country` instead of `city`, are not highlighted since they're more than expected:

```
<div class="country-edit">  
  <h1>{{title}}</h1>  
  
  <p *ngIf="this.id && !country"><em>Loading...</em></p>  
  
  <div class="form" [formGroup]="form" (ngSubmit)="onSubmit()">  
    <div class="form-group">  
      <label for="name">Country name:</label>  
      <br />  
      <input type="text" id="name"  
             formControlName="name" required  
             placeholder="Country name..."  
             class="form-control"  
             />  
  
      <div *ngIf="form.get('name').invalid &&  
            (form.get('name').dirty || form.get('name').touched)"  
            class="invalid-feedback">  
        <div *ngIf="form.get('name').errors?.required">  
          Name is required.  
        </div>  
        <div *ngIf="form.get('name').errors?.isDuplicateField">
```

```
        Name already exists: please choose another.  
    </div>  
  </div>  
  
<div class="form-group">  
  <label for="iso2">ISO 3166-1 ALPHA-2 Country Code (2  
    letters)</label>  
  <br />  
  <input type="text" id="iso2"  
    formControlName="iso2" required  
    placeholder="2 letters country code..."  
    class="form-control" />  
  
  <div *ngIf="form.get('iso2').invalid &&  
    (form.get('iso2').dirty || form.get('iso2').touched)"  
    class="invalid-feedback">  
    <div *ngIf="form.get('iso2').errors?.required">  
      ISO 3166-1 ALPHA-2 country code is required.  
    </div>  
    <div *ngIf="form.get('iso2').errors?.pattern">  
      ISO 3166-1 ALPHA-2 country code requires 2 letters.  
    </div>  
    <div *ngIf="form.get('iso2').errors?.isDupeField">  
      This ISO 3166-1 ALPHA-2 country code already exist:  
      please choose another.  
    </div>  
  </div>  
</div>  
  
<div class="form-group">  
  <label for="iso3">ISO 3166-1 ALPHA-3 Country Code (3  
    letters)</label>  
  <br />  
  <input type="text" id="iso3"  
    formControlName="iso3" required  
    placeholder="3 letters country code..."  
    class="form-control" />  
  
  <div *ngIf="form.get('iso3').invalid &&  
    (form.get('iso3').dirty || form.get('iso3').touched)"  
    class="invalid-feedback">  
    <div *ngIf="form.get('iso3').errors?.required">  
      ISO 3166-1 ALPHA-3 country code is required.  
    </div>  
    <div *ngIf="form.get('iso3').errors?.pattern">  
      ISO 3166-1 ALPHA-3 country code requires 3 letters.  
    </div>
```

```
<div *ngIf="form.get('iso3').errors?.isDupeField">
    This ISO 3166-1 ALPHA-3 country code already exist:
    please choose another.
</div>
</div>
<div class="form-group commands">
    <button *ngIf="id" type="submit"
        (click)="onSubmit()"
        [disabled]="form.invalid"
        class="btn btn-success">
        Save
    </button>
    <button *ngIf="!id" type="submit"
        (click)="onSubmit()"
        [disabled]="form.invalid"
        class="btn btn-success">
        Create
    </button>
    <button type="submit"
        [routerLink]=["'/countries']"
        class="btn btn-default">
        Cancel
    </button>
</div>
</div>
</div>
```

As we can see, the most relevant differences are all related to the HTML code that's required to show the new `pattern` and `isDupeField` validators. Now, we have as many as *three* different validators for our fields, which is pretty awesome: our users won't be given a chance to input wrong values!

country-edit.component.css

Last but not least, let's apply the UI styling.

Open the `/ClientApp/src/app/countries/country-edit.component.css` file and fill it with the following code:

```
input.ng-valid {  
    border-left: 5px solid green;  
}  
  
input.ng-invalid.ng-dirty,  
input.ng-invalid.ng-touched {  
    border-left: 5px solid red;  
}  
input.ng-valid ~ .valid-feedback,  
input.ng-invalid ~ .invalid-feedback {  
    display: block;  
}
```

No surprises here; the preceding stylesheet code is identical to the one we used for `CityEditComponent`.

Our component is finally done! Now, we need to reference it in the `AppModule` file and implement the *navigation routes* in the `CountriesComponent`.

AppModule

Open the `/ClientApp/src/app/app.module.ts` file and add the following code (the new lines are highlighted):

```
import { BrowserModule } from '@angular/platform-browser';  
import { NgModule } from '@angular/core';  
import { FormsModule } from '@angular/forms';  
import { HttpClientModule, HTTP_INTERCEPTORS } from  
    '@angular/common/http';  
import { RouterModule } from '@angular/router';  
  
import { AppComponent } from './app.component';  
import { NavMenuComponent } from './nav-menu/nav-menu.component';  
import { HomeComponent } from './home/home.component';  
import { CitiesComponent } from './cities/cities.component';  
import { CityEditComponent } from './cities/city-edit.component';  
import { CountriesComponent } from './countries/countries.component';  
import { CountryEditComponent } from './countries/country-  
edit.component';  
import { BrowserAnimationsModule } from '@angular/platform-  
browser/animations';  
import { AngularMaterialModule } from './angular-material.module';  
import { FormControl, ReactiveFormsModule } from '@angular/forms';
```

```
@NgModule({
  declarations: [
    AppComponent,
    NavMenuComponent,
    HomeComponent,
    CitiesComponent,
    CityEditComponent,
    CountriesComponent,
    CountryEditComponent
  ],
  imports: [
    BrowserModule.withServerTransition({ appId: 'ng-cli-universal' }),
    HttpClientModule,
    FormsModule,
    RouterModule.forRoot([
      { path: '', component: HomeComponent, pathMatch: 'full' },
      { path: 'cities', component: CitiesComponent },
      { path: 'city/:id', component: CityEditComponent },
      { path: 'city', component: CityEditComponent },
      { path: 'countries', component: CountriesComponent },
      { path: 'country/:id', component: CountryEditComponent },
      { path: 'country', component: CountryEditComponent }
    ]),
    BrowserAnimationsModule,
    AngularMaterialModule,
    ReactiveFormsModule
  ],
  providers: [],
  bootstrap: [AppComponent]
})
export class AppModule { }
```

Now that we've laid down the two routes so that we can *edit* and *add* countries, we just need to implement them in the CountriesComponent's template file.

countries.component.ts

Open the /ClientApp/src/app/countries/countries.component.html file and add the following code (the new lines are highlighted):

```
<h1>Countries</h1>

<p>Here's a list of countries: feel free to play with it.</p>

<p *ngIf="!countries"><em>Loading...</em></p>

<div class="commands text-right" *ngIf="countries">
  <button type="submit"
    [routerLink]=["/country"]
    class="btn btn-success">
    Add a new Country
  </button>
</div>

<mat-form-field [hidden]="!countries">
  <input matInput (keyup)="loadData($event.target.value)"
    placeholder="Filter by name (or part of it)...">
</mat-form-field>

<table mat-table [dataSource]="countries" class="mat-elevation-z8"
[hidden]="!countries"
  matSort (matSortChange)="loadData()"
  matSortActive="{{defaultSortColumn}}"
  matSortDirection="{{defaultSortOrder}}>

  <!-- Id Column -->
  <ng-container matColumnDef="id">
    <th mat-header-cell *matHeaderCellDef mat-sort-header>ID</th>
    <td mat-cell *matCellDef="let country"> {{country.id}} </td>
  </ng-container>

  <!-- Name Column -->
  <ng-container matColumnDef="name">
    <th mat-header-cell *matHeaderCellDef mat-sort-header>Name</th>
    <td mat-cell *matCellDef="let country">
      <a [routerLink]=[ '/country', country.id ]>{{country.name}}</a>
    </td>
  </ng-container>

  <!-- ...existing code... -->
```

... And that's it! Now, we're ready to test everything out.

Testing the CountryEditComponent

Now, it's time to press *F5* and admire the result of our hard work.

Once the app has been launched in *debug* mode, navigate to the **Countries** view to see the **Add a new Country** button and the edit links on the various country names, as shown in the following screenshot:

The screenshot shows a web application interface titled "WorldCities". At the top right, there are navigation links: "Home", "Cities", and "Countries". Below the title, the word "Countries" is prominently displayed in a large, bold font. A sub-instruction "Here's a list of countries: feel free to play with it." is present. On the right side of the page, a green button labeled "Add a new Country" is visible. A search bar with the placeholder "Filter by name (or part of it)..." is located above the table. The main content is a table listing countries with columns for ID, Name, ISO 2, and ISO 3 codes. The table contains 10 entries, starting with Afghanistan and ending with Armenia. At the bottom of the table, there is a pagination control showing "Items per page: 10" and "1 - 10 of 235", along with navigation arrows for page navigation.

ID	Name ↑	ISO 2	ISO 3
120	Afghanistan	AF	AFG
123	Albania	AL	ALB
173	Algeria	DZ	DZA
232	American Samoa	AS	ASM
118	Andorra	AD	AND
125	Angola	AO	AGO
122	Anguilla	AI	AIA
121	Antigua And Barbuda	AG	ATG
126	Argentina	AR	ARG
124	Armenia	AM	ARM

Now, let's search for Denmark using our filter and click on the name to enter the `CountryEditComponent` in *edit mode*. If everything works fine, the `name`, `iso2`, and `iso3` fields should all be green, meaning that our `isDupeField` custom validator(s) are not raising errors:

The screenshot shows the 'Edit - Denmark' form from the WorldCities application. The 'Country name:' field contains 'Denmark'. The 'ISO 3166-1 ALPHA-2 Country Code (2 letters)' field contains 'DK'. The 'ISO 3166-1 ALPHA-3 Country Code (3 letters)' field contains 'DNK'. Both the 'DK' and 'DNK' fields have a green border, indicating they are valid. At the bottom, there are 'Save' and 'Cancel' buttons.

Now, let's try to change the **Country name** to Japan and the **ISO 3166-1 ALPHA-2 Country Code** to IT and see what happens:

The screenshot shows the 'Edit - Denmark' form with the 'Country name:' field set to 'Japan'. A red border around the 'Japan' input field indicates it is invalid. Below the input, a red message says 'Name does already exist: please choose another.' In the 'ISO 3166-1 ALPHA-2 Country Code (2 letters)' field, the value 'IT' is entered, highlighted with a blue border, and a red message below it says 'This ISO 3166-1 ALPHA-2 country code already exist: please choose another.' The 'ISO 3166-1 ALPHA-3 Country Code (3 letters)' field contains 'DNK' and has a green border. At the bottom, there are 'Save' and 'Cancel' buttons.

This is a great result: this means that our custom validators are doing their job, positively raising some dupe errors since these values have been reserved for other existing countries (Japan and Italy, respectively).

Now, let's hit the **Cancel** button and go back to the Countries view. From there, click the **Add a new Country** button and try to insert a country with the following values:

- **Country name:** New Japan
- **ISO 3166-1 ALPHA-2 Country Code:** JP
- **ISO 3166-1 ALPHA-3 Country Code:** NJ2

If everything is working fine, we should raise two more validation errors, as shown in the following screenshot:

The screenshot shows a web application interface for creating a new country. At the top, there is a navigation bar with links for Home, Cities, and Countries. Below the navigation, the title "Create a new Country" is displayed. The form has three input fields: "Country name" containing "New Japan", "ISO 3166-1 ALPHA-2 Country Code (2 letters)" containing "JP", and "ISO 3166-1 ALPHA-3 Country Code (3 letters)" containing "NJ". Under the second field, a red error message says "This ISO 3166-1 ALPHA-2 country code already exists: please choose another.". Under the third field, another red message says "ISO 3166-1 ALPHA-3 country code requires 3 letters.". At the bottom of the form are two buttons: a green "Create" button and a grey "Cancel" button.

The former error is raised by our `isDupeField` custom validator and is due to the fact that ALPHA-2 country code already belongs to an existing country (Japan); the latter one is raised by the built-in `Validators.pattern`, which we configured with a *regular expression*, '`[a-zA-Z]{3}`', that doesn't allow digits.

Let's fix these errors by typing in the following values:

- **Country name:** New Japan
- **ISO 3166-1 ALPHA-2 Country Code:** NJ
- **ISO 3166-1 ALPHA-2 Country Code:** NJP

Once you're done, click **Create** to create the new country. If everything is working as expected, the view should redirect us to the main **Countries** view.

From there, we can type New Japan into our text filter to ensure that our brand-new country is actually there:

The screenshot shows a web application interface for managing countries. At the top, there is a navigation bar with links for Home, Cities, and Countries. The main title is "WorldCities". Below the title, the section title is "Countries". A sub-instruction says "Here's a list of countries: feel free to play with it.". There is a green button labeled "Add a new Country". A search input field contains the text "New Japan", which is underlined, indicating it is the current filter. Below the search field is a table with four columns: ID, Name, ISO 2, and ISO 3. One row is visible in the table, corresponding to the filtered search result. At the bottom of the page, there are pagination controls: "Items per page: 10" with a dropdown arrow, "1 - 1 of 1", and navigation arrows (|<, <, >, >|).

ID	Name	ISO 2	ISO 3
236	New Japan	NJ	NJP

... Here it is! This means that we're finally done with `CountryEditComponent` and ready to move on to new exciting tasks.

Summary

This chapter was entirely dedicated to Angular forms. We started by clarifying what a form actually is and enumerated the features it needs to have in order to fulfill its duties, grouping them into two main requirements: providing a good user experience and properly handling the submitted data.

Then, we turned our focus to the Angular framework and to the two form design models it offers: the *Template-Driven* approach, mostly inherited from AngularJS, and the *Model-Driven* or *Reactive* alternative. We took some valuable time to analyze the pros and cons provided by both of them, and then we performed a detailed comparison of the underlying logic and workflow. At the end of the day, we chose to embrace the *Reactive* way of doing things as it gives the developer more control and enforces a more consistent separation of duties between the *Data Model* and the *Form Model*.

Right after that, we went from theory to practice by creating a `CityEditComponent` and used it to implement a fully-featured *Reactive Form*; we also added the *client-side* and *server-side* data validation logic by making good use of the *Angular template syntax* in conjunction with the classes and directives granted by Angular's `ReactiveFormsModule`. Once done, we did the same with `CountryEditComponent`, where we took the chance to try and use a `FormBuilder` instead of the `FormGroup/FormControl` instances we used previously.

Once done, we performed a surface test with our browser to check all the *built-in* and *custom* validators, ensuring that they worked properly on the *front-end* as well as on their *back-end* APIs.

In the next chapter, we're going to refine what we've done so far by refactoring some rough aspects of our Angular Components in a better way. By doing so, we'll learn how to post process the data, add decent error handling, implement some retry logic to deal with connection issues, debug our form using the Visual Studio *client-side* debugger, and – most importantly – perform some *unit tests*.

Suggested topics

Template-Driven Forms, Model-Driven Forms, Reactive Forms, JSON, RFC 7578, RFC 1341, URL Living Standard, HTML Living Standard, data validation, Angular validators, custom validators, asynchronous validators, Regular Expressions (RegEx), Angular pipes, FormBuilder, RxJS, Observables, Safe Navigation Operator (Elvis Operator).

References

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- *RFC 1341, section 7.2- The Multipart Content-Type*: https://www.w3.org/Protocols/rfc1341/7_2_Multipart.html
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- *Angular: Template-driven forms*: <https://angular.io/guide/forms#template-driven-forms>
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- *RegExr: Learn, Build, and Test RegEx*: <https://regexr.com/>
- *Safe Navigation Operator*: <https://angular.io/guide/template-syntax#safe-navigation-operator>

7

Code Tweaks and Data Services

Our `WorldCities` web application is now a full-fledged project providing a number of interesting features: we can **retrieve a list** of all the *cities* and *countries* available in our DBMS and browse them through paged tables that we can *order* and *filter*; thanks to our *master/detail* UI pattern we can also access a detailed view of each *city* and *country*, where we can **read** and/or **edit** the most relevant fields for both of them; and last but not least, we can **create** new *cities* and *countries* thanks to the '*add new* capabilities' of the aforementioned *Detail* view.

Now, before going further, it could be wise to spend some time consolidating what we learned so far and improve the basic patterns we have followed: after all, refining our *front-end* and *back-end* and the overall logic they're currently relying upon will definitely make them more *versatile* and *fail-proof* for what is yet to come.

This chapter is entirely dedicated to those tasks. Here's what we're going to do through the various sections that we're about to face:

- **Optimizations and tweaks**, where we'll implement some high-level source code and UI refinements.
- **Bug fixes and improvements**, where we'll leverage the preceding tweaks to enhance our app's consistency and add some new features.
- **Data Services**, where we'll learn how to migrate from our current simplified implementation – where we used the raw `HttpClient` service directly inside the Components – to a more versatile approach that would allow us to add features such as post-processing, error handling, retry logic, and more.

All these changes will be worth their time because they'll strengthen our app's source code and prepare it for the *debugging* and *testing* phase that will appear in the next chapter.

All right, then... Let's get to work.

Technical requirements

In this chapter, we're going to need all of the previous technical requirements that were listed in all the previous chapters, with no additional resources, libraries, or packages.

The code files for this chapter can be found at https://github.com/PacktPublishing/ASP.NET-Core-3-and-Angular-9-Third-Edition/tree/master/Chapter_07/

Optimizations and tweaks

In computer programming, the term **code bloat** is commonly used to describe an unnecessarily long, slow, or wasteful amount of source code. Such code is hardly desirable because it inevitably makes our app more vulnerable to human errors, regression bugs, logical inconsistencies, wasted resources, and so on. It also makes *debugging* and *testing* a lot more difficult and stressful; for all of the previously mentioned reasons, we should try to prevent that from happening as much as we can.

The most effective way to counter *code bloat* is to adopt and adhere to the **DRY** principle, which is something that any developer should try to follow whenever they can. As already stated in Chapter 5, *Fetching and Displaying Data*, **Don't Repeat Yourself (DRY)** is a widely achieved principle of software development: whenever we violate it we fall into a *WET* approach, which could mean *Write Everything Twice*, *We Enjoy Typing*, or *Waste Everyone's Time*, depending on what we like the most.

In this section, we'll try to address some rather *WET* parts of our current code and see how we can make them more *DRY*: doing that will greatly help our *debugging* and *testing sessions* later on.

Template improvements

If we take another look at our `CityEditComponent` and `CountryEditComponent` template files, we can definitely see a certain amount of code bloat. The `form.get()` method is called no less than 10 times per form, and poses a serious threat to our template's readability. And we're talking about very small and easy forms. What would happen when dealing with big ones? Is there a way to address that?

As a matter of fact, there is: whenever we feel like we're writing too much code or repeating a complex task too many times, we can create one or more helper methods within our Component class in order to centralize the underlying logic. These helper methods will act as *shortcuts* that we can call instead of repeating the whole validation logic. Let's try to add them to our *form*-related Angular Components.

Form validation shortcuts

Let's see how to do that in the `CityEditComponent` class.

Open the `/ClientApp/src/app/cities/city-edit.component.ts` file, and add the following methods (new lines are highlighted):

```
// retrieve a FormControl
getControl(name: string) {
    return this.form.get(name);
}

// returns TRUE if the FormControl is valid
isValid(name: string) {
    var e = this.getControl(name);
    return e && e.valid;
}

// returns TRUE if the FormControl has been changed
isChanged(name: string) {
    var e = this.getControl(name);
    return e && (e.dirty || e.touched);
}

// returns TRUE if the FormControl is raising an error,
// i.e. an invalid state after user changes
hasError(name: string) {
    var e = this.getControl(name);
    return e && (e.dirty || e.touched) && e.invalid;
}
```

The comments are self-explanatory, so there's nothing more to say. These helper methods grant us the chance to shrink our previous validation code, as follows:

```
<!-- ...existing code... -->

<div *ngIf="hasError('name')"
      class="invalid-feedback">
  <div *ngIf="form.get('name').errors?.required">
    Name is required.
  </div>
</div>

<!-- ...existing code... -->

<div *ngIf="hasError('lat')"
      class="invalid-feedback">
  <div *ngIf="form.get('lat').errors?.required">
    Latitude is required.
  </div>
</div>

<!-- ...existing code... -->
```

... and so on. Much better, right?

Let's do the same for all the form controls for `CityEditComponent`, then switch to `CountryEditComponent` and do the same there as well...

... Or not.

Wait a minute: didn't we just say we would adhere to the *DRY* pattern as much as we can? How can we reasonably expect to do that if we're about to *copy and paste* the same identical methods throughout different classes? What if we had 10 form-based Components to patch instead of just 2? That doesn't sound anything but *WET*. Now that we've found a good way to shrink our template code, we also need to find a decent way to implement those form-related methods without spawning clones everywhere.

Luckily enough, TypeScript provides a great way to handle these kinds of scenario: **class inheritance**. Let's see how we can use such features to our advantage.

Class inheritance

Object-oriented programming (OOP) is usually defined by two core concepts: *polymorphism* and *inheritance*. Although both concepts are related, they are not the same. Here's what they mean in a nutshell:

- **Polymorphism** allows us to assign multiple interfaces on the same *entity* (such as a *variable*, *function*, *object*, or *type*), and/or to assign the same interface on different *entities*: in other words, it allows *entities* to have more than one form.
- **Inheritance** allows us to *extend* an object or class by *deriving* it from another object (*prototype-based inheritance*) or class (*class-based inheritance*), while retaining a similar implementation; the extended class is commonly called a *subclass* or *child class*, while the inherited class takes the name of *superclass* or *base class*.

Let's now focus on **inheritance**: in TypeScript, as in most class-based, object-oriented languages, a type created through *inheritance* (a *child class*) acquires all the properties and behaviors of the parent type, except constructors, destructors, overloaded operators, and *private* members of the *base class*.

If we think about it, it's just what we need in our scenario: if we create a base class and implement all our form-related methods there, we'll just need to *extend* our current Component class without having to write it more than once.

Let's see how we can pull this off.

Implementing a BaseFormComponent

From Solution Explorer, right-click on the `/ClientApp/src/app/` folder and create a new `base.form.component.ts` file. Open it, and fill it with the following content:

```
import { Component } from '@angular/core';
import { FormGroup } from '@angular/forms';

@Component({
  template: ''
})
export class BaseFormComponent {

  // the form model
  form: FormGroup;
```

```
constructor() { }

// retrieve a FormControl
getControl(name: string) {
    return this.form.get(name);
}

// returns TRUE if the FormControl is valid
isValid(name: string) {
    var e = this.getControl(name);
    return e && e.valid;
}

// returns TRUE if the FormControl has been changed
isChanged(name: string) {
    var e = this.getControl(name);
    return e && (e.dirty || e.touched);
}

// returns TRUE if the FormControl is raising an error,
// i.e. an invalid state after user changes
hasError(name: string) {
    var e = this.getControl(name);
    return e && (e.dirty || e.touched) && e.invalid;
}
}
```

Now, we do have a `BaseFormComponent` *superclass* that we can use to *extend* our subclasses; as we can see, there's nothing much there, only the form-related methods and the `form` variable itself, because it's used (and therefore is required) by those methods.

As always, before we can use our new *superclass*, we need to have it referenced in the `/ClientApp/src/app/app.module.ts` file in the following way:

```
// ... existing code...

import { AppComponent } from './app.component';
import { BaseFormComponent } from './base.form.component';

// ... existing code...

@NgModule({
  declarations: [
    AppComponent,
    BaseFormComponent,
    NavMenuComponent,
```

```
    HomeComponent,  
    CitiesComponent,  
    CityEditComponent,  
    CountriesComponent,  
    CountryEditComponent  
],  
  
// ... existing code...
```



From now on, we'll take for granted that we've got the logic behind our code samples; consequently, we're going to present them in a more succinct way to avoid wasting more pages by saying the obvious: please bear with it! After all, whenever we need to see the full file, we can always find it on the book's online source code repository on [GitHub](#).

Right after that, we can update our current `CityEditComponent` TypeScript file in order to extend its class accordingly.

Extending `CityEditComponent`

Open the `/ClientApp/src/app/cities/city-edit.component.ts` file, then add the `BaseFormComponent` *superclass* at the end of the `import` list at the beginning of the file:

```
import { Component, Inject } from '@angular/core';  
import { HttpClient, HttpParams } from '@angular/common/http';  
import { ActivatedRoute, Router } from '@angular/router';  
import { FormGroup, FormControl, Validators, AbstractControl,  
  AsyncValidatorFn } from '@angular/forms';  
import { Observable } from 'rxjs';  
import { map } from 'rxjs/operators';  
  
import { City } from './city';  
import { Country } from '../countries/country';  
  
import { BaseFormComponent } from '../base.form.component';  
  
// ...existing code...
```

Now, we need to implement the class inheritance using the `extends` modifier that is right after the class declaration:

```
// ...existing code...

export class CityEditComponent
  extends BaseFormComponent {

// ...existing code...
```

That's it: `CityEditComponent` has now officially become a *child class* of the `BaseFormComponent` *superclass*.

Last but not least, we need to invoke the *superclass* constructor by calling `super()` inside the *child class* constructor's implementation:

```
// ...existing code...
constructor(
  private activatedRoute: ActivatedRoute,
  private router: Router,
  private http: HttpClient,
  @Inject('BASE_URL') private baseUrl: string) {
  super();
}

// ...existing code...
```

And that's it: now we can freely remove all the form-related methods that we added early on - `getControl`, `isValid`, `isChanged`, and `hasError` – to the `CityEditComponent` class file, as our *child class* will now transparently *inherit* them from its *superclass*.



As for the `form` variable, it's worth noting that we're actually **overriding** it in the *child class* source code: in TypeScript, this can be done without any fancy modifier. We just need to redefine it: since we have already got it, we don't need to do anything.

Let's now test what we did by hitting *F5*, and navigating through `CityEditComponent` in both the *edit* and *add new* modes. If we did everything correctly, we should see no issues: everything should work just like it was – with a fairly smaller amount of source code.



Don't forget to test our validators, since the form-related methods that we have implemented mostly impact them: if the form validators are still working and show their errors when triggered, it means that the *child class* is able to inherit and use its *base class* methods – thus proving that our brand-new *superclass/subclass* implementation is working fine.

Extending CountryEditComponent

As soon as we're sure that everything is working fine, we can extend the `CountryEditComponent` class and make it become a *child class* of `BaseFormComponent` as well: let's quickly do this, so that we can move on.

We're not going to show the source code changes here, because the required steps are almost identical to what we've just seen; if we've got any doubts, we can refer to this chapter's source code on the GitHub repository.

Bug fixes and improvements

Let's be honest: although we made a decent job of building up our *master/detail* UI pattern, and we assembled both views using the most relevant *city* and *country* fields, our app is still lacking something that our users might want to see. More specifically, the following detail is missing:

- **Our City Detail view doesn't validate the lat and lon input values** properly: for example, we are allowed to type letters instead of numbers, which utterly crashes the form.
- **Our Countries view doesn't show the number of cities that each country actually contains.**
- **Our Cities view doesn't show the country name** for each listed city.

Let's do our best to fix all of these issues for good.

Validating lat and lon

Let's start with the only real *bug*: a form that can be broken from the *front-end* is something that we should always avoid – even if those input types are implicitly checked in the *back-end* by our .NET Core API.

Luckily enough, we already know how to fix those kinds of errors: we need to add some *pattern-based validators* to the `lat` and `lon` `FormControl`s for `CityEditComponent`, just like we did with the `iso2` and `iso3` controls in the `CountryEditComponent` files. As we already know, we'll need to update two files:

- The `CityEditComponent class` file, in order to implement the validators and define a *validation pattern* based upon a *regex*.
- The `CityEditComponent template` file, in order to implement the validator's error messages and their show/hide logic.

Let's do this!

city-edit.component.ts

Open the `/ClientApp/src/app/cities/city-edit.component.ts` file, and update its content accordingly (new/updated lines are highlighted):

```
// ...existing code...

ngOnInit() {
  this.form = new FormGroup({
    name: new FormControl('', Validators.required),
    lat: new FormControl('', [
      Validators.required,
      Validators.pattern('^-?[0-9]+(\.[0-9]{1,4})?$',)
    ]),
    lon: new FormControl('', [
      Validators.required,
      Validators.pattern('^-?[0-9]+(\.[0-9]{1,4})?$',)
    ]),
    countryId: new FormControl('', Validators.required)
  }, null, this.isDuplicateCity());

  this.loadData();
}

// ...existing code...
```

Here we go. As we already know from Chapter 6, *Forms and Data Validation*, this form's implementation is still based on the manually instantiated `FormGroup` and `FormControl` objects instead of using `FormBuilder`: however, there's no reason to change it now, since we were still able to implement `Validators.pattern` without any issues.

Let's spend a couple minutes explaining the *regular expression* that we've used there:

- `^` defines the start of the *user input* string that we need to check.
- `[-]?` allows the presence of an *optional* minus sign, which is required when dealing with negative coordinates.
- `[0-9]+` asks for *one or more* numbers between 0 and 9.
- `(\.[0-9]{1,4})?` defines an *optional group* (thanks to `?` at the end), which, if present, needs to respect the following rules:
 - `\.:` It must start with *a single dot* (the decimal sign). The dot is escaped because it's a reserved *regex* character, which, when unescaped, means *any character*.
 - `[0-9]{1,4}` asks for *one to four* numbers between 0 and 9 (since we do want *between 1 and 4 decimal values* after the dot).
- `$` defines the end of the *user input* string.



We could've used `\d` (*any digit*) as an alternative of `[0-9]`, which is a slightly more succinct syntax; however, we have chosen to stick with `[0-9]` for better readability: feel free to replace it with `\d` at any time.

Now that the validators have been set in place, we need to add the error messages to the `CityEditComponent` template file.

city-edit.component.html

Open the `/ClientApp/src/app/cities/city-edit.component.html` file and update its content accordingly (new/updated lines are highlighted):

```
<!-- ...existing code -->

<div *ngIf="form.get('lat').errors?.required">
    Latitude is required.
</div>
<div *ngIf="form.get('lat').errors?.pattern">
    Latitude requires a positive or negative number with 0-4
    decimal values.
</div>

<!-- ...existing code -->

<div *ngIf="form.get('lon').errors?.required">
    Longitude is required.
```

```
</div>
<div *ngIf="form.get('lon').errors?.pattern">
    Longitude requires a positive or negative number with 0-4
    decimal values.
</div>

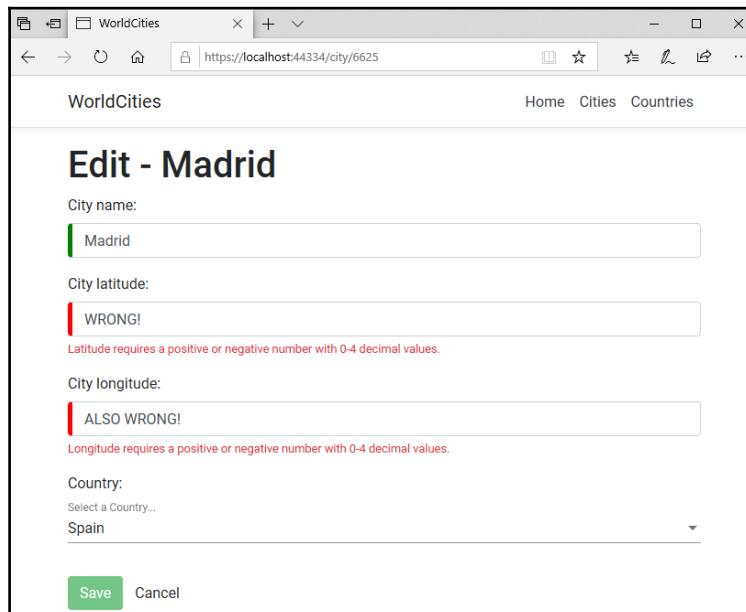
<!-- ...existing code -->
```

Here we go.

Let's quickly test it:

1. Hit *F5* to start the app in *debug* mode.
2. Navigate through the **Cities** view.
3. Filter the list to find **Madrid**.
4. Type some invalid characters in the **City latitude** and **City longitude** input fields.

If the validators have been implemented properly, we should see our error messages appear in all their glory and the **Save** button disabled, just like in the following screenshot:



That's it. Now that we have fixed our first UI bug, let's move on to the next task.

Adding the number of cities

What we need to do now is find a way to show an additional column in the **Countries** view that will allow the users to instantly see the *number of cities* for each listed *country*. In order to do that we definitely need to improve our *back-end* Web API, because we know that there's currently no way to retrieve such info from the server.

Well, technically speaking, there is a way: we could use the `CitiesController`'s `GetCities()` method with a huge `pageSize` parameter (99,999 or so) and a suitable filter to retrieve the whole amount of cities for each given country, then count that collection and output the number.

However, doing this would indeed have a *huge* performance impact: not only we would have to retrieve all the cities for all the listed *countries*, but we would have to do that by issuing a separate HTTP request for each table row. That's definitely not what we want if we are aiming to fulfill our task in a smart and efficient way.

Here's what we're going to do instead:

- Find a smart and efficient way to count the number of cities for each listed country from the *back-end*.
- Add a `totCities` property to our `Country` Angular *interface* to store that same number on the *client*.

Let's do this.

CountriesController

Let's start with the *back-end* part. Finding a *smart and efficient way* to count the number of cities for each country might be harder than it seems.

If we want to retrieve such value in a single shot, that is, without doing additional API requests with Angular, there's no doubt that we need to improve our current `CountriesController`'s `GetCountries()` method – which is what we're currently using to fetch the *countries* data.

Let's open our `/Controllers/CountriesController.cs` file and see how .NET Core and **Entity Framework Core (EF Core)** can help us to perform what we want.

Here's the `GetCountries()` method that we need to update:

```
public async Task<ActionResult<ApiResult<Country>>> GetCountries(
    int pageIndex = 0,
    int pageSize = 10,
    string sortColumn = null,
    string sortOrder = null,
    string filterColumn = null,
    string filterQuery = null)
{
    return await ApiResult<Country>.CreateAsync(
        _context.Countries,
        pageIndex,
        pageSize,
        sortColumn,
        sortOrder,
        filterColumn,
        filterQuery);
}
```

As we can see, there's no trace of `Cities`. Although we know that our `Country` entity contains a `Cities` property that is meant to store a list of *cities*, we also remember (from Chapter 4, *Data Model with Entity Framework Core*) that this property is set to `null`, since we've never told EF Core to load the entity's related data.

What if we do it now? We could be tempted to solve our issue by activating the *Eager Loading* pattern and fill our `Cities` property with actual values with which to feed our Angular client. Here's how we could do that:

```
return await ApiResult<Country>.CreateAsync(
    _context.Countries
        .Include(c => c.Cities),
    pageIndex,
    pageSize,
    sortColumn,
    sortOrder,
    filterColumn,
    filterQuery);
```

However, it doesn't take a genius to understand that such a workaround is hardly smart and efficient: a *country* entity might have lots of cities—sometimes *hundreds* of them. Do we really think it would be acceptable for our *back-end* to retrieve them all from the DBMS? Are we really going to flood our Angular *front-end* with those huge JSON arrays?

That's definitely a no-go: we can do better than that. Especially considering that, after all, we don't need to retrieve each country's whole cities' data to fulfill our goal: we just need to know their *number*.

Here's how we can do that:

```
[HttpGet]
public async Task<ActionResult<ApiResult<CountryDTO>>> GetCountries(
    int pageIndex = 0,
    int pageSize = 10,
    string sortColumn = null,
    string sortOrder = null,
    string filterColumn = null,
    string filterQuery = null)
{
    return await ApiResult<CountryDTO>.CreateAsync(
        _context.Countries
            .Select(c => new CountryDTO()
            {
                Id = c.Id,
                Name = c.Name,
                ISO2 = c.ISO2,
                ISO3 = c.ISO3,
                TotCities = c.Cities.Count
            }),
        pageIndex,
        pageSize,
        sortColumn,
        sortOrder,
        filterColumn,
        filterQuery);
}
```

As we can see, we went for a totally different approach: the `Include()` method is out of the way; now, instead of eagerly loading the cities, we're using the `Select()` method to *project* our resulting *countries* into a brand-new `CountryDTO` object that contains the exact same properties of its source, plus a new `TotCities` variable: that way we never get the cities, we only fetch their number.



It's also worth noting that, since we switched out our `Country` entity class for a new `CountryDTO` class, we had to change the `ApiResult` generic type (from `ApiResult<Country>` to `ApiResult<CountryDTO>`) in the method's return type.

Although this method is a bit more complex to pull off, it's definitely a *smart and efficient* way to deal with our task; the only downside is that we need to create the `CountryDTO` class, which doesn't exist yet.

Creating the `CountryDTO` class

From **Solution Explorer**, right-click on the `/Data/` folder, then add a new `CountryDTO.cs` file, open it, and fill it with the following content:

```
using System.Text.Json.Serialization;

namespace WorldCities.Data
{
    public class CountryDTO
    {
        public CountryDTO() { }

        #region Properties
        public int Id { get; set; }

        public string Name { get; set; }

        [JsonPropertyName("iso2")]
        public string ISO2 { get; set; }

        [JsonPropertyName("iso3")]
        public string ISO3 { get; set; }

        public int TotCities { get; set; }
        #endregion
    }
}
```

As we can see, the previous `CountryDTO` class contains most of the properties that are already provided by the `Country` entity class, without the `Cities` property – which we know we won't need here – and a single, additional `TotCities` property: it's a **Data Transfer Object (DTO) class** that serves only the purpose of feeding the client with (only) the data that we need to send.



As the name implies, a **DTO** is an object that carries data between processes. That's a widely used concept when developing web services and micro-services, where each HTTP call is an expensive operation that should always be *cut* to the bare minimum amount of required data.

The difference between DTOs and *business objects* and/or *data access objects* (such as *DataSets*, *DataTables*, *DataRow*s, *IQueryables*, *Entities*, and so on) is that a DTO should only store, serialize, and deserialize their own data.

It's worth noting that we had to use the `[JsonPropertyName]` attributes here as well, since this class will be converted to JSON and the `ISO2` and `ISO3` properties won't be converted in the way that we expect (as we've already seen in Chapter 5, *Fetching and Displaying Data*).

Angular front-end updates

It is time to switch to Angular and update the *front-end* accordingly, with the new changes applied to the *back-end*.

Follow these steps:

1. Open the `/ClientApp/src/app/countries/country.ts` file to add the `TotCities` property to the `Country` interface in the following way:

```
export interface Country {  
    id: number;  
    name: string;  
    iso2: string;  
    iso3: string;  
    totCities: number;  
}
```

2. Right after that, open the

/ClientApp/src/app/countries/countries.component.ts file and update the displayedColumns inner variable in the following way:

```
// ...existing code...

public displayedColumns: string[] = ['id', 'name', 'iso2',
  'iso3', ''totCities'';

// ...existing code...
```

3. Once done, open the

/ClientApp/src/app/countries/countries.component.html file and add the **TotCities** column to the *Angular Material's MatTable* template in the following way (updated lines are highlighted):

```
<!-- ...existing code... -->

<!-- Lon Column -->
<ng-container matColumnDef="iso3">
  <th mat-header-cell *matHeaderCellDef mat-sort-header>
    ISO 3
  </th>
  <td mat-cell *matCellDef="let country"> {{country.iso3}}
  </td>
</ng-container>

<!-- TotCities Column -->
<ng-container matColumnDef="totCities">
  <th mat-header-cell *matHeaderCellDef mat-sort-header>
    Tot. Cities
  </th>
  <td mat-cell *matCellDef="let country">
    {{country.totCities}}
  </td>
</ng-container>

<tr mat-header-row *matHeaderRowDef="displayedColumns"></tr>
<tr mat-row *matRowDef="let row; columns:
displayedColumns;"></tr>

<!-- ...existing code... -->
```

4. Now, we can finally hit *F5* and see the results of our hard work. If we did everything correctly, we should be able to see the new **Tot. Cities** column, as shown in the following screenshot:

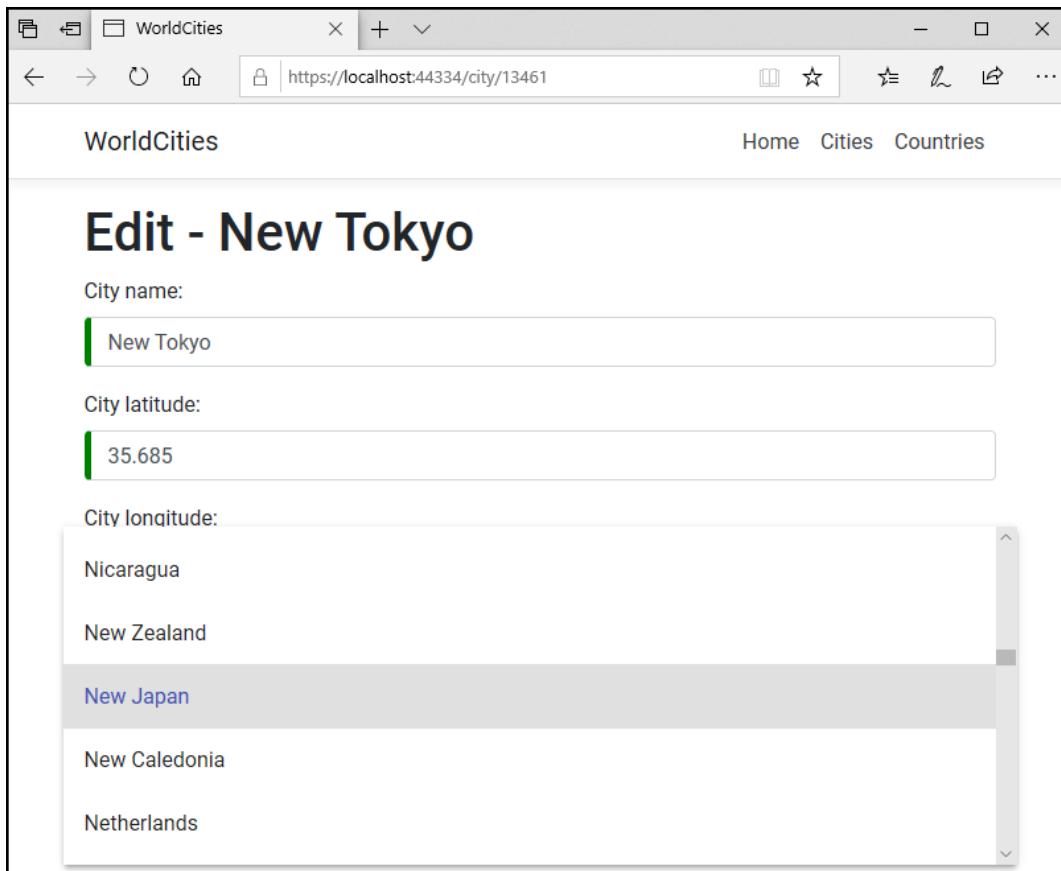
The screenshot shows a Microsoft Edge browser window titled "WorldCities". The address bar displays "https://localhost:44334/countries". The page content is titled "Countries" and contains a heading "Here's a list of countries: feel free to play with it.". A green button labeled "Add a new Country" is visible. Below the heading is a search input field with the placeholder "Filter by name (or part of it)...". The main content is a table with the following columns: ID, Name ↑, ISO 2, ISO 3, and Tot. Cities. The table lists 10 countries from the beginning of the list, each with its ID, name, ISO 2 code, ISO 3 code, and total number of cities. At the bottom of the table, there is a pagination control with "Items per page: 10" and navigation arrows.

ID	Name ↑	ISO 2	ISO 3	Tot. Cities
120	Afghanistan	AF	AFG	41
123	Albania	AL	ALB	26
173	Algeria	DZ	DZA	60
232	American Samoa	AS	ASM	1
118	Andorra	AD	AND	7
125	Angola	AO	AGO	49
122	Anguilla	AI	AIA	1
121	Antigua And Barbuda	AG	ATG	1
126	Argentina	AR	ARG	155
124	Armenia	AM	ARM	12

Items per page: 10 | < < > >|

Not bad at all: on top of that, the new column will also be *sortable*, meaning that we can order our *Countries* by the number of listed cities in *ascending* or *descending* order, using one or two clicks. Thanks to this new feature, we can learn that the **United States** is the country that has the most listed cities (4,864), while **New Japan**, the imaginary country that we created back in Chapter 6, *Forms and Data Validation*, still has zero.

While we're here, let's quickly fix this by going to the **Cities** view, using it to edit **New Tokyo**, and changing its *country* in the following way:



If we set the New Tokyo's *country* to **New Japan**, hit the **Save** button to apply the changes, and then go back to the **Countries** view, we should see that **New Japan** now has a single city (as shown in the following screenshot):

The screenshot shows a web browser window with the title "WorldCities". The address bar displays the URL "https://localhost:44334/countries". The main content area is titled "Countries" and contains the text "Here's a list of countries: feel free to play with it.". Below this is a green button labeled "Add a new Country". A search bar is present with the text "Filter by name (or part of it)...". The word "New Japan" is typed into the search bar. A table follows, showing the following data:

ID	Name	ISO 2	ISO 3	Tot. Cities
236	New Japan	NJ	NJP	1

At the bottom, there is a pagination control with the text "Items per page: 10" and a dropdown menu, followed by "1 - 1 of 1" and navigation arrows.

Now that we've successfully shown the number of cities for each *country* in our **Countries** views – and bound **New Japan** together with **New Tokyo** in the process – we're ready to move on to the third improvement.

However, before doing that, it could be useful to spend some time thinking about that *DTO class* that we had to create to fulfill our latest task.

DTO classes – should we really use them?

Now that we've seen how similar the *Country entity class* and the *CountryDTO class* actually are, we should be asking ourselves whether we could do something better than that. For example, we could inherit the *Country entity class* in the *CountryDTO class*, thus avoiding the repetition of four properties; or we could entirely avoid the *CountryDTO class*, and just add the *TotCities* property to the *Country entity* instead.

Well, the answer is **yes**: we could've definitely used those workarounds, thus avoiding the need to create additional properties (or classes) and keeping the code undeniably more *DRY*. Why we didn't do that?

The answer is rather simple: because both of the previous workarounds come with some relevant design and *security* flaws. Let's do our best to address them and understand why they should be avoided whenever we can.

Separation of concerns

As a general rule of thumb, *entity classes* shouldn't be burdened with properties that only exist to fulfill our *client-side* needs: whenever we need to create them, it's wise to create an intermediate class, and then separate the *Entity* from the output object that we send to the client through the Web APIs.



If we've worked with the ASP.NET MVC Framework, we can relate this *separation of concerns* with the one that distinguishes the **Model** from the **ViewModel** in the **Model-View-ViewModel (MVVM)** presentation pattern. The scenario is basically the same: both are simple classes with attributes, but they do have different audiences – the *controller* and the *view*. In our scenario, the *view* is nothing less than our Angular client.

Now, it goes without saying that putting a `TotCities` property within an *Entity* class would break that *separation of concerns*. There's no `TotCities` column in our `Countries` database table; that property would only be there to send some additional data to the *front-end*.

On top of that, there would be no relations between the `TotCities` property and the already existing `Cities` property: if we do activate the EF Core *Eager Loading* pattern and fill the `Cities` property, the `TotCities` property will be still set to zero (and vice versa); such misleading behavior would be a bad design choice and could even result in implementation errors for those who reasonably expect our *Entity classes* to be a C# version of our data source.

Security considerations

Keeping entity classes separate from the *client-side* API output classes is often a good choice, even for security purposes: now that we're dealing with *cities* and *countries*, we don't really suffer from it, but what if we were to handle a *users* table with personal and/or login data? If we think about it, there are a lot of possible scenarios where it wouldn't be wise to just pull the whole fields from the database and send them to the client in JSON format. The default methods created by .NET Core Web API Controllers when we add them from the Visual Studio interface – which is what we did in Chapter 4, *Data Model with Entity Framework Core* – don't care about that, which is perfectly fine for code samples and even simple API-based projects. However, when things become more complex, it's recommended to feed the client with limited data and in a controlled way.

That said, the most effective way to do that in .NET is to create and serve thinner, and more secure, *DTO classes* instead of the main *Entities*: this is precisely what we have done with the `CountryDTO` class in the preceding sections.

DTO classes versus anonymous types

The only acceptable alternative to the aforementioned *DTO classes* would be using the `Select()` method to *project* the main Entity classes to *anonymous types*, and serve them, instead.

Here's another version of the previous `CountriesController`'s `GetCountries()` method using an *anonymous type* instead of the `CountryDTO` class (relevant changes are highlighted in the following code):

```
[HttpGet]
public async Task<ActionResult<ApiResult<dynamic>>> GetCountries(
    int pageIndex = 0,
    int pageSize = 10,
    string sortColumn = null,
    string sortOrder = null,
    string filterColumn = null,
    string filterQuery = null)
{
    return await ApiResult<dynamic>.CreateAsync(
        _context.Countries
            .Select(c => new
            {
                id = c.Id,
                name = c.Name,
                iso2 = c.ISO2,
```

```
        iso3 = c.ISO3,
        totCities = c.Cities.Count
    }),
    pageIndex,
    pageSize,
    sortColumn,
    sortOrder,
    filterColumn,
    filterQuery);
}
```

As expected, we had to change our `ApiResult` generic type to `dynamic` in the code, and also in the method's *return value*; other than that, the preceding method seems to be fine and it will definitely work just like the previous one.

What should we use, then? *DTO classes* or *anonymous types*?

Truth to be told, both methods are perfectly fine: *anonymous types* can often be a great alternative, especially when we need to quickly define JSON return types; however, there are some specific scenarios (such as *unit testing*, as we're going to see later on) where we would prefer to deal with *named types* instead. The choice, as always, depends on the situation. In our current scenario, we'll stick to the `CountryDTO` class, but we're going to use *anonymous types* as well in the near future.



For additional info on the *anonymous types* in C#, read the following document:

<https://docs.microsoft.com/en-us/dotnet/csharp/programming-guide/classes-and-structs/anonymous-types>

Securing Entities

If we don't want to use *DTO classes*, and *anonymous types* aren't our cup of tea, there's a third viable alternative that we can consider: securing our *Entities* to prevent them from either giving wrong instructions (such as creating wrong columns) to EF Core, or sending too much data through our RESTful APIs: if we manage to do that, we could just continue to use them and keep our Web API code DRY.

We can achieve such a result by decorating our Entities' properties with some specific *Data Annotation attributes*, such as the following:

- `[NotMapped]`: Prevents EF Core from creating a *database column* for that property.
- `[JsonIgnore]`: Prevents a property from being serialized or deserialized.

- `[JsonPropertyName ("name")]`: Allows us to override the property name upon the JSON class serialization and deserialization, overriding the property name and any naming policy that is specified by the `JsonNamingPolicy` settings within the `Startup.cs` file.

The former attribute requires the `Microsoft.EntityFrameworkCore` namespace, while the others are part of the `System.Text.Json.Serialization` namespace.

We've already used the `[JsonPropertyName]` attribute back in Chapter 5, *Fetching and Displaying Data*, where we had to specify a JSON property name for the `ISO2` and `ISO3` properties of the `Country Entity`: let's implement the other two as well.

[NotMapped] and [JsonIgnore] attributes

Open the `/Data/Models/Country.cs` file and update the existing code at the end of the file as follows (new/updated lines are highlighted):

```
#region Client-side properties
/// <summary>
/// The number of cities related to this country.
/// </summary>
[NotMapped]
public int TotCities
{
    get
    {
        return (Cities != null)
            ? Cities.Count
            : _TotCities;
    }
    set { _TotCities = value; }
}

private int _TotCities = 0;
#endregion

#region Navigation Properties
/// <summary>
/// A list containing all the cities related to this country.
/// </summary>
[JsonIgnore]
public virtual List<City> Cities { get; set; }
#endregion
```

Here's what we did, in a nutshell:

- We have implemented the `TotCities` property in the *Entity* code and decorated it with the `[NotMapped]` attribute, so that EF Core won't create its corresponding database column upon any *migration* and/or *update* task.
- While we were there, we took the chance to write some additional logic to *link* this property to the `Cities` property value (only when it's not `null`): that way our *Entity* won't give misleading info, such as having 20+ cities in the `Cities` list property and a `TotCities` value of zero at the same time.
- Last but not least, we added the `[JsonIgnore]` attribute to the `Cities` properties, thus preventing such info from being sent to the client (regardless of its value – even when `null`).



The `[NotMapped]` attribute, which we've never used before, helps mitigate the fact that we're using an Entity to store the properties that are required by the *front-end*, and are therefore completely unrelated to the *Data Model*: in a nutshell, such an attribute will tell EF Core that we do not want to create a database column for that property in the database. Since we've created our database using EF Core's *Code-First* approach (see Chapter 4, *Data Model with Entity Framework Core*), and we're using *migrations* to keep the database structure updated, we need to use that attribute each and every time we want to create an *extra property* on our Entity classes. Whenever we forget to do that, we would definitely end with unwanted database fields.

Using `[JsonIgnore]` to prevent the server from sending away the `Cities` property might seem like overkill: why would we even want to skip such a value, since it's currently `null`?

As a matter of fact, we've taken this decision as a precaution: since we're directly using *Entities*, instead of relying upon *DTO classes* or *anonymous types*, we want to implement a restrictive approach with our data. Whenever we don't need it, it's wise to apply `[JsonIgnore]` to be sure we won't be disclosing anything more than we need to; we could call it a *Data Protection by Default* approach, which will hopefully help us to keep our Web API under control and prevent it from sharing too much. After all, we can always remove that attribute whenever we need to.

It goes without saying that, if we want to adopt the *Secured Entities* alternative approach, we won't need the `CountryDTO.cs` class anymore; therefore, we could *revert* the `/Controllers/CountriesController.cs` file's `GetCountries()` method, which we changed a short while ago, and put the `Country` reference back where it was:

```
return await ApiResult<Country>.CreateAsync(
    _context.Countries
        .Select(c => new Country()
    {
        Id = c.Id,
        Name = c.Name,
        ISO2 = c.ISO2,
        ISO3 = c.ISO3,
        TotCities = c.Cities.Count
    }),
    pageIndex,
    pageSize,
    sortColumn,
    sortOrder,
    filterColumn,
    filterQuery);
```



All three alternative implementations of the `GetCountries()` method that have been discussed in this section – `CountryDTO`, `dynamic`, and `Country` – are available in the `/Controllers/CountriesController.cs` file in the GitHub source code for Chapter07; the former is what we'll be using for this book's samples, while the other two have been commented out and put there for reference only: feel free to switch them at will!

That's it: now we can finally move on to our third and final task.

Adding the country name

Now, we need to find a way to add a `Country` column to the `Cities` view, so that our users will be able to see the *country* name for each listed city; considering what we just did with the *countries*, this should be a rather easy task.

CitiesController

As always, let's start with the Web API. Follow these steps:

1. Open the `/Controllers/CitiesController.cs` file and change the `GetCities()` method in the following way:

```
// ...existing code...

[HttpGet]
public async Task<ActionResult<ApiResult<CityDTO>>> GetCities(
    int pageIndex = 0,
    int pageSize = 10,
    string sortColumn = null,
    string sortOrder = null,
    string filterColumn = null,
    string filterQuery = null)
{
    return await ApiResult<CityDTO>.CreateAsync(
        _context.Cities
            .Select(c => new CityDTO()
            {
                Id = c.Id,
                Name = c.Name,
                Lat = c.Lat,
                Lon = c.Lon,
                CountryId = c.Country.Id,
                CountryName = c.Country.Name
            }),
        pageIndex,
        pageSize,
        sortColumn,
        sortOrder,
        filterColumn,
        filterQuery);
}

// ...existing code...
```

As we can see, we're sticking to the DTO-based pattern – meaning that we'll have to create an additional `CountryDTO` class.

2. Use the Visual Studio's **Solution Explorer** to add a new `/Data/CityDTO.cs` file and fill it with the following content:

```
namespace WorldCities.Data
{
    public class CityDTO
    {
        public CityDTO() { }

        public int Id { get; set; }

        public string Name { get; set; }

        public string Name_ASCII { get; set; }

        public decimal Lat { get; set; }

        public decimal Lon { get; set; }

        public int CountryId { get; set; }

        public string CountryName { get; set; }
    }
}
```

That's it: our Web API is ready, so let's move to Angular.



As we've seen when working with the `CountriesController`'s `GetCountries()` method early on, we could've implemented the Web API by using *anonymous types*, or with a secured `City` entity, thus avoiding having to write the `CityDTO` class.

Angular front-end updates

Let's start with the `/ClientApi/src/app/cities/city.ts` interface, where we need to add the `countryName` property; open that file, and update its content in the following way:

```
interface City {
    id: number;
    name: string;
    lat: number;
```

```
    lon: number;
    countryId: number;
countryName: string;
}
```

Once done, open the `/ClientApi/src/app/cities/cities.component.ts` class, where we need to add the `countryName` column definition:

```
// ...existing code...

public displayedColumns: string[] = ['id', 'name', 'lat', 'lon',
'countryName'];

// ...existing code...
```

Then, open the `/ClientApi/src/app/cities/cities.component.html` class and add a new `<ng-container>` accordingly:

```
<!-- ...existing code... -->

<!-- Lon Column -->
<ng-container matColumnDef="lon">
  <th mat-header-cell *matHeaderCellDef mat-sort-header>Longitude</th>
  <td mat-cell *matCellDef="let city"> {{city.lon}} </td>
</ng-container>

<!-- CountryName Column -->
<ng-container matColumnDef="countryName">
  <th mat-header-cell *matHeaderCellDef mat-sort-header>Country</th>
  <td mat-cell *matCellDef="let city">
    <a [routerLink]=["'/country",
      city.countryId"]>{{city.countryName}}</a>
  </td>
</ng-container>

<!-- ...existing code... -->
```

As we can see, we wrapped `countryName` within `routerLink`, pointing to the *Edit Country* view, so that our users will be able to use it as a navigation element.

Let's test what we did: hit *F5* to launch the app in *debug* mode, then go to the **Cities** view. If we did everything properly, we should be welcomed by the following result:

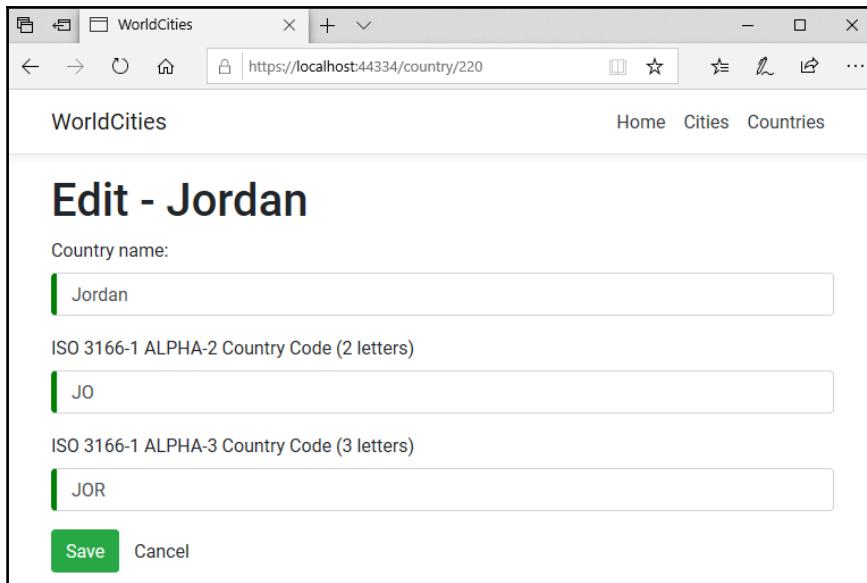
The screenshot shows a web browser window titled "WorldCities" at the URL <https://localhost:44334/cities>. The page has a header with "WorldCities" and navigation links for "Home", "Cities", and "Countries". Below the header, the word "Cities" is prominently displayed in a large font. A sub-header says "Here's a list of cities: feel free to play with it." A green button labeled "Add a new City" is located on the right. A search bar below the header contains the placeholder "Filter by name (or part of it)...". The main content is a table listing ten cities from the database:

ID	Name ↑	Latitude	Longitude	Country
7835	'Ajlūn	32.3333	35.7528	Jordan
3954	'Ajmān	25.4056	55.4618	United Arab Emirates
51	'Amrān	15.6594	43.9439	Yemen
4172	25 de Mayo	-37.8	-67.6833	Argentina
4092	28 de Noviembre	-51.65	-72.3	Argentina
6377	Aalborg	57.0337	9.9166	Denmark
5579	Aarau	47.3896	8.0524	Switzerland
5607	Aarau	47.39	8.034	Switzerland
7096	Aasiaat	68.7167	-52.8667	Greenland
1378	Aba	5.1004	7.35	Nigeria

At the bottom, there are pagination controls: "Items per page: 10" with a dropdown arrow, "1 – 10 of 12960", and navigation arrows.

Not bad, right?

From there, if we click on a *country name* – let's say, **Jordan** – we should be brought to the *Edit Country* view:



That's awesome!

This brings us to the end of the *minor* code improvements and UI tweaks: in the next section, we'll face a more demanding task, which will require a *code refactoring* of all the Angular Components that we've created so far.

In software development, *code refactoring* is the process of restructuring existing source code without changing its external behavior: there could be multiple reasons to perform *refactoring* activities, such as improving the code's readability, extensibility or performance, making it more secure, reducing its complexity, and so on.



For additional information regarding the *code refactoring* high-level concept, check out the following URL:

<https://docs.microsoft.com/en-us/visualstudio/ide/refactoring-in-visual-studio>

Data Services

The two web applications that we have created so far – `HealthCheck` in *Chapters 1 to 3* and `WorldCities` in *Chapters 4 to 7* – both feature *front-end to back-end* communication over the HTTP(S) protocol, and to establish such communication we made good use of the `HttpClient` class, a built-in Angular HTTP API client shipped with the `@angular/common/http` package that rests on the `XMLHttpRequest` interface.

The Angular's `HttpClient` class has a lot of benefits, including testability features, `request` and `response` typed objects, `request` and `response` interception, `Observable` APIs, and streamlined error handling. It can even be used without a *data server* thanks to the *in-memory Web API package*, which emulates CRUD operations over a RESTful API: we briefly talked about that at the beginning of *Chapter 4, Data Model with Entity Framework Core*, when we were asking ourselves if we really needed a *data server* or not (the answer was yes, therefore we didn't use it).

For all of the previously mentioned reasons, making good use of the `HttpClient` class is arguably the most logical choice for anyone who wants to develop a *front-end* web app using the Angular framework; that said, there are multiple ways to implement it, depending on how much we want to take advantage of its valuable features.

In this section, after a brief look at other available alternatives, we'll see how to refactor our app in order to replace our current `HttpClient` implementation to a more versatile approach, based upon a dedicated *HTTP Data Service*.

XMLHttpRequest versus Fetch (vs HttpClient)

As we said a moment ago, the Angular's `HttpClient` class is based on **XMLHttpRequest (XHR)**, an API consisting of an object that is provided by the browser through its JavaScript engine, which can be used to transfer data between a web browser and a web server in an *asynchronous* way, and without having to reload the whole page. This technique, which recently celebrated its 20-year anniversary, was basically the only available alternative until 2017, when the **Fetch API** eventually came out.

The Fetch API is another interface for fetching resources that aims to be a modern alternative to the `XMLHttpRequest` API, providing a more powerful and flexible feature set; in the next section, we'll quickly review both of them and discuss their pros and cons.

XMLHttpRequest

The concept behind it made its first appearance back in 1999, when Microsoft released the first version of **Outlook Web Access (OWA)** for MS Exchange Server 2000.

Here's an excerpt of a very old post written by Alex Hopmann, one of the developers who gave birth to it:

"XMLHTTP actually began its life out of the Exchange 2000 team. I had joined Microsoft in November 1996 and moved to Redmond in the spring of 1997 working initially on some Internet Standards stuff as related to the future of Outlook. I was specifically doing some work on meta-data for web sites including an early proposal called "Web Collections". During this time period Thomas Reardon one day dragged me down the hall to introduce me to this guy named Jean Paoli that had just joined the company. Jean was working on this new thing called XML that some people suspected would be very big some day (for some unclear reason at the time)."

– Alex Hopmann, The Story of XMLHttpRequest, <http://www.alexhopmann.com/xmlhttp.htm>

Alex was right: a few months later his team released an interface called `IXMLHTTPRequest`, which was implemented into the second version of the **Microsoft XML Core Services (MSXML)** library: that version was then shipped with Internet Explorer 5.0 in March 1999, which arguably was the first browser that was able to access that interface (through ActiveX).

Soon after that, the Mozilla project developed an interface called `nsIXMLHttpRequest`, and implemented it into their Gecko layout engine; this was very similar to the Microsoft interface, but it also came with a wrapper that allowed it to be used through JavaScript, thanks to an object that was returned by the browser. The object, which was made accessible on Gecko v0.6 on December 6, 2000, was called `XMLHttpRequest`.

In the following years, the `XMLHttpRequest` object became a *de facto* standard in all major browsers, being implemented in *Safari* 1.2 (February 2004), *Opera* 8.0 (April 2005), *iCab* 3.0b352 (September 2005), and *Internet Explorer* 7 (October 2006). These early adoptions allowed Google engineers to develop and release *Gmail* (2004) and *Google Maps* (2005), two pioneering web applications, which were entirely based upon the XMLHttpRequest API. A single look at these apps was enough to understand that web development had entered a new era.

The only missing thing for this exciting technology was a name, which was found on February 18, 2005, when Jesse James Garrett wrote an iconic article called *AJAX: A New Approach to Web Applications*.

This was the first known appearance of the term **AJAX**, the acronym for *Asynchronous JavaScript + XML*: a set of web-development techniques that can be used to create asynchronous web applications from the *client side*, where the XMLHttpRequest object played a pivotal role.

On April 5, 2006, the **World Wide Web Consortium (W3C)** released the first draft specification for the XMLHttpRequest object, in an attempt to create an official web standard.



The latest draft of the XMLHttpRequest object was published on 6 October, 2016, and is available at the following URL:

<https://www.w3.org/TR/2016/NOTE-XMLHttpRequest-20161006/>

The W3C draft paved the way to the wide adoption of AJAX development. However, the first implementations were rather difficult for most web developers, due to some relevant differences among the various browsers' implementation of the involved APIs. Luckily enough, things became a lot easier thanks to the many cross-browser JavaScript libraries – such as *jQuery*, *Axios*, and *MooTools* – that were smart enough to add it to their available set of tools: this allowed developers to use the underlying XMLHttpRequest object functionality indirectly, through a standardized set of high-level methods.

During the course of time, the XHR data format quickly switched from XML to JSON, HTML, and *plain text*, which were more suited to work with the DOM page, without changing the overall approach; also, when the **Reactive Extensions for JavaScript (RxJS)** library came out, the XMLHttpRequest object could be easily put behind Observable, thus gaining a lot of advantages (such as being able to mix and match it with other observables, *subscribe/unsubscribe*, *pipe/map*, and so on).

This is the main idea behind the Angular's `HttpClient` class, which can be described as *the Angular way to deal with XMLHttpRequest*: a very convenient wrapper that allows developers to effectively use it through the Observable pattern.

Fetch

During its early years, using the raw XMLHttpRequest object was rather difficult for most web developers, and could easily lead to a large amount of JavaScript source code which was often difficult to read and understand: these issues were eventually solved by the *superstructures* that were brought by libraries such as *jQuery* and the like, but at the cost of some inevitable code (and resource) overheads.

The Fetch API was released to address such issues in a cleaner way, using a *built-in, promise-based* approach, which could be used to perform the same *asynchronous* server requests in an easy way, without requiring third-party libraries.

Here's an example of an HTTP request using *XHR*:

```
var oReq = new XMLHttpRequest();
oReq.onload = function() {
    // success
    var jsonData = JSON.parse(this.responseText);
};
oReq.onerror = function() {
    // error
    console.error(err);
};
oReq.open('get', './api/myCmd', true);
oReq.send();
```

And here's the same request performed using *fetch*:

```
fetch('./api/myCmd')
.then((response) => {
    response.json().then((jsonData) => {
        // success
    });
})
.catch((err) => {
    // error
    console.error(err);
});
```

As we can see, the *fetch*-based code is definitely more readable. Its generic interfaces provide better consistency, the native JSON capabilities make the code more DRY, and the *Promises* it returns permit easier *chaining* and *async/await* tasks without having to define callbacks.

Long story short, it doesn't take a genius to see that, if we compare the raw XHR implementation with the brand-new *fetch()* API, the latter clearly wins.

HttpClient

However, thanks to the Angular's `HttpClient` class, using raw XHR is out of the question; what we'll use is the built-in abstraction that is provided by the client, which allows us to write the previous code in the following way:

```
this.http.get('./api/myCmd')
  .subscribe(jsonData => {
    // success
  },
  error => {
    // error
    console.error(error));
});
```

As we can see, the *Observable*-based code of `HttpClient` in the previous code provides similar benefits to the *fetch*-based code that we've seen before: we get a consistent interface, native JSON capabilities, *chaining*, and *async/await* tasks.

On top of that, *Observables* can be also converted into *Promises*, meaning that we could even do the following:

```
this.http.get('./api/myCmd')
  .toPromise()
  .then((response) => {
    response.json().then((jsonData) => {
      // success
    });
  })
  .catch((err) => {
    // error
    console.error(err);
});
```

At the same time, it's true that *Promises* can also be converted to *Observables* using the RxJS library.



All in all, both the *JavaScript-native* Fetch API and the *Angular-native* `HttpClient` class are perfectly viable and either of them can be effectively used in an Angular app.

Here are the major advantages of using **Fetch**:

- It's the *newest* industry standard that can be used to handle HTTP *requests* and *responses*.
- It's *JavaScript-native*, therefore, it can be used not only on *Angular*, but also on any other JavaScript-based *front-end* framework (such as *React*, *Vue*, and so on).
- It simplifies working with *service workers*, as the *Request* and *Response* objects are the same as the ones we are using in our normal code.
- It's built around the *norm* that HTTP requests have *single return values*, thus returning a *Promise* instead of a stream-like type, like the *Observer* is (this can be an advantage in most scenarios, but it can also become a con).

And here are the most relevant advantages of using `HttpClient`:

- It's *Angular-native*, and therefore widely supported and constantly updated by the framework (and it will most likely be in the future as well).
- It allows easy mixing and matching of multiple *Observables*.
- Its abstraction level allows us to easily implement some *HTTP magic* (such as defining *auto-retry* attempts in case of request failures).
- *Observers* are arguably more versatile and feature-rich than *Promises*, which can be useful in some complex scenarios, such as performing *sequencing calls*, being able to cancel HTTP *requests* after they have been sent, and so on.
- It can be *injected*, and therefore used to write *unit tests* for various scenarios.

For all of these reasons, after careful consideration, we genuinely think that adopting `HttpClient` in Angular might be a better choice, and therefore we'll be sticking to it for the rest of the book. That said, since the Fetch API is almost as viable in most scenarios, readers can definitely try both approaches and see which one is the most fitting for any given task.

For the sake of simplicity, we're not going any further with these topics. Those who wants to know more about *XMLHttpRequest*, *Fetch API*, *Observables*, and *Promises* are encouraged to check out the following URIs:

**XMLHttpRequest Living Standard (September 24, 2019):**

<https://xhr.spec.whatwg.org/>

Fetch API - Concepts and usage:

https://developer.mozilla.org/en-US/docs/Web/API/Fetch_API

RxJS - Observable:

<http://w3sdesign.com/?gr=b07ugr=proble>

MDN - Promise:

https://developer.mozilla.org/en-US/docs/Web/JavaScript/Reference/Global_Objects/Promise

Building a Data Service

Since we've chosen to stick with the Angular's `HttpClient` class that we've already used everywhere, it means we're good, right?

Well, as a matter of fact, no. Although using `HttpClient` is definitely a good choice, we have implemented it using an oversimplified approach. If we look at our Angular source code, we can see how the actual HTTP calls are placed inside the *Components*, which could be acceptable for small-scale sample apps but it's definitely not the best way of doing it in real-life scenarios. What if we want to handle the HTTP errors in a more complex way (for example, sending them all to a remote server for statistical purposes)? What if we need to *cache* and/or *post-process* the data that we fetch through the *back-end API*? Not to mention the fact that we would definitely implement a retry logic in order to deal with potential connectivity issues – which is a typical requirement of any *Progressive Web App*.

Shall we implement all of the previous stuff within each *Component's* set of methods? That's definitely not an option if we want to stick to the DRY pattern; maybe we could define a *superclass*, provide it with HTTP capabilities, and adapt our *subclasses*, source code to perform everything by calling the *super* methods with a bunch of highly customized parameters. Such a workaround could work for small tasks, but it could easily become a mess once things become more complex.

As a general rule, we should try our best to prevent our *TypeScript* classes – be them *standard*, *super*, or *sub* – from being cluttered with huge amounts of data access code; as soon as we fall into that pit, our Component will become much more difficult to understand, and we will have a hard time whenever we want to upgrade, standardize, and/or test them. In order to avoid such an outcome, it's highly advisable to separate the *Data Access Layer* from the *Data Presentation Logic*, which can be done by encapsulating the former in a separate service, and then *injecting* that service in the Component itself.

This is precisely what we're about to do.

Creating the BaseService

Since we're dealing with multiple Component classes that handle different tasks depending on their *context* (that is, the data source that they need to access), it's highly advisable to create multiple services: one for each *context*.

More specifically, we'll need the following:

- `CityService`, to deal with the *city-related* Angular Components and .NET Core Web APIs.
- `CountryService`, to deal with the *country-related* Angular Components and .NET Core Web APIs.

Also, assuming that they will most likely have some relevant things in common, it might be useful to provide them both with a *superclass* that will act as a *common interface*. Let's do it.

Using an abstract superclass as a common interface might seem a bit counter intuitive: why don't we just create an *interface*, then? We already have two of them, for *cities* (`/citirs/city.ts`) and *countries* (`/countries/country.ts`).



As a matter of fact, we did that for a good reason: [Angular does not allow us to provide interfaces as providers](#), because interfaces aren't compiled into the JavaScript output of TypeScript; therefore, to create an *interface* for a *service* to an interface, the most effective way to do that is to use an *abstract class*.

From **Solution Explorer**, browse to the `/ClientApp/src/app/` folder, *right-click* to create a new `base.service.ts` file, and fill its contents with the following code:

```
import { Injectable } from '@angular/core';
import { HttpClient } from '@angular/common/http';

@Injectable()
export abstract class BaseService {
  constructor(
    protected http: HttpClient,
    protected baseUrl: string
  ) {
  }
}
```

The previous source code (minus the `abstract` and `protected` highlighted modifiers) is also the *core* of a typical HTTP Data Service: we're going to use it as a *base class* with which to extend our service classes; more precisely, we'll have a single *superclass* (`BaseService`) containing a *common interface* for the two different *superclasses* (`CityService` and `CountryService`) that will be injected in our *Components*.

The `@Injectable` decorator that we've used before the class declaration will tell Angular that this class is going to provide an *injectable* service that can be used, through *dependency injection*, by other classes and Components.

As for the two highlighted modifiers, let's try to shed some light on them:

- **abstract**: In TypeScript, an abstract class is a class that may have some unimplemented methods: these methods are called *abstract methods*. Abstract classes can't be created as instances, but other classes can extend the abstract class, and therefore reuse its constructor and members.
- **protected**: The `HttpClient` class will be required by all the service *subclasses*, therefore, it's the first member that we're going to make available to them (and also the only one, at least for now). In order to do that, we need to use an *access modifier* that allows the subclasses to use it. In our sample we've used `protected`, but we could've used `public`, as well.

Before going any further, it might be useful to briefly recap how many *access modifiers* are supported by TypeScript and how they actually work; if we already know them from C# or other OO programming languages, it'll be a familiar story for the most part.

TypeScript access modifiers

Access modifiers are a TypeScript concept that allow developers to declare methods and properties as *public*, *private*, *protected*, and *read-only*. If no modifier is provided, then the method or property is assumed to be *public*, meaning that it can be accessed internally and externally without issues. Conversely, if it is marked as *private*, that method or property will be only accessible within the class, *not including its subclasses* (if any). *Protected* implies that the method or property is accessible only internally *within the class and all its subclasses*, that is, any class that extends it, but not externally. Finally, *read-only* will cause the TypeScript compiler to throw an error if the value of the property is changed after its initial assignment in the class constructor.

However, it's important to keep in mind that *these access modifiers will be enforced only at compile-time*. The TypeScript transpiler will warn us about all inappropriate uses, but it won't be able to stop inappropriate usage at runtime.

Adding the common interface methods

Let's now expand our `BaseService` *common interface* with some high-level methods that correspond to what we'll need to do in our subclasses. Since the *Components* we're refactoring are already there, the best way to define these *common interface methods* is by reviewing their source code, and acting accordingly.

Here's a good start:

```
import { Injectable } from '@angular/core';
import { HttpClient } from '@angular/common/http';
import { Observable } from 'rxjs';

@Injectable()
export abstract class BaseService {
  constructor(
    protected http: HttpClient,
    protected baseUrl: string
  ) {}

  abstract getData<ApiResult>(
    pageIndex: number,
    pageSize: number,
    sortColumn: string,
    sortOrder: string,
    filterColumn: string,
    filterQuery: string): Observable<ApiResult>;
}
```

```
abstract get<T>(id: number): Observable<T>;
abstract put<T>(item: T): Observable<T>;
abstract post<T>(item: T): Observable<T>;
}

interface ApiResult<T> {
  data: T[];
  pageIndex: number;
  pageSize: number;
  totalCount: number;
  totalPages: number;
  sortColumn: string;
  sortOrder: string;
  filterColumn: string;
  filterQuery: string;
}
```

Let's briefly review each one of the preceding abstract methods:

- `getData<ApiResult>()`: This is meant to replace our current implementation for the `getData()` methods in our `CitiesComponent` and `CountriesComponent` TypeScript files to retrieve, respectively, the `cities` and `countries` lists. As we can see, we took the chance to specify a new *strongly typed* interface – `ApiResult` – which will be populated with the structured JSON output that we already receive from the `GetCities` and `GetCountries` .NET Core Web APIs.
- `get<T>()`: This will replace our current implementation for the `loadData()` methods of our `CityEditComponent` and `CountryEditComponent` TypeScript files.
- `put<T>()` and `post<T>()`: These will replace our current implementations for the `submit()` methods of our `CityEditComponent` and `CountryEditComponent` TypeScript files.

Since we're using a good amount of generic-type variables, it can be useful to briefly recap what they are and how they can help us to define our common interfaces.

Type variables and generic types – `<T>` and `<any>`

It's worth noting that for the `get`, `put`, and `post` methods, we didn't use a *strongly typed* interface, but we went for a *type variable* instead; we were kind of forced to do that because these methods will return either a `City` or a `Country` interface, depending on the *derived* class that will implement them.

Taking that into account, we will choose to use `<T>`, instead of `<any>`, so that we won't lose the information about what that type was when the function returns. The `<T>` generic type allows us to defer the specification of the returned variable type until the class or method is declared and instantiated by the client code, meaning that *we'll be able to capture the type of the given argument whenever we implement the method in the derived class* (that is, when we know what is being returned).



The type `<T>` variable is a great way to deal with unknown types in an interface, to the point that we've also used it in the preceding `ApiResult` Angular interface – just like we did in the `/Data/ApiResult.cs` C# file in the .NET Core back-end.

These concepts are nothing new, since we've already used them in our *back-end* code: it's just great that we can also use them on the Angular *front-end*, thanks to the TypeScript programming language.

Why return Observables and not JSON?

Before moving on, it could be wise to briefly explain why we've chosen to return `Observable` types instead of the actual *JSON-based interfaces* that we already have, such as `City`, `Country`, and `ApiResult`: wouldn't it be a more practical choice?

As a matter of fact, it's the exact opposite: our *interface* types do have extremely limited options if we compare them to the feature-rich `Observable` collections that we talked about earlier on. Why would we want to limit ourselves – and the Components that will call these methods? Even if we wanted (or needed) to actually execute the HTTP call and retrieve the data from within them, we could always re-create `Observable`, and return it after such a task: we'll talk more about that in the next chapters.

Creating the CityService

Let's now create our first derived service, that is, our first `BaseService`'s *derived* class (or *subclass*).

From **Solution Explorer**, browse to the `/ClientApp/src/app/cities/` folder, *right-click* to create a new `city.service.ts` file, and fill it with the following code:

```
import { Injectable, Inject } from '@angular/core';
import { HttpClient, HttpParams } from '@angular/common/http';
import { BaseService, ApiResult } from '../base.service';
import { Observable } from 'rxjs';
```

```
@Injectable({
  providedIn: 'root',
})
export class CityService
  extends BaseService {
constructor(
  http: HttpClient,
  @Inject('BASE_URL') baseUrl: string) {
  super(http, baseUrl);
}

getData<ApiResult>(
  pageIndex: number,
  pageSize: number,
  sortColumn: string,
  sortOrder: string,
  filterColumn: string,
  filterQuery: string
): Observable<ApiResult> {
  var url = this.baseUrl + 'api/Cities';
  var params = new HttpParams()
    .set("pageIndex", pageIndex.toString())
    .set("pageSize", pageSize.toString())
    .set("sortColumn", sortColumn)
    .set("sortOrder", sortOrder);

  if (filterQuery) {
    params = params
      .set("filterColumn", filterColumn)
      .set("filterQuery", filterQuery);
  }

  return this.http.get<ApiResult>(url, { params });
}

get<City>(id): Observable<City> {
  var url = this.baseUrl + "api/Cities/" + id;
  return this.http.get<City>(url);
}

put<City>(item): Observable<City> {
  var url = this.baseUrl + "api/Cities/" + item.id;
  return this.http.put<City>(url, item);
}

post<City>(item): Observable<City> {
  var url = this.baseUrl + "api/Cities/" + item.id;
  return this.http.post<City>(url, item);
```

```
    }  
}
```

The most relevant aspect of the preceding source code is the `providedIn` property in the service's `@Injectable()` decorator, which we've set to `root`: this will tell Angular to provide this injectable in the application root, thus making it a *singleton* service, by all means.



A *singleton* service is a service for which only one instance exists in an app: in other words, Angular will create only one instance of that service, which will be shared to all the Components that will use it (through *dependency injection*) in our application. Although Angular services are not required to be singleton, such a technique provides an efficient use of memory and good performance, thus being the most used implementation approach.



For additional info about singleton services, check out the following URL:

<https://angular.io/guide/singleton-services>

Other than that, there's nothing new in the preceding code: we just copied (and slightly adapted) the implementation that already exists in our `CitiesComponent` and `CityEditComponent` TypeScript files. The main difference is that we're now using `HttpClient` there, meaning that we can remove it from the Component classes and abstract its usage with `CityService` instead.

Implementing the CityService

Let's now refactor our Angular Components to use our brand-new `CityService` instead of the raw `HttpClient`. As we'll be able to see in a short while, the new singleton services pattern that we used (and talked about) earlier will make things slightly easier than before.

AppModule

In Angular versions prior to 6.0, the only way to make a *singleton* service available throughout the app would've been referencing it within the `AppModule` file in the following way:

```
// ...existing code...

import { CityService } from './cities/city.service';

// ...existing code...

providers: [ CityService ],

// ...existing code...
```

As we can see, we should've added the `import` statement for the new service at the beginning of the `AppModule` file, and also registered the service itself in the existing (yet still empty) `providers: []` section.

Luckily enough, since we've used the `providedIn: root` approach that was introduced with Angular 6.0, the previous technique is no longer required – although it is still supported as a viable alternative.

As a matter of fact, the `providedIn: root` approach is preferable, because it makes our service *tree-shakable*. **Tree shaking** is a method of optimizing the JavaScript-compiled code bundles by eliminating any code from the final file that isn't actually being used.



For additional info about tree shaking in JavaScript, take a look at the following URL:

https://developer.mozilla.org/en-US/docs/Glossary/Tree_shaking

Long story short, thanks to the new approach we don't have to update the `AppModule` file anymore: we just need to refactor the Components that will use the service.

CitiesComponent

From **Solution Explorer**, open the /ClientApp/src/app/cities/cities.component.ts file and update its content accordingly:

```
import { Component, Inject, ViewChild } from '@angular/core';
// import { HttpClient, HttpParams } from '@angular/common/http';
import { MatTableDataSource } from '@angular/material/table';
import { MatPaginator, PageEvent } from '@angular/material/paginator';
import { MatSort } from '@angular/material/sort';

import { City } from './city';
import { CityService } from './city.service';
import { ApiResult } from '../base.service';

@Component({
  selector: 'app-cities',
  templateUrl: './cities.component.html',
  styleUrls: ['./cities.component.css']
})

// ...existing code...

constructor(
  private cityService: CityService) {
}

// ...existing code...

getData(event: PageEvent) {

  var sortColumn = (this.sort)
    ? this.sort.active
    : this.defaultSortColumn;

  var sortOrder = (this.sort)
    ? this.sort.direction
    : this.defaultSortOrder;

  var filterColumn = (this.filterQuery)
    ? this.defaultFilterColumn
    : null;

  var filterQuery = (this.filterQuery)
    ? this.filterQuery
    : null;
```

```
    this.cityService.getData<ApiResult<City>>(
      event.pageIndex,
      event.pageSize,
      sortColumn,
      sortOrder,
      filterColumn,
      filterQuery)
      .subscribe(result => {
        this.paginator.length = result.totalCount;
        this.paginator.pageIndex = result.pageIndex;
        this.paginator.pageSize = result.pageSize;
        this.cities = new MatTableDataSource<City>(result.data);
      }, error => console.error(error));
    }
}
```

As we can see, we just had to perform some minor updates:

- In the `import` section, we added some references to our new files.
- In the constructor, we switched the existing `http` variable of the `HttpClient` type with a brand-new `cityService` variable of `CityService` type: we could also keep the old variable name and just change the type, but we preferred to change that as well, to avoid confusion.
- Since we're not dealing with the `HttpClient` directly anymore, we don't need `BASE_URL` to be injected in this `Component` class; therefore, we removed the DI entry from the constructor's parameters.
- Last but not least, we changed the `getData()` method's existing implementation—based upon the `HttpClient`—with a new one relying upon the new `CityService`.

It's worth noting that we have commented out all the `import` references from the `@angular/common/http` package, simply because we don't need them anymore now that we're not directly using that stuff in this class.

CityEditComponent

Implementing `CityService` in `CityEditComponent` is going to be just as easy as it was for `CitiesComponents`.

From **Solution Explorer**, open the `/ClientApp/src/app/cities/city-edit.component.ts` file and update its content accordingly:

```
import { Component, Inject } from '@angular/core';
import { HttpClient, HttpParams } from '@angular/common/http';
import { ActivatedRoute, Router } from '@angular/router';
import { FormGroup, FormControl, Validators, AbstractControl,
AsyncValidatorFn } from '@angular/forms';
import { Observable } from 'rxjs';
import { map } from 'rxjs/operators';
import { BaseFormComponent } from '../base.form.component';

import { City } from './city';
import { Country } from '../countries/country';
import { CityService } from './city.service';
import { ApiResult } from '../base.service';

// ...existing code...

constructor(
  private activatedRoute: ActivatedRoute,
  private router: Router,
  private http: HttpClient,
  private cityService: CityService,
  @Inject('BASE_URL') private baseUrl: string) {
  super();
}

// ...existing code...

onSubmit() {

  var city = (this.id) ? this.city : <City>{};

  city.name = this.form.get("name").value;
  city.lat = +this.form.get("lat").value;
  city.lon = +this.form.get("lon").value;
  city.countryId = +this.form.get("countryId").value;

  if (this.id) {
    // EDIT mode
    this.cityService
      .put<City>(city)
      .subscribe(result => {

        console.log("City " + city.id + " has been updated.");
        // go back to cities view
      });
  }
}
```

```
        this.router.navigate(['/cities']);
    }, error => console.log(error));
}
else {
    // ADD NEW mode
    this.cityService
        .post<City>(city)
        .subscribe(result => {

            console.log("City " + result.id + " has been created.");

            // go back to cities view
            this.router.navigate(['/cities']);
        }, error => console.log(error));
}
}

// ...existing code...
```

As we can see, this time we weren't able to get rid of the `@angular/common/http` package reference, because we still need `HttpClient` to perform some specific tasks – `loadCountries()` and `isDupeCity()` – that we can't handle with our current service. In order to fix these issues, it definitely seems like we need to implement two more methods in `CityService`.

Let's do this!

Implementing `loadCountries()` and `IsDupeCity()` in `CityService`

From **Solution Explorer**, open the `/ClientApp/src/app/cities/city.service.ts` file and add the following methods at the end of the file, just before the last curly bracket:

```
// ...existing code...

getCountries<ApiResult>(
    pageIndex: number,
    pageSize: number,
    sortColumn: string,
    sortOrder: string,
    filterColumn: string,
    filterQuery: string
): Observable<ApiResult> {
    var url = this.baseUrl + 'api/Countries';
    var params = new HttpParams()
        .set("pageIndex", pageIndex.toString())
        .set("pageSize", pageSize.toString())
        .set("sortColumn", sortColumn)
        .set("sortOrder", sortOrder)
        .set("filterColumn", filterColumn)
        .set("filterQuery", filterQuery);
    return this.httpClient.get(url, {params: params});
}

isDupeCity(city: City): boolean {
    return this.cities.find(c => c.id === city.id) !== null;
}
```

```
.set("pageSize", pageSize.toString())
.set("sortColumn", sortColumn)
.set("sortOrder", sortOrder);

if (filterQuery) {
  params = params
    .set("filterColumn", filterColumn)
    .set("filterQuery", filterQuery);
}

return this.http.get<ApiResult>(url, { params });
}

isDupeCity(item): Observable<boolean> {
  var url = this.baseUrl + "api/Cities/IsDupeCity";
  return this.http.post<boolean>(url, item);
}
```

With this new service method, we can patch our `CityEditComponent` class file in the following way:

```
import { Component, Inject } from '@angular/core';
// import { HttpClient, HttpParams } from '@angular/common/http';

// ...existing code...

constructor(
  private activatedRoute: ActivatedRoute,
  private router: Router,
  private cityService: CityService) {
  super();
}

// ...existing code...

loadCountries() {
  // fetch all the countries from the server
  this.cityService.getCountryList<ApiResult<Country>>(
    0,
    9999,
    "name",
    null,
    null,
    null,
  ).subscribe(result => {
    this.countries = result.data;
  }, error => console.error(error));
}
```

```
// ...existing code...

isDupeCity(): AsyncValidatorFn {
  return (control: AbstractControl): Observable<{ [key: string]: any } | null> => {

    var city = <City>{};
    city.id = (this.id) ? this.id : 0;
    city.name = this.form.get("name").value;
    city.lat = +this.form.get("lat").value;
    city.lon = +this.form.get("lon").value;
    city.countryId = +this.form.get("countryId").value;

    return this.cityService.isDupeCity(city)
      .pipe(map(result => {
        return (result ? { isDupeCity: true } : null);
      }));
  }
}
```

And that's it! Now, we are able to remove the `@angular/common/http` references, the `HttpClient` usage, and the `BASE_URL` injected parameter from our `CityEditComponent` code.

In the next section, we'll do the same with the *country-related* components.



Before going further, it could be wise to check what we have done so far by hitting *F5*, and ensuring that everything is still working like before. If we did everything correctly, we should see no differences: our new `CityService` should be able to transparently perform all the tasks that were previously handled by `HttpClient`; that's expected since we're still using it under the hood!

Creating the CountryService

It's now time to create `CountryService`, which will be our second – and last – `BaseService`'s *derived* class (or *subclass*).

From **Solution Explorer**, browse to the `/ClientApp/src/app/countries/` folder, *right-click* to create a new `country.service.ts` file, and fill it with the following code:

```
import { Injectable, Inject } from '@angular/core';
import { HttpClient, HttpParams } from '@angular/common/http';
import { BaseService, ApiResult } from '../base.service';
import { Observable } from 'rxjs';

import { Country } from './country';

@Injectable({
  providedIn: 'root',
})
export class CountryService
  extends BaseService {
  constructor(
    http: HttpClient,
    @Inject('BASE_URL') baseUrl: string) {
    super(http, baseUrl);
  }

  getData<ApiResult>(
    pageIndex: number,
    pageSize: number,
    sortColumn: string,
    sortOrder: string,
    filterColumn: string,
    filterQuery: string
  ): Observable<ApiResult> {
    var url = this.baseUrl + 'api/Countries';
    var params = new HttpParams()
      .set("pageIndex", pageIndex.toString())
      .set("pageSize", pageSize.toString())
      .set("sortColumn", sortColumn)
      .set("sortOrder", sortOrder);

    if (filterQuery) {
      params = params
        .set("filterColumn", filterColumn)
        .set("filterQuery", filterQuery);
    }

    return this.http.get<ApiResult>(url, { params });
  }

  get<Country>(id): Observable<Country> {
    var url = this.baseUrl + "api/Countries/" + id;
```

```
        return this.http.get<Country>(url);
    }

    put<Country>(item): Observable<Country> {
        var url = this.baseUrl + "api/Countries/" + item.id;
        return this.http.put<Country>(url, item);
    }

    post<Country>(item): Observable<Country> {
        var url = this.baseUrl + "api/countries/" + item.id;
        return this.http.post<Country>(url, item);
    }

    isDupeField(countryId, fieldName, fieldValue): Observable<boolean> {
        var params = new HttpParams()
            .set("countryId", countryId)
            .set("fieldName", fieldName)
            .set("fieldValue", fieldValue);
        var url = this.baseUrl + "api/Countries/IsDupeField";
        return this.http.post<boolean>(url, null, { params });
    }
}
```

As we can see, this time we went ahead of time and took the chance to directly add the `isDupeField()` method, since we're definitely going to need it to refactor the validator of our `CountryEditComponent` in a short while.

As always, now that we have created the service, we need to implement it within our app. Luckily enough, as we already explained earlier on, we don't have to reference it in our `AppModule` file, we just need to properly implement it in our country-related components.

CountriesComponent

From **Solution Explorer**, open the

`/ClientApp/src/app/countries/countries.component.ts` file and update its content accordingly:

```
import { Component, Inject, ViewChild } from '@angular/core';
// import { HttpClient, HttpHeaders } from '@angular/common/http';
import { MatTableDataSource } from '@angular/material/table';
import { MatPaginator, PageEvent } from '@angular/material/paginator';
import { MatSort } from '@angular/material/sort';

import { Country } from './country';
import { CountryService } from './country.service';
```

```
import { ApiResult } from '../base.service';

@Component({
  selector: 'app-countries',
  templateUrl: './countries.component.html',
  styleUrls: ['./countries.component.css']
})
export class CountriesComponent {
  public displayedColumns: string[] = ['id', 'name', 'iso2', 'iso3',
'totCities'];
  public countries: MatTableDataSource<Country>;

  defaultPageIndex: number = 0;
  defaultPageSize: number = 10;
  public defaultSortColumn: string = "name";
  public defaultSortOrder: string = "asc";

  defaultFilterColumn: string = "name";
  filterQuery: string = null;

  @ViewChild(MatPaginator) paginator: MatPaginator;
  @ViewChild(MatSort) sort: MatSort;

  constructor(
    private countryService: CountryService) {
  }

  ngOnInit() {
    this.loadData(null);
  }

  loadData(query: string = null) {
    var pageEvent = new PageEvent();
    pageEvent.pageIndex = this.defaultPageIndex;
    pageEvent.pageSize = this.defaultPageSize;
    if (query) {
      this.filterQuery = query;
    }
    this.getData(pageEvent);
  }

  getData(event: PageEvent) {

    var sortColumn = (this.sort)
      ? this.sort.active
      : this.defaultSortColumn;

    var sortOrder = (this.sort)
```

```
    ? this.sort.direction
    : this.defaultSortOrder;

var filterColumn = (this.filterQuery)
    ? this.defaultFilterColumn
    : null;

var filterQuery = (this.filterQuery)
    ? this.filterQuery
    : null;

this.countryService.getData<ApiResult<Country>>(
    event.pageIndex,
    event.pageSize,
    sortColumn,
    sortOrder,
    filterColumn,
    filterQuery)
    .subscribe(result => {
        this.paginator.length = result.totalCount;
        this.paginator.pageIndex = result.pageIndex;
        this.paginator.pageSize = result.pageSize;
        this.countries = new MatTableDataSource<Country>(result.data);
    }, error => console.error(error));
}
}
```

Nothing new here, we just repeated what we did on the `CitiesComponent` a short while ago.

CountryEditComponent

From **Solution Explorer**, open the `/ClientApp/src/app/countries/country-edit.component.ts` file and change its content in the following way:

```
import { Component, Inject } from '@angular/core';
// import { HttpClient, HttpParams } from '@angular/common/http';
import { ActivatedRoute, Router } from '@angular/router';
import { FormBuilder, Validators, AbstractControl, AsyncValidatorFn } from '@angular/forms';
import { map } from 'rxjs/operators';
import { Observable } from 'rxjs';
import { BaseFormComponent } from '../base.form.component';

import { Country } from '../countries/country';
import { CountryService } from './country.service';
```

```
@Component({
  selector: 'app-country-edit',
  templateUrl: './country-edit.component.html',
  styleUrls: ['./country-edit.component.css']
})
export class CountryEditComponent
  extends BaseFormComponent {

  // the view title
  title: string;

  // the form model
  form = this.fb.group({
    name: ['', Validators.required,
      this.isDupeField("name")]
  ],
  iso2: ['', [
    Validators.required,
    Validators.pattern('[a-zA-Z]{2}')],
  ],
  this.isDupeField("iso2")
  ],
  iso3: ['', [
    Validators.required,
    Validators.pattern('[a-zA-Z]{3}')],
  ],
  this.isDupeField("iso3")
  ]
});

// the city object to edit or create
country: Country;

// the city object id, as fetched from the active route:
// It's NULL when we're adding a new country,
// and not NULL when we're editing an existing one.
id?: number;

constructor(
  private fb: FormBuilder,
  private activatedRoute: ActivatedRoute,
  private router: Router,
  private countryService: CountryService) {
  super();
}
```

```
ngOnInit() {
  this.loadData();
}

loadData() {

  // retrieve the ID from the 'id'
  this.id = +this.activatedRoute.snapshot.paramMap.get('id');
  if (this.id) {
    // EDIT MODE

    // fetch the country from the server
    this.countryService.get<Country>(this.id)
      .subscribe(result => {
        this.country = result;
        this.title = "Edit - " + this.country.name;

        // update the form with the country value
        this.form.patchValue(this.country);
      }, error => console.error(error));
  }
  else {
    // ADD NEW MODE

    this.title = "Create a new Country";
  }
}

onSubmit() {

  var country = (this.id) ? this.country : <Country>{};

  country.name = this.form.get("name").value;
  country.iso2 = this.form.get("iso2").value;
  country.iso3 = this.form.get("iso3").value;

  if (this.id) {
    // EDIT mode
    this.countryService
      .put<Country>(country)
      .subscribe(result => {

        console.log("Country " + country.id + " has been updated.");

        // go back to cities view
        this.router.navigate(['/countries']);
      }, error => console.log(error));
  }
}
```

```
        else {
          // ADD NEW mode
          this.countryService
            .post<Country>(country)
            .subscribe(result => {

              console.log("Country " + result.id + " has been created.");

              // go back to cities view
              this.router.navigate(['/countries']);
            }, error => console.log(error));
        }
      }

isDupeField(fieldName: string): AsyncValidatorFn {
  return (control: AbstractControl): Observable<{ [key: string]: any } | null> => {

    var countryId = (this.id) ? this.id.toString() : "0";

    return this.countryService.isDupeField(
      countryId,
      fieldName,
      control.value)
      .pipe(map(result => {
        return (result ? { isDupeField: true } : null);
      }));
  }
}
```

As we can see, the code changes that we applied here are very similar to what we did in `CityEditComponent`: since we took the chance to preventively add the `isDupeField()` method in our `CountryService` class, this time we were able to get rid of the `@angular/common/http` package in a single shot.

That's it, at least for now. In the next chapter, we'll make good use of these new services. However, before going further, you are strongly advised to perform some debug runs (by hitting *F5*) in order to ensure that everything is still working.

Summary

In this chapter, we have spent some valuable time consolidating the existing source code of our WorldCities Angular app: we successfully implemented some optimizations and tweaks by making good use of the TypeScript class inheritance features: we learned how to create base classes (*superclasses*) and derived classes (*subclasses*), thus making our source code more maintainable and DRY. At the same time, we took the chance to perform some bug-fixing and add a couple of new features to our app's UI.

Right after that, we refined the data-fetching capabilities of our Angular app, by switching from a direct usage of the Angular's `HttpClient` class in our components, to a more versatile *service-based* approach: eventually, we created `CityService` and `CountryService` – both extending a `BaseService` abstract class – to deal with all the HTTP requests, thus paving the way for post-processing, error handling, retry logic, and more interesting stuff that will be introduced in the upcoming chapter.

Suggested topics

Object-oriented programming, polymorphism, inheritance, AJAX, XMLHttpRequest, Fetch API, Angular `HttpClient`, Angular services, RxJS, Observables, Promises, tree shaking, singleton services, TypeScript access modifiers, TypeScript generic types, base classes and derived classes, superclasses and subclasses, access modifiers.

References

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- *Fetch API – Concepts and usage*: https://developer.mozilla.org/en-US/docs/Web/API/Fetch_API

- *RxJS – Observable*: <http://w3sdesign.com/?gr=b07ugr=problem>
- *MDN – Promise*: https://developer.mozilla.org/en-US/docs/Web/JavaScript/Reference/Global_Objects/Promise
- *Angular – singleton services*: <https://angular.io/guide/singleton-services>
- *Tree shaking in JavaScript*: https://developer.mozilla.org/en-US/docs/Glossary/Tree_shaking
- *TypeScript: Access Modifiers*: <http://www.typescriptlang.org/docs/handbook/classes.html#public-private-and-protected-modifiers>
- *TypeScript: Generic Types*: <http://www.typescriptlang.org/docs/handbook/generics.html>
- *Anonymous Types in C#*: <https://docs.microsoft.com/en-us/dotnet/csharp/programming-guide/classes-and-structs/anonymous-types>
- *Create Data Transfer Objects (DTOs)*: <https://docs.microsoft.com/en-us/aspnet/web-api/overview/data/using-web-api-with-entity-framework/part-5>
- *Pros and Cons of Data Transfer Objects*: <https://docs.microsoft.com/en-us/archive/msdn-magazine/2009/brownfield/pros-and-cons-of-data-transfer-objects>
- *Microsoft.EntityFrameworkCore Namespace*: <https://docs.microsoft.com/en-us/dotnet/api/microsoft.entityframeworkcore>
- *System.Text.Json.Serialization Namespace*: <https://docs.microsoft.com/en-us/dotnet/api/system.text.json.serialization>
- *Refactor code*: <https://docs.microsoft.com/en-us/visualstudio/ide/refactoring-in-visual-studio>

8

Back-end and Front-end Debugging

One of the most relevant features of all *programming* languages (such as C#) and most *scripting* languages (such as JavaScript) is the debugging capabilities they offer to developers.

"If debugging is the process of removing software bugs, then programming must be the process of putting them in."

— E. W. Dijkstra

The term debugging universally refers to the process of finding and resolving the issues and/or problems (commonly called bugs) that prevent a program or an application working as expected. In a nutshell, we can say that the debugging process allows the developer to better understand how the source code is being executed under the hood and why it produces the result that it does.

Debugging is a very important skill for any developer, arguably as much as programming itself; it's a skill that all developers have to learn with theory, practice, and experience, just like coding.

The best way to fulfill these tasks is by making use of a debugger – a tool that allows running the target program under controlled conditions. This enables the developer to track its operations in real-time, halting them using breakpoints, executing them step by step, viewing the values of the underlying type, and so on. Advanced debugger features also allow the developer to access the memory contents, CPU registers, storage device activities, and so on, viewing or altering their values to reproduce specific conditions that might be causing the addressed issues.

Luckily enough, **Visual Studio** provides a set of debuggers that can be used to track any .NET Core application. Although most of its features have been designed to debug the managed code portion of our app (for example, our C# files), some of them – when configured properly – can be very useful to track the client-side code as well. Throughout this chapter, we'll learn how to use them, as well as the various debugging tools built-in by some web browsers such as Chrome, Firefox, and Edge to constantly monitor and keep under control the whole HTTP workflow of our *WorldCities* app.

For practical reasons, the debugging process has been split into two separate sections:

- The back-end, where the debug tasks are mostly being handled using the Visual Studio and .NET Core tools
- The front-end, where both Visual Studio and the web browser play a major role

By the end of this chapter, we'll have learned how to properly debug our web application's Web API, as well as our Angular Components, using the various debugging tools provided by Visual Studio to their full extent.

Technical requirements

In this chapter, we're going to need all previous technical requirements listed in the previous chapters, with no additional resources, libraries, or packages.

The code files for this chapter can be found here: https://github.com/PacktPublishing/ASP.NET-Core-3-and-Angular-9-Third-Edition/tree/master/Chapter_08/

Back-end debugging

In this section, we'll learn how to make use of the debug features offered by the Visual Studio environment to take a look at the server-side life cycle of our web application and understand how we can properly troubleshoot some potential flaws.

However, before doing that, let's spend a couple of minutes seeing how it works for the various operating systems available.

Windows or Linux?

For the sake of simplicity, we'll take for granted that we're using the Visual Studio Community, Professional, or Enterprise edition for Windows operating systems. However, since .NET Core has been designed to be cross-platform, there are at least two options for those who want to debug to other environments, such as Linux or macOS:

- Using Visual Studio Code, a lightweight and open source alternative to Visual Studio available for Windows, Linux, and macOS with full debug support
- Using Visual Studio, thanks to the Docker container tools available since Visual Studio 2017 and built into Visual Studio 2019 since version 16.3

Visual Studio Code can be downloaded for free (under MIT license) from the following URL:

<https://code.visualstudio.com/download>

Visual Studio Docker container tools require Docker for Windows, which can be installed from the following URL:

<https://docs.docker.com/docker-for-windows/install/>



The container tools usage information is available here:

<https://docs.microsoft.com/en-us/aspnet/core/host-and-deploy/docker/visual-studio-tools-for-docker>

For additional information about the .NET Core debugging features under Linux and macOS, check out the following URL:

<https://github.com/Microsoft/MIEngine/wiki/Offroad-Debugging-of-.NET-Core-on-Linux---OSX-from-Visual-Studio>

In this book, for the sake of simplicity, we'll stick to the Windows environment, thus making use of the Visual Studio set of debuggers available for Windows.

The basics

We'll take for granted that everyone who bought this book already knows all the basic debugging features offered by Visual Studio, such as the following:

- Debug versus Release build configuration modes
- Breakpoints and how to set and use them
- Stepping in and out of a program
- *Watch*, *Call Stack*, *Locals*, and *Immediate* windows



For those who don't know (or remember) them well enough, here's a great tutorial that can be useful if you want a quick recap:

<https://docs.microsoft.com/en-US/dotnet/core/tutorials/debugging-with-visual-studio?tabs=csharp>

In the following section, we'll briefly introduce some advanced debug options that can be useful in our specific scenarios.

Conditional breakpoints

The conditional breakpoint is a useful debugging feature that is often unknown to (or underutilized by) most developers; it acts just like a normal breakpoint, but it only triggers when certain conditions are met.

To set a conditional breakpoint, just click on the **Settings** contextual icon (the one with a cogwheel) that appears when we create a standard breakpoint, as shown in the following screenshot:

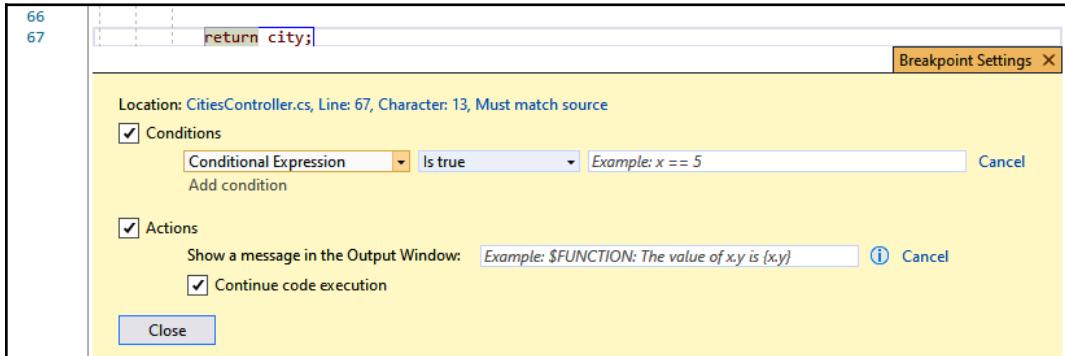
A screenshot of the Visual Studio code editor. A red arrow points to the settings icon (a gear and a circle) located next to a standard blue square breakpoint icon on the left margin. The code in the editor is as follows:

```
// GET: api/Cities/5
[HttpGet("{id}")]
0 references | 0 changes | 0 authors, 0 changes
public async Task<ActionResult<City>> GetCity(int id)
{
    var city = await _context.Cities.FindAsync(id);

    if (city == null)
    {
        return NotFound();
    }

    return city;
}
```

As soon as we do that, a modal panel will appear at the bottom of the window showing a number of possible conditional settings that we can configure for that breakpoint:



As we can see, there are a number of possible settings available (**Conditions**, **Actions**, and so on). Let's see how we can use them.

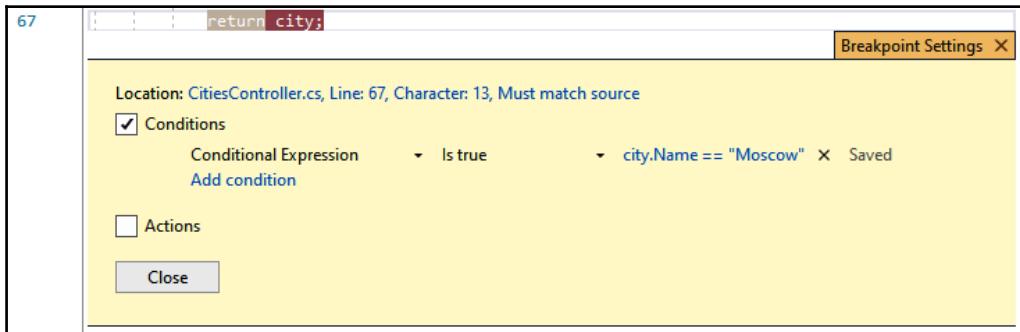
Conditions

If we check the **Conditions** checkbox, we'll be able to define the code condition that will trigger the breakpoint.

To better explain how it works, let's perform a quick debugging test:

1. From the **Solution Explorer**, open the `/Controllers/CitiesController.cs` file.
2. Set a breakpoint on the last line of the `GetCity()` method (the one that returns the city to the client once it has been found – see the following screenshot for details).
3. Click the **Settings** icon to access the **Breakpoint Settings** panel.
4. Activate the **Conditions** checkbox.
5. Select **Conditional Expression** and **Is true** in the two drop-down lists.
6. Type the following condition into the textbox to the right: `city.Name == "Moscow"`.

Once done, our **Breakpoint Settings** panel should look like the following screenshot:

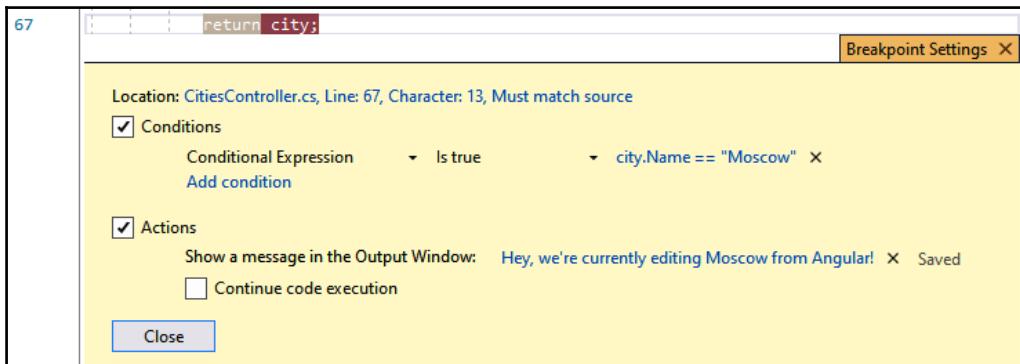


As we can see, our condition has been created; the interface lets us add other conditions, as well as perform certain **Actions** by activating another checkbox below it.

Actions

The **Actions** feature can be used to show a custom message in the **Output window** (such as, **Hey, we're currently editing Moscow from Angular!**) and/or choose whether the code execution should continue or not. If no **Action** is specified, the breakpoint will behave normally, without emitting messages and halting the code execution.

While we're here, let's take the chance to test the **Actions** feature as well. Activate the checkbox, then type the message in the previous paragraph into the rightmost textbox. Once done, our **Breakpoint Settings** panel should look like the following screenshot:

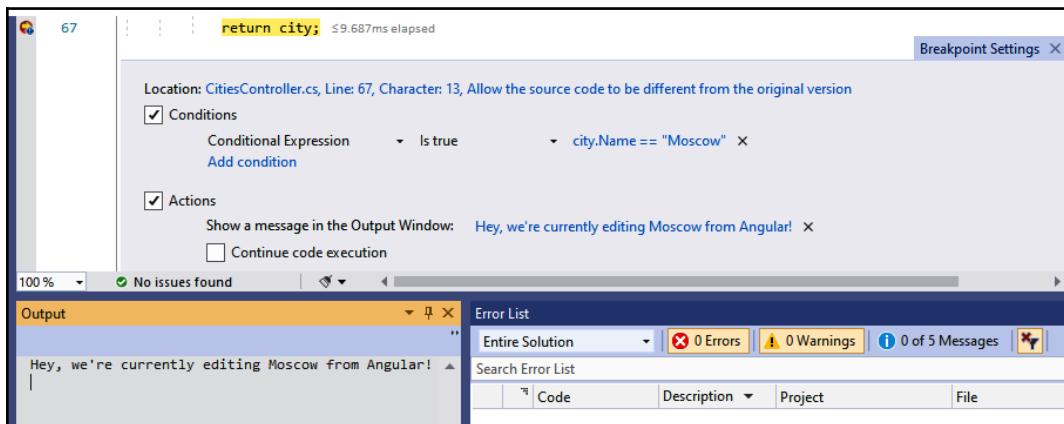


We've just created our first conditional breakpoint; let's quickly test it to see how it works.

Testing the conditional breakpoint

To test what happens when the breakpoint is hit, run the `WorldCities` app in debug mode (by hitting `F5`), navigate to the **Cities** view, filter the table to locate the city of Moscow, and click on its name to enter edit mode.

If everything has been done properly, our conditional breakpoint should trigger and behave in the following way:



As we can see, the **Output** window has been populated with our custom message as well. If we now repeat the same test with any other city with a different name (for example, Rome, Prague, or New York), that same breakpoint won't trigger at all; nothing will happen.



It's worth mentioning that there are two cities called Moscow in our `WorldCities` database: the Russian capital city and a city in Idaho, USA. It goes without saying that our conditional breakpoint will trigger on both of them because it only checks for the `Name` property. If we wanted to limit its scope to the Russian city only, we should refine the **Conditional Expression** to also match the `CityId`, the `CountryId`, or any other suitable property.

All good so far; let's move on.

The Output window

In the previous section, we've talked about the Visual Studio **Output** window, which we used to write a custom message whenever our conditional breakpoint was being hit.

If you have some experience with the Visual Studio debugger, you'll need to know about the utmost importance of that window to understand what happens behind the curtains. The **Output** window shows the status messages for various features in the IDE, meaning that most .NET middlewares, libraries, and packages write their relevant information there, just like we did with our conditional breakpoint.



To open the **Output** window, either choose **View | Output** from the main menu bar or press *Ctrl + Alt + O*.

If we take a look at what happened in the **Output** window during the test we have just performed, we can see a lot of interesting stuff:

```
Output
Show output from: Debug
END
Microsoft.AspNetCore.Hosting.Diagnostics: Information: Request starting HTTP/2.0 POST https://localhost:44334/
Microsoft.AspNetCore.Routing.EndpointMiddleware: Information: Executing endpoint 'WorldCities.Controllers.Citi
Microsoft.AspNetCore.Mvc.Infrastructure.ControllerActionInvoker: Information: Executed action method WorldCiti
Microsoft.AspNetCore.Mvc.Infrastructure.ControllerActionInvoker: Information: Route matched with {action = "Is
Microsoft.AspNetCore.Mvc.Infrastructure.ObjectResultExecutor: Information: Executing ObjectResult, writing val
Microsoft.AspNetCore.Mvc.Infrastructure.ControllerActionInvoker: Information: Executed action WorldCities.Cont
Microsoft.AspNetCore.Mvc.Infrastructure.ControllerActionInvoker: Information: Executing action method WorldCit
Microsoft.AspNetCore.Routing.EndpointMiddleware: Information: Executed endpoint 'WorldCities.Controllers.Citi
Microsoft.EntityFrameworkCore.Infrastructure: Information: Entity Framework Core 3.0.0 initialized 'Applicatio
Microsoft.AspNetCore.Hosting.Diagnostics: Information: Request finished in 64.9188ms 200 application/json; cha
Microsoft.EntityFrameworkCore.Database.Command: Information: Executing DbCommand [Parameters=@__city_Name_0'
SELECT CASE
    WHEN EXISTS (
        SELECT 1
        FROM [Cities] AS [c]
        WHERE ((([[c].[Name] = @_city_Name_0) AND ([c].[Name] IS NOT NULL AND @_city_Name_0 IS NOT NULL)) )
    ELSE CAST(0 AS bit)
END
Microsoft.AspNetCore.Mvc.Infrastructure.ControllerActionInvoker: Information: Executed action method WorldCiti
Microsoft.AspNetCore.Mvc.Infrastructure.ObjectResultExecutor: Information: Executing ObjectResult, writing val
Microsoft.AspNetCore.Mvc.Infrastructure.ControllerActionInvoker: Information: Executed action WorldCities.Cont
Microsoft.AspNetCore.Routing.EndpointMiddleware: Information: Executed endpoint 'WorldCities.Controllers.Citi
Microsoft.AspNetCore.Hosting.Diagnostics: Information: Request finished in 66.8664ms 200 application/json; cha
```

As we can see, there are pieces of information coming out from a number of different sources, including the following:

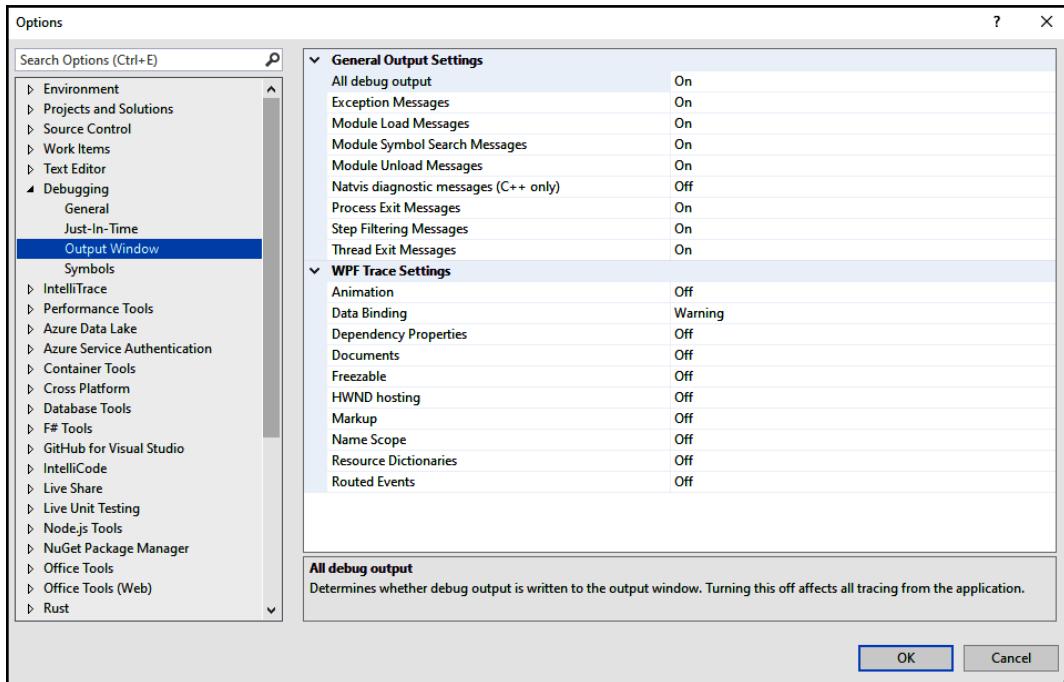
- `Microsoft.AspNetCore.Hosting.Diagnostics`: The .NET Core middleware dedicated to exception handling, exception display pages, and diagnostics information. It handles developer exception page middleware, exception handler middleware, runtime information middleware, status code page middleware, and welcome page middleware. In a nutshell, it's the king of the **Output** window when debugging web applications.
- `Microsoft.AspNetCore.Mvc.Infrastructure`: The namespace that handles (and tracks) the Controller's actions and responds to the .NET Core MVC middleware.
- `Microsoft.AspNetCore.Routing`: The .NET Core middleware that handles static and dynamic routing, such as all our web application's URI endpoints.
- `Microsoft.EntityFrameworkCore`: The .NET Core middleware that handles the connections to the data source; for example, our SQL Server, which we extensively talked about in Chapter 4, *Data Model with Entity Framework Core*.

All this information is basically a sequential log of everything that happens during our web application's execution. We can learn a lot from the .NET Core life cycle just by performing a user-driven action and reading it.

Configuring the Output window

Needless to say, the Visual Studio interface allows us to filter the output and/or choose the level of detail of the captured information.

To configure what to show and what to hide, select **Tools | Options** from the main menu, then navigate to **Debugging | Output Window** from the tree menu item to the right. From that panel, we can select (or deselect) a number of output messages: **Exception Messages**, **Module Load Messages/Module Unload Messages**, **Process Exit Messages**, **Step Filtering Messages**, and so on:



Now that we've got the gist of the back-end debugging output, let's move our focus to one of the middlewares that arguably requires special attention: **Entity Framework (EF) Core**.

Debugging EF Core

If we take a look at the **Output** window right after one of our web application's runs in debug mode, we should be able to see a bunch of SQL queries written in plain text. These are the queries used by the underlying **LINQ to SQL provider**, which is in charge of translating all our lambda expressions, query expressions, IQueryables, objects, and expression trees into valid T-SQL queries.

Here's the output information line emitted by the Microsoft.EntityFrameworkCore middleware containing the SQL query used to retrieve the city of Moscow (the actual SQL query is highlighted):

```
Microsoft.EntityFrameworkCore.Database.Command: Information: Executing
DbCommand [Parameters=@__p_0='?' (DbType = Int32), @__p_1='?' (DbType
= Int32)], CommandType='Text', CommandTimeout='30']
SELECT [c].[Id], [c].[Name], [c].[Lat], [c].[Lon], [c0].[Id] AS
[CountryId], [c0].[Name] AS [CountryName]
FROM [Cities] AS [c]
INNER JOIN [Countries] AS [c0] ON [c].[CountryId] = [c0].[Id]
WHERE CHARINDEX(N'moscow', [c].[Name]) > 0
ORDER BY [c].[Name]
OFFSET @__p_0 ROWS FETCH NEXT @__p_1 ROWS ONLY
```

Not bad, right? These SQL queries in clear text might be very useful to determine whether the LINQ to SQL provider does a good job or not when converting our lambda or LINQ query expressions in terms of performance.

The GetCountries() SQL query

Let's try to use this same technique to retrieve the SQL query that corresponds to the CountriesController's GetCountries() method implementation, which we refined during Chapter 7, *Code Tweaks and Data Services*, to include the cities count.

Here's the source code snippet:

```
return await ApiResult<CountryDTO>.CreateAsync(
    _context.Countries
        .Select(c => new CountryDTO()
    {
        Id = c.Id,
        Name = c.Name,
        ISO2 = c.ISO2,
        ISO3 = c.ISO3,
        TotCities = c.Cities.Count
    }),
    pageIndex,
    pageSize,
    sortColumn,
    sortOrder,
    filterColumn,
    filterQuery);
```

To see how it was converted into T-SQL, do the following:

1. Hit *F5* to run the web app in debug mode.
2. Navigate to the **Countries** view.
3. Take a look at the resulting **Output** window (searching for `TotCities` will help there).

Here's the SQL query that we should find there:

```
SELECT [c0].[Id], [c0].[Name], [c0].[ISO2], [c0].[ISO3], (
    SELECT COUNT(*)
    FROM [Cities] AS [c]
    WHERE [c0].[Id] = [c].[CountryId]) AS [TotCities]
FROM [Countries] AS [c0]
ORDER BY [c0].[Name]
OFFSET @_p_0 ROWS FETCH NEXT @_p_1 ROWS ONLY
```

That's not bad; the LINQ to SQL provider converted it using a subquery, which is a good choice in terms of performance. The `OFFSET` part of the SQL query, together with the `DBCommand Parameters` mentioned in the preceding code snippet, handles the pagination and ensures that we're only getting the rows we've been asking for.

However, the Visual Studio **Output** window is not the only way to take a look at those SQL queries – we can provide ourselves with an even better alternative by implementing a simple, yet effective, extension method, as we're going to see in the following sections.

Getting the SQL code programmatically

The **Output** window is good enough for most scenarios, but what if we want to retrieve the SQL code from an `IQueryable<T>` programmatically? Such an option might be very useful to debug (or conditionally debug) some parts of our app, especially if we want to automatically save these SQL queries outside the **Output** window (for example, a log file or a log aggregator service).

In order to achieve such a result, we need to create a dedicated helper function that will be able to do that using `System.Reflection`. Let's quickly do that and test out how it works.

From the **Solution Explorer**, right-click the `/Data/` folder, create a new `IQueryableExtensions.cs` file, and fill its content with the following source code:

```
using Microsoft.EntityFrameworkCore.Query;
using Microsoft.EntityFrameworkCore.Query.SqlExpressions;
```

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Reflection;
using System.Threading.Tasks;

namespace WorldCities.Data
{
    public static class IQueryableExtension
    {
        public static string ToSql<T>(this IQueryable<T> query)
        {
            var enumerator = query.Provider
                .Execute<IEnumerable<T>>
                (query.Expression).GetEnumerator();
            var relationalCommandCache = enumerator
                .Private("_relationalCommandCache");
            var selectExpression = relationalCommandCache
                .Private<SelectExpression>("_selectExpression");
            var factory = relationalCommandCache
                .Private<IQuerySqlGeneratorFactory>
                ("_querySqlGeneratorFactory");

            var sqlGenerator = factory.Create();
            var command = sqlGenerator.GetCommand(selectExpression);

            string sql = command.CommandText;
            return sql;
        }

        private static object Private(this object obj, string
            privateField) =>
            obj?.GetType()
                .GetField(privateField, BindingFlags.Instance |
                    BindingFlags.NonPublic)?
                .GetValue(obj);
        private static T Private<T>(this object obj, string
            privateField) =>
            (T)obj?
                .GetType()
                .GetField(privateField, BindingFlags.Instance |
                    BindingFlags.NonPublic)?
                .GetValue(obj);
    }
}
```

As we can see, we took the chance to create the helper class as an `IQueryable<T>` extension method. This allows us to extend the functionality of the `IQueryable<T>` type without creating a new derived type, modifying the original type, or creating a static function that will explicitly require it as a reference parameter.



For those who have never heard of them, C# extension methods are static methods that can be called as if they were instance methods on the extended type. For further information, take a look at the following URL from the Microsoft C# programming guide:

<https://docs.microsoft.com/en-us/dotnet/csharp/programming-guide/classes-and-structs/extension-methods>

Now that we've created the `IQueryableExtension` static class, we can use the `ToSql()` extension method in any other class, as long as it includes a reference to the `WorldCities.Data` namespace.

Let's see how we can implement the previous extension in our `ApiResult.cs` class, which is the place where most of our `IQueryable<T>` objects get executed.

Implementing the `ToSql()` method

From **Solution Explorer**, select the `/Data/ApiResult.cs` file, open it for editing, and add the following lines to the existing `CreateAsync` method implementation (the new lines are highlighted):

```
// ...existing code...

public static async Task<ApiResult<T>> CreateAsync(
    IQueryable<T> source,
    int pageIndex,
    int pageSize,
    string sortColumn = null,
    string sortOrder = null,
    string filterColumn = null,
    string filterQuery = null)
{
    if (!String.IsNullOrEmpty(filterColumn)
        && !String.IsNullOrEmpty(filterQuery)
        && IsValidProperty(filterColumn))
    {
        source = source.Where(
            String.Format("{0}.Contains(@0)",
            filterColumn),
```

```
        filterQuery);
    }

    var count = await source.CountAsync();

    if (!String.IsNullOrEmpty(sortColumn)
        && IsValidProperty(sortColumn))
    {
        sortOrder = !String.IsNullOrEmpty(sortOrder)
            && sortOrder.ToUpper() == "ASC"
            ? "ASC"
            : "DESC";
        source = source.OrderBy(
            String.Format(
                "{0} {1}",
                sortColumn,
                sortOrder)
        );
    }

    source = source
        .Skip(pageIndex * pageSize)
        .Take(pageSize);

    // retrieve the SQL query (for debug purposes)
    var sql = source.ToSql();

    var data = await source.ToListAsync();

    return new ApiResult<T>(
        data,
        count,
        pageIndex,
        pageSize,
        sortColumn,
        sortOrder,
        filterColumn,
        filterQuery);
}

// ...existing code...
```

As we can see, we added a single variable to store the results of our new extension method. Let's quickly test it out to see how it works.



It's worth noting that, since the `ApiResult.cs` class is part of the `WorldCities.Data` namespace, we didn't have to add the `using` reference at the top.

Put a breakpoint on the line of the `ApiResult.cs` class, immediately below the new lines we added earlier on (as shown in the following screenshot). Once done, hit `F5` to run the web application in debug mode, then navigate to the **Countries** view.

The breakpoint should hit, as shown in the following screenshot:

The screenshot shows a code editor and a **Text Visualizer** window. The code editor displays the `ApiResult.cs` file with several lines highlighted in yellow, indicating they were executed. A green vertical bar marks the current line of execution. The `Text Visualizer` window has the expression `sql` set, and its value is a generated SQL query:

```
SELECT [c0].[Id], [c0].[Name], [c0].[ISO2], [c0].[ISO3], (
    SELECT COUNT(*)
    FROM [Cities] AS [c]
    WHERE [c0].[Id] = [c].[CountryId]) AS [TotCities]
FROM [Countries] AS [c0]
ORDER BY [c0].[Name]
OFFSET @_p_0 ROWS FETCH NEXT @_p_1 ROWS ONLY
```

If we move our mouse cursor over the `sql` variable and click the **magnifier lens** icon, we'll be able to see the SQL query in the **Text Visualizer** window. Now, we know how to quickly view the SQL queries produced by EF Core from our `IQueryable<T>` objects.

Using the #if preprocessor

If we are worried about the performance hit of the `ToSql()` method task, we can definitely tweak the previous code using the `#if` preprocessor in the following way:

```
// retrieve the SQL query (for debug purposes)
#if DEBUG
{
    var sql = source.ToSql();
    // do something with the sql string
}
#endif
```

As we can see, we have wrapped the `ToSql()` method call in an *#if preprocessor directive* block: when the C# compiler encounters these directives, it will compile the code between them only if the specified symbol is defined. More specifically, the `DEBUG` symbol that we used in the previous code will prevent that wrapped code from being compiled unless the web application is being run in debug mode, thus avoiding any performance loss in release/production builds.

For additional information regarding the C# preprocessor directives, take a look at the following URLs:



C# preprocessor directives:

<https://docs.microsoft.com/en-us/dotnet/csharp/language-reference/preprocessor-directives/>

#if preprocessor directives:

<https://docs.microsoft.com/en-us/dotnet/csharp/language-reference/preprocessor-directives/preprocessor-if>

There is still a lot to say about the back-end debugging features offered by Visual Studio and .NET Core; however, for reasons of space, it's better to stop here for the time being and move on to the front-end.

Front-end debugging

In this section, we'll briefly review the various front-end debugging options we have available (Visual Studio or the browser's developer tools). Right after that, we'll take a look at some Angular features that we can leverage to increase the awareness of the various tasks performed by our client-side application under the hood and debug them.

Visual Studio JavaScript debugging

Front-end debugging works just like back-end debugging, thanks to the **JavaScript debugging** feature of Visual Studio. The JS debugger is not enabled by default, but the Visual Studio IDE will automatically ask whether to activate it or not the first time we put a breakpoint on a JavaScript (or TypeScript) file and run our app in debug mode.

As of today, client-side debugging support is only provided for Chrome and Microsoft Edge. On top of that, since we're using TypeScript and not JavaScript directly, the use of source maps is required if we want to set and hit breakpoints in the TypeScript file (our Angular Component class file) and not in the JavaScript-transpiled file.

Luckily enough, the Angular template we're using (see [Chapter 1, Getting Ready](#) and [Chapter 2, Looking Around](#)) already provides source maps support, as we can see by taking a look at the `sourceMap` parameter value in the `/ClientApp/tsconfig.json` file:

```
[...]  
  "sourceMap": true  
[...]
```

This means that we can do the following:

1. Open the `/ClientApp/src/app/countries/countries.component.ts` file.
2. Place a debugger inside the subscription to the `Observable` returned by the `countryService` (see the following screenshot for details).
3. Hit `F5` to launch the web application in debug mode.

If we did everything correctly, the Visual Studio IDE should ask us whether we want to enable JavaScript debugging, as shown in the following screenshot:

```

52
53     var filterColumn = (this.filterQuery)
54     ? this.defaultFilterColumn
55     : null;
56
57     var filterQuery = (this.filterQuery)
58     ? this.filterQuery
59     : null;
60
61     this.countryService.getData<ApiResult<Country>>(
62       event.pageIndex,
63       event.pageSize,
64       sortColumn,
65       sortOrder,
66       filterColumn,
67       filterQuery)
68     .subscribe(result => {
69       this.paginator.length = result.totalCount;
70       this.paginator.pageIndex = result.pageIndex;
71       this.paginator.pageSize = result.pageSize;
72       this.countries = new MatTableDataSource<Country>(result.data);
73     }, error => console.error(error));
74   }
75 }
76

```

Once enabled, the runtime environment will stop the program execution as soon as we navigate to the **Countries** view. Needless to say, we'll be able to inspect the various members of the Angular Component class:

```

61   this.countryService.getData<ApiResult<Country>>(
62     event.pageIndex,
63     event.pageSize,
64     sortColumn,
65     sortOrder,
66     filterColumn,
67     filterQuery)
68   .subscribe(result =>
69     this.paginator.length = result.totalCount;
70     this.paginator.pageIndex = result.pageIndex;
71     this.paginator.pageSize = result.pageSize;
72     this.countries = new MatTableDataSource<Country>(result.data);
73   }, error => console.error(error));
74 }
75

```

Index	Object
0	Object {id: 120, name: "Afghanistan", iso2: "AF", ...}
1	Object {id: 123, name: "Albania", iso2: "AL", ...}
2	Object {id: 173, name: "Algeria", iso2: "DZ", ...}
3	Object {id: 232, name: "American Samoa", iso2: "AS", ...}
4	Object {id: 118, name: "Andorra", iso2: "AD", ...}
5	Object {id: 125, name: "Angola", iso2: "AO", ...}
6	Object {id: 122, name: "Anguilla", iso2: "AI", ...}
7	Object {id: 121, name: "Antigua And Barbuda", iso2: "AG", ...}
8	Object {id: 126, name: "Argentina", iso2: "AR", ...}
9	Object {id: 124, name: "Armenia", iso2: "AM", ...}

That's pretty cool, right? We can even define conditional breakpoints and use the *Watch*, *Call Stack*, *Locals*, and *Immediate* windows without significant flaws.



For additional information about debugging a TypeScript or JavaScript app in Visual Studio, take a look at the following URL:

<https://docs.microsoft.com/en-US/visualstudio/javascript/debug-nodejs>.

In the next section, we're going to introduce another important front-end debugging resource: JavaScript source maps.

JavaScript source maps

For those who don't know what source maps actually are, let's try to briefly summarize the concept.

Technically speaking, a source map is a file that maps the code within a compressed, combined, minified, and/or transpiled file back to its original position in a source file. Thanks to these mappings, we can debug our applications even after our assets have been optimized.

As we saw a moment ago, source maps are extensively used by the Visual Studio JavaScript debugger to enable us to set breakpoints within the TypeScript source code, and they are also supported by the Google Chrome, Mozilla Firefox, and Microsoft Edge developer tools, thus allowing these browsers' built-in debuggers to display the unminified and uncombined source to the developer, even when dealing with compressed and minified files.

For additional information about JavaScript source maps, check out the following URLs:



Introduction to JavaScript Source Maps, Ryan Seddon:
<https://www.html5rocks.com/en/tutorials/developertools/sourcemaps/>.

An introduction to Source Maps, Matt West:
<https://blog.teamtreehouse.com/introduction-source-maps>.

However, given our specific scenario, the debugging capabilities of the aforementioned browsers might not be as ideal; in the next section, we'll do our best to explain why.

Browser developer tools

As we can easily guess, the Visual Studio JavaScript debugging feature is not the only way we can debug a client-side script. However, since we're dealing with a TypeScript application, it's arguably the best available option due to the fact that it allows debugging the .ts files through the autogenerated source maps.

Although the browser's built-in debugging tools can definitely use the source maps to make us deal with the unminified and uncombined files, they cannot do anything to revert these transpiled files back into their former TypeScript classes – because they have never seen them, to begin with.

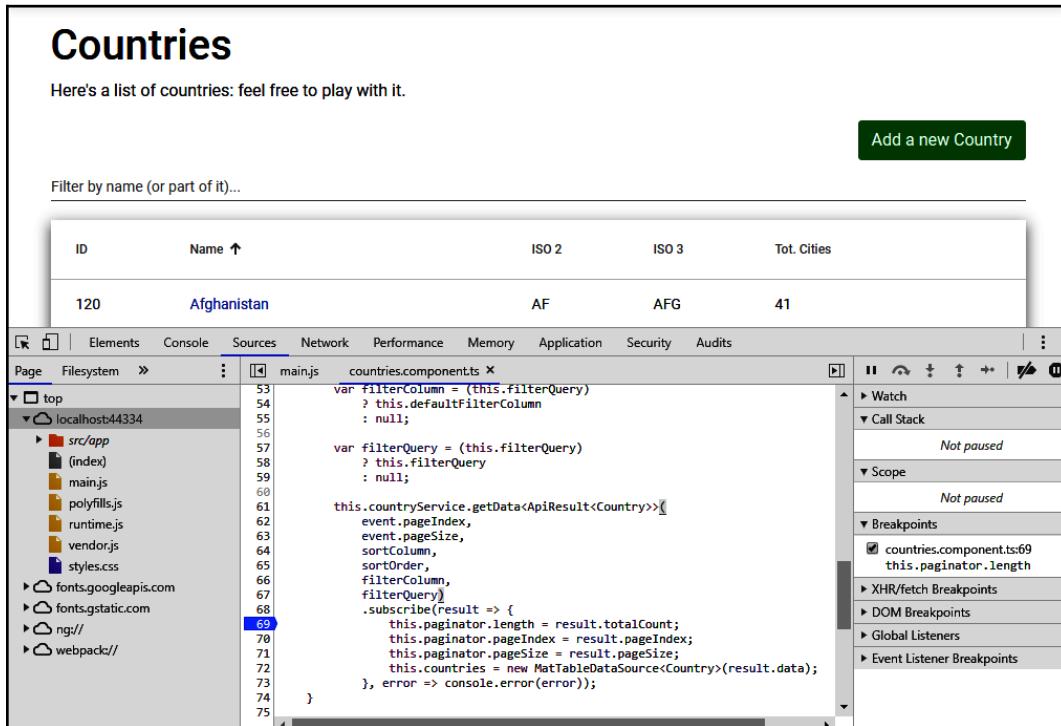
For that very reason, if we try to activate, for example, the Chrome developer tools to debug our `CountriesComponent` Angular class, we'll experience something like this:

The screenshot shows the Chrome DevTools interface. At the top, there is a green button labeled "Add a new Country". Below it is a search bar with the placeholder "Filter by name (or part of it)...". Underneath is a table listing countries with columns for ID, Name, ISO 2, ISO 3, and Tot. Cities. The table contains four rows: Afghanistan (ID 120), Albania (ID 123), Algeria (ID 173), and American Samoa (ID 232). The "Sources" tab is selected in the bottom navigation bar. The left sidebar shows the project structure under "top": src/app, index.html, main.js, polyfills.js, runtime.js, vendor.js, and styles.css. The "main.js" file is currently open. A tooltip indicates "Source Map detected." To the right of the code editor, the "Breakpoints" panel is visible, showing two checked breakpoints: one at line 68 and another at line 69. The code editor highlights line 888, which corresponds to the breakpoint at line 68.

```
880     : this.defaultSortOrder;
881     filterColumn = (this.filterQuery)
882     ? this.defaultFilterColumn
883     : null;
884     var filterQuery = (this.filterQuery)
885     ? this.filterQuery
886     : null;
887     this.countryService.getData(event.pageIndex, event.pageSize, sortColumn,
888     :subscribe(result => {
889       this.paginator.length = result.totalCount;
890       this.paginator.pageIndex = result.pageIndex;
891       this.paginator.pageSize = result.pageSize;
892       this.countries = new _angular_material_IMPORTED_MODULE_1_
893     }, error => console.error(error));
894   }
895 }
```

As we can see, the TypeScript file is not there. The browser is dealing with a huge `main.js` transpiled file, which basically contains all the Angular Components. In that file, the aforementioned line of the `CountriesComponent` class (line 69 or so) corresponds to line 888 (see the previous screenshot; the actual line number might vary).

However, as soon as we click on that line to set a breakpoint there, the corresponding TypeScript file will also become accessible, just like in Visual Studio:



How is such a thing possible? Didn't we just say that the browser doesn't know anything about the TypeScript class?

As a matter of fact, it doesn't; however, since we're running the app in a development environment, our .NET Core application is using `AngularCliMiddleware` to serve our Angular app, thus forwarding all the HTTP requests there. We've already seen this setting in the `Startup.cs` file:

```
// [ ... ]

app.UseSpa(spa =>
{
    // To learn more about options for serving an Angular SPA from
    // ASP.NET Core,
    // see https://go.microsoft.com/fwlink/?linkid=864501

    spa.Options.SourcePath = "ClientApp";
```

```

        if (env.IsDevelopment())
        {
            spa.UseAngularCliServer(npmScript: "start");
        }
    });

// [...]

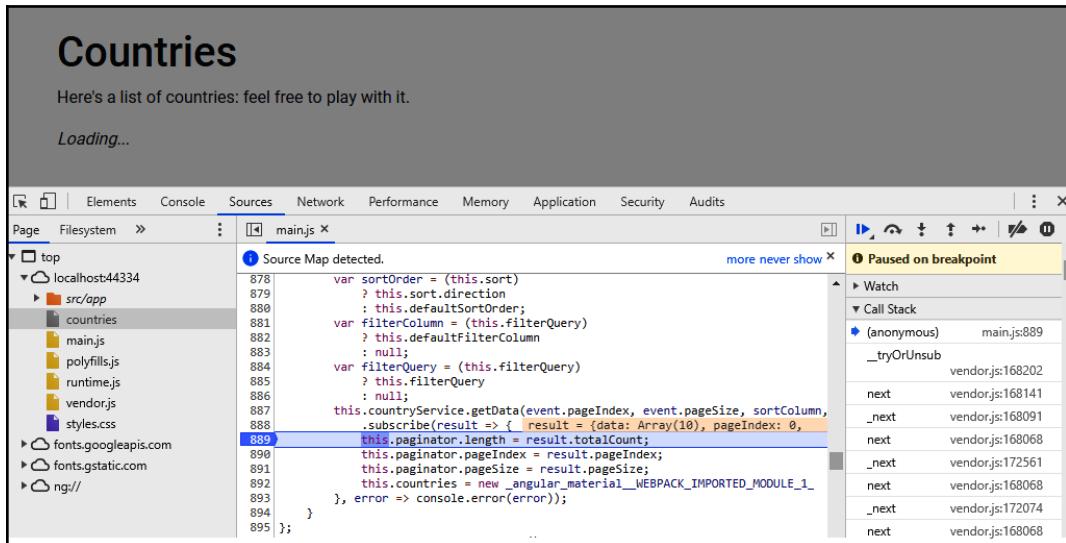
```

The `UseAngularCliServer()` method will internally invoke `AngularCliMiddleware`, which will do the following:

1. Start an npm instance (using a dynamic port)
2. Use that dynamic port to perform an `ng serve` (serve the Angular app)
3. Create a transparent proxy to forward all the HTTP requests to the Angular dev server

Thanks to all this, the browser, although receiving only the `main.js` JavaScript transpiled file, will still be able to follow the source map to reach the underlying TypeScript files.

However, even if we set the breakpoint on the TypeScript page, as soon as we make it trigger, we'll be brought back to the `main.js` file, as shown in the following screenshot:



This behavior is hardly a surprise; the browser's built-in debugger can retrieve the TypeScript classes from the proxy using the source maps, yet it's clearly unable to directly handle/debug them.

For that very reason, at least in our specific scenario, the Visual Studio front-end debugging features (using the built-in JavaScript debugger) are arguably the most effective way to debug our Angular application nowadays.

Angular form debugging

In this section, we're going to spend some of our valuable time understanding some key concepts related to form debugging.

As we mentioned in [Chapter 6, Forms and Data Validation](#), one of the advantages granted by the model-driven approach is the fact that it allows us to have granular control on our form elements. How can we use these features to our advantage and translate them into writing more robust code?

In the following sections, we'll try to address this question by showing some useful techniques that can be used to gain more control over our forms.

A look at the Form Model

We've talked a lot about the Form Model in [Chapter 6, Forms and Data Validation](#), yet we've never seen it up close. It would greatly help to have it on screen while developing the form templates, especially if it can be updated in real time as we play with the form inputs and controls.

Here's a convenient HTML snippet containing the template syntax required to let it happen:

```
<!-- Form debug info panel -->
<div class="card bg-light mb-3">
  <div class="card-header">Form Debug Info</div>
  <div class="card-body">
    <div class="card-text">
      <div><strong>Form value:</strong></div>
      <div class="help-block">
        {{ form.value | json }}
      </div>
      <div class="mt-2"><strong>Form status:</strong></div>
      <div class="help-block">
        {{ form.status | json }}
      </div>
    </div>
  </div>
</div>
```

```
</div>
</div>
</div>
</div>
```

We can put this snippet on any of our form-based Components, for example, `CityEditComponent`, to obtain the following result:

The screenshot shows a web application interface. At the top, there is a navigation bar with the title "WorldCities" and links for "Home", "Cities", and "Countries". Below the navigation, the main content area has a heading "Edit - Prague". The form fields are as follows:

- City name:**
- City latitude:**
- City longitude:**
- Country:** A dropdown menu showing "Select a Country..." and "Czechia".
- Buttons:** "Save" (green button) and "Cancel".

Below the form, there is a panel titled "Form Debug Info" containing the following information:

- Form value:** `{ "name": "Prague", "lat": 50.0833, "lon": 14.466, "countryId": 167 }`
- Form status:** "VALID"

Pretty useful, right? If we play with the form a bit, we can see how the values contained in the **Form Debug Info** panel will change as we change the input controls; something like that will definitely come in handy when dealing with complex forms.

The pipe operator

By looking at the highlighted lines of the preceding source code, we can see how we used the pipe operator (`|`), which is another useful tool coming from the Angular template syntax.

To quickly summarize what it does, we can say the following: the pipe operator allows the use of some transformation functions that can be used to perform various tasks such as format strings, join array elements into a string, uppercase/lowercase a text, and sort a list.

Here are the pipes that come built-in with Angular:

- DatePipe
- UppercasePipe
- LowerCasePipe
- CurrencyPipe
- PercentPipe
- JsonPipe

These are all available for use in any template. Needless to say, we used the latter in the preceding script to transform the `form.value` and `form.status` objects into readable JSON strings.



It's worth noting that we can also chain multiple pipes and define custom pipes; however, we don't need to do that for the time being, and talking about such a topic will take us far away from the scope of this chapter. Those who want to know more about pipes should take a look at the official Angular documentation at <https://angular.io/guide/pipes>.

Reacting to changes

One of the reasons we chose the Reactive approach was to be able to react to the changes issued by the user. We can do that by subscribing to the `valueChanges` property exposed by the `FormGroup` and `FormControl` classes, which returns an *RxJS Observable* that emits the latest values.

We've been using observables since Chapter 3, *Front-end and Back-end Interactions*, when we subscribed to the `get()` method of `HttpClient` to handle the HTTP response received by the web server for the first time. We used them again in Chapter 6, *Forms and Data Validation*, when we had to implement support for the `put()` and `post()` methods as well, and last but not least, we extensively talked about them in Chapter 7, *Code Tweaks and Data Services*, when we explained their pros and cons against Promises, learned about some of their most relevant features, and integrated them in our `CityService` and `CountryService`. As a matter of fact, we'll arguably keep using them wherever and whenever we need to fetch the JSON data that feeds our Data Model interfaces and Form Model objects.

In the following section, we're going to use them to demonstrate how we can perform some arbitrary operations whenever the user changes something within a form. More precisely, we'll try to observe the observable by implementing a custom Activity Log.

The Activity Log

Once again, `CityEditComponent` will be our lab rat.

Open the `/ClientApp/src/app/cities/city-edit.component.ts` class file and update its code with the following highlighted lines:

```
// ...existing code...

// Activity Log (for debugging purposes)
activityLog: string = '';

constructor(
  private activatedRoute: ActivatedRoute,
  private router: Router,
  private cityService: CityService,
  @Inject('BASE_URL') private baseUrl: string) {
  super();
}

ngOnInit() {
  this.form = new FormGroup({
    name: new FormControl('', Validators.required),
    lat: new FormControl('', [
      Validators.required,
      Validators.pattern('^-?[0-9]+(\.[0-9]{1,4})?$/')
    ]),
    lon: new FormControl('', [
      Validators.required,
      Validators.required
    ])
  });
}

onSubmit() {
  const city = this.form.value;
  this.cityService.createOrEditCity(city).subscribe();
  this.activityLog += `Form submitted: ${city.name}\n`;
}
```

```
        Validators.pattern('^-?[0-9]+(\.[0-9]{1,4})?$',  
    ],  
    countryId: new FormControl('', Validators.required)  
, null, this.isDupeCity());  
  
    // react to form changes  
    this.form.valueChanges  
    .subscribe(val => {  
        if (!this.form.dirty) {  
            this.log("Form Model has been loaded.");  
        }  
        else {  
            this.log("Form was updated by the user.");  
        }  
    });  
  
    this.loadData();  
}  
  
log(str: string) {  
    this.activityLog += "["  
    + new Date().toLocaleString()  
    + "] " + str + "<br />";  
}  
  
// ...existing code
```

In the previous code, we provided our Form Model with a simple, yet effective, logging feature that will register any change activity performed by the framework and/or by the user.

As we can see, all the logic has been put within the `constructor` because this is where the Component class gets initialized, along with the observable we need to monitor. The `log()` function is just a shortcut to append a basic timestamp to the log activity string and add it to the `activityLog` local variable in a centralized way.

In order to enjoy our new logging feature to the fullest, we have to find a way to put the `activityLog` on screen.

To do that, open the `/ClientApp/src/app/cities/city-edit.component.html` template file and append the following HTML code snippet at the end of the file, right below the previous **Form Debug Info** panel:

```
<!-- Form activity log panel -->
<div class="card bg-light mb-3">
  <div class="card-header">Form Activity Log</div>
  <div class="card-body">
    <div class="card-text">
      <div class="help-block">
        <span *ngIf="activityLog"
              [innerHTML]="activityLog"></span>
      </div>
    </div>
  </div>
</div>
```

That's it; now, the Activity Log will be shown in real time, meaning in a truly reactive way.

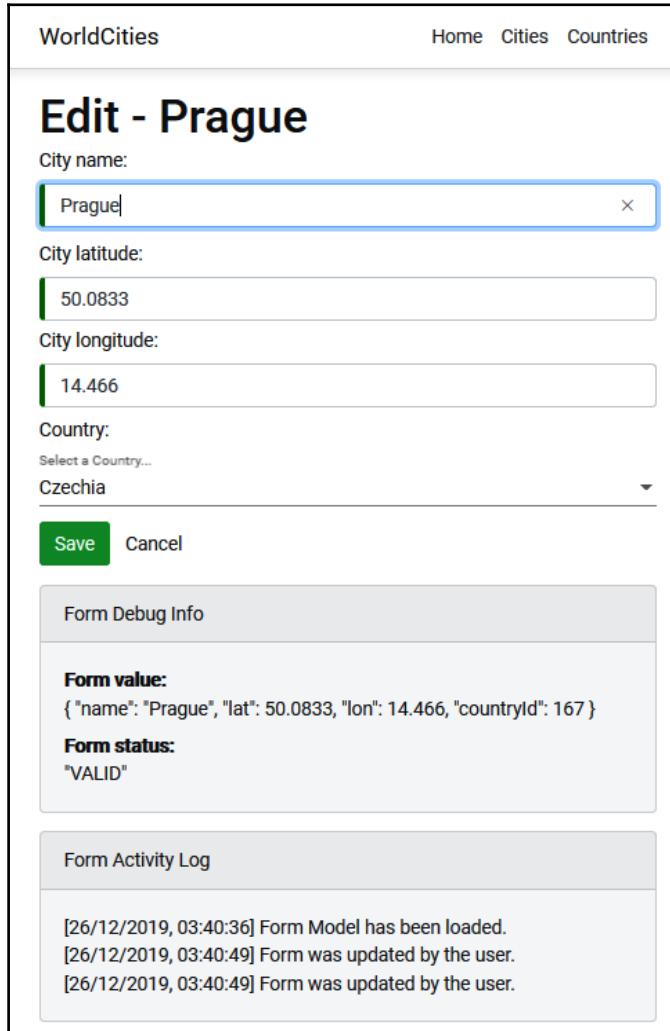


It's worth noting that we didn't use the double curly braces of interpolation here—we went straight for the `[innerHTML]` directive instead. The reason for that is very simple. The interpolation strips the HTML tags from the source string; hence, we would've lost the `
` tag that we used in the `log()` function to separate all log lines with a line feed. If not for that, we would have used the `{ { activityLog } }` syntax instead.

Testing the Activity Log

All we need to do now is test our new Activity Log.

To do so, run the project in debug mode, go straight to `CityEditComponent` by editing an already existing city (for example, **Prague**), play with the form fields, and see what happens in the **Form Activity Log** panel:



The first log line should trigger automatically as soon as the `HttpClient` retrieves the city JSON from the back-end Web API and the Form Model gets updated. Then, the form will log any update performed by the user; all we can do is change the various input fields, yet that's more than enough for our humble reactivity test to complete successfully.

Extending the Activity Log

Reacting to the Form Model changes is not the only thing we can do; we can extend our subscriptions to observe any form control as well. Let's perform a further upgrade on our current Activity Log implementation to demonstrate that.

Open the `/ClientApp/src/app/cities/city-edit.component.ts` class file and update the code in the `constructor` method with the following highlighted lines:

```
// ...existing code...

// react to form changes
this.form.valueChanges
    .subscribe(val => {
        if (!this.form.dirty) {
            this.log("Form Model has been loaded.");
        }
        else {
            this.log("Form was updated by the user.");
        }
    });

// react to changes in the form.name control
this.form.get("name")!.valueChanges
    .subscribe(val => {
        if (!this.form.dirty) {
            this.log("Name has been loaded with initial values.");
        }
        else {
            this.log("Name was updated by the user.");
        }
    });

// ...existing code...
```

The previous code will add further log lines within the **Form Activity Log**, all related to the changes occurred in the name form control, which contains the city name, as follows:

Form Activity Log
[26/12/2019, 03:51:10] Name has been loaded with initial values. [26/12/2019, 03:51:10] Form Model has been loaded. [26/12/2019, 03:53:09] Name was updated by the user. [26/12/2019, 03:53:09] Form was updated by the user.

What we just did here is more than enough to demonstrate the wonders of the `valueChanges` observable property; let's move on to the next topic.



We can definitely keep the **Form Debug Info** and **Form Activity Log** panels in the `CityEditComponent` template for further reference, yet there's no need to copy/paste it within the other form-based Components' templates or anywhere else.

Client-side debugging

Another great advantage of observables is that we can use them to debug a good part of the whole Reactive workflow by placing breakpoints within our subscription source code. To quickly demonstrate this, just add a Visual Studio breakpoint to our latest subscription, as follows:

```
69 // react to changes in the form.name control
70 this.form.get("name")!.valueChanges
71     .subscribe(val => {
72         if (!this.form.dirty) {
73             this.log("Name has been loaded with initial values.");
74         }
75         else {
76             this.log("Name was updated by the user.");
77         }
78     });

```

Once done, run the project in debug mode and navigate to `CityEditComponent`; the breakpoint will be hit as soon as the Form Model will be loaded, since the `name` control will be updated as well, and also every time we make a change to that control. Whenever this happens, we'll be able to use all the Visual Studio JavaScript debugging tools and features that are available on client-side debugging, such as *Watch*, *Locals*, *Autos*, *Immediate*, *Call Stack*, and more.



For additional information about client-side debugging with Google Chrome, we strongly suggest reading the following post on the official MSDN blog:

<https://blogs.msdn.microsoft.com/webdev/2016/11/21/client-side-debugging-of-asp-net-projects-in-google-chrome/>.

Summary

Throughout this chapter, we talked about a number of debugging features and techniques that can be very useful during development. Let's try to quickly summarize what we've learned so far.

We started our journey with the Visual Studio server-side debugging features. These are a set of runtime debugging features that can be used to prevent most compiler errors on our Web API and allow us to track the whole back-end application life cycle: from the middleware initialization, through to the whole HTTP request/response pipeline, down to the Controllers, entities, and `IQueryable` objects.

Right after that, we moved to the Visual Studio client-side debugging feature. This is a neat JavaScript debugger that, thanks to the source maps created by the TypeScript transpiler, allows us to directly debug our TypeScript classes and access variables, subscriptions, and initializers in a truly efficient way.

Last but not least, we designed and implemented a real-time Activity Log. This is a quick and effective way to exploit the Reactive features of the various observables exposed by the Angular modules to keep track of what happens to our Components; not to mention the fact that the Visual Studio TypeScript transpiler (and Intellisense) will hopefully shield us from most syntax, semantic, and logical programming errors, freeing us from the pests of script-based programming, at least for the most part.

However, what if we want to test our forms against some specific use cases? Is there a way we can mock our back-end .NET Core Controllers' behaviors, as well as those of our front-end Angular Components, and perform unit tests?

The answer is yes. As a matter of fact, our two frameworks of choice provide various open-source testing tools to perform unit tests. In the next chapter, we'll learn how to use them to improve the quality of our code and prevent bugs during refactoring, regression, and new implementation processes.

Suggested topics

Visual Studio Code, debugger, server-side debugging, client-side debugging, extension methods, C# preprocessor directives, JavaScript source maps, and Angular pipes.

References

- Visual Studio Code: <https://code.visualstudio.com/>
- *Visual Studio Container Tools with ASP.NET Core*: <https://docs.microsoft.com/en-us/aspnet/core/host-and-deploy/docker/visual-studio-tools-for-docker>
Offroad Debugging of .NET Core on Linux OSX from Visual Studio: <https://github.com/Microsoft/MIEngine/wiki/Offroad-Debugging-of-.NET-Core-on-Linux---OSX-from-Visual-Studio>
- *Debug an application using Visual Studio*: <https://docs.microsoft.com/en-US/dotnet/core/tutorials/debugging-with-visual-studio?tabs=csharp>
- *Extension Methods*: <https://docs.microsoft.com/en-us/dotnet/csharp/programming-guide/classes-and-structs/extension-methods>
- *Microsoft.EntityFrameworkCore Namespace*: <https://docs.microsoft.com/en-us/dotnet/api/microsoft.entityframeworkcore>
- *C# Preprocessor Directives*: <https://docs.microsoft.com/en-us/dotnet/csharp/language-reference/preprocessor-directives/>
- *The #IF preprocessor directive in C#*: <https://docs.microsoft.com/en-us/dotnet/csharp/language-reference/preprocessor-directives/preprocessor-if>
- *Debug a JavaScript or TypeScript app in Visual Studio*: <https://docs.microsoft.com/en-US/visualstudio/javascript/debug-nodejs>
- *Introduction to JavaScript Source Maps*: <https://www.html5rocks.com/en/tutorials/developertools/sourcemaps/>
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- *Angular Pipes*: <https://angular.io/guide/pipes>
- *Client-Side Debugging of ASP.NET projects in Google Chrome*: <https://blogs.msdn.microsoft.com/webdev/2016/11/21/client-side-debugging-of-asp-net-projects-in-google-chrome/>
- *Angular Debugging*: <https://blog.angular-university.io/angular-debugging/>

9

ASP.NET Core and Angular Unit Testing

Unit Testing is the name given to a method of software testing that helps to determine whether the isolated modules of a program (units) are working correctly. After the various units have been verified, they can be merged together and tested as a whole (integration testing and system testing) and/or released in production.

Given this definition, it's pretty easy to understand the importance of properly defining and isolating the various units. These are the smallest testable parts of our software, featuring a few inputs and a single output. In **Object-Oriented Programming (OOP)**, where the program's source code is split into classes, a unit is often a method of a super, abstract, or derived class, yet it can also be a static function of a helper class.

Although they've become a *de facto* standard for high-quality projects, unit tests are often underestimated by most developers and project managers who are eager to speed up the whole development process and therefore reduce its overall cost. Such an approach may not be acceptable for small-scale projects with low-profit margins since creating unit tests undeniably requires some additional work. However, it's very important to understand their huge benefits for medium-to-big projects and enterprise solutions, especially if they require the coordinated effort of a large number of developers.

This chapter is entirely dedicated to unit tests. More precisely, we'll learn how to define, implement, and perform the following:

- **Back-end unit tests in .NET Core**, using the **xUnit.net** testing tool
- **Front-end unit tests in Angular**, using the **Jasmine** testing framework and the **Karma** test runner that we've briefly seen in [Chapter 2, Looking Around](#)

We'll also get the opportunity to briefly introduce some widely used testing practices that can help us to get the most from our tests, such as **Test-Driven Development (TDD)** and **Behavior-Driven Development (BDD)**. By the end of this chapter, we'll have learned how to properly design and implement *back-end* and *front-end* unit tests following these practices.

For the sake of simplicity, we're going to perform our unit test in our existing `WorldCities` Angular app. However, to do this, we're going to add some new packages to our project.

Technical requirements

In this chapter, we're going to need all of the previous technical requirements listed in previous chapters, with the following additional packages:

- `Microsoft.NET.Test.Sdk`
- `xunit`
- `xunit.runner.visualstudio`
- `Moq`
- `Microsoft.EntityFrameworkCore.InMemory`

As always, it's advisable to avoid installing them straight away. We're going to bring them in during this chapter to better contextualize their purpose within our project.

The code files for this chapter can be found here: https://github.com/PacktPublishing/ASP.NET-Core-3-and-Angular-9-Third-Edition/tree/master/Chapter_09/.

.NET Core unit tests

In this section, we'll learn how to build a .NET Core unit test project using xUnit.net: a free, open-source, community-focused unit testing tool for the .NET Framework created by Brad Wilson, who also developed NUnit v2. We've chosen this tool because it's arguably one of the most powerful and easy-to-use unit testing tools available today. It's part of the .NET Foundation, hence operating under their code of conduct, and is licensed under Apache License, version 2.

Before moving on, we'll also take the opportunity to talk about TDD and BDD in the following sections. These are the two widely used testing approaches that have a number of similarities and differences that are worth exploring.

Creating the WorldCities.Test project

To create the test project, perform the following steps:

1. Open a command-line Terminal.
2. Navigate to the `WorldCities` solution's root folder (be careful: the *solution* root folder, not the project one!).
3. Type the following command and hit *Enter*:

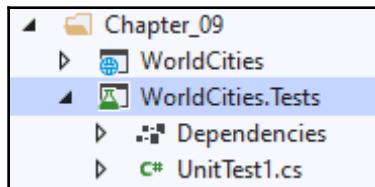
```
> dotnet new xunit -o WorldCities.Tests
```

The .NET CLI should create a new project for us and process some post-creation actions. Once done, a text message will inform us that the restore task has been completed (**Restore completed**). If we have done everything correctly, a new `WorldCities.Tests` project should be present at the same folder level of the existing `WorldCities` project.

Immediately after this, we can add our new `WorldCities.Tests` project to our main solution in the following way:

1. From **Solution Explorer**, right-click on the root solution's node and select **Add Existing Project**.
2. Navigate inside the `/WorldCities.Tests/` folder and select the `WorldCities.Tests.proj` file.

The new `WorldCities.Tests` project will be loaded in the existing solution, right below the `WorldCities` existing project, as shown in the following screenshot:



Let's delete the existing `UnitTest1.cs` file, since we won't need it. We'll create our own unit testing classes in a short while.

The new `WorldCities.Test` project should already have the following NuGet package references:

- **Microsoft.NET.Test.Sdk** (version 1.6.4 or later)
- **xunit** (version 2.4.1 or later)
- **xunit.runner.visualstudio** (version 2.4.1 or later)



The preceding packages' version numbers are the latest at the time of writing and the ones that we're going to use in this book.

However, we also require two more NuGet packages: **Moq** and **Microsoft.EntityFrameworkCore.InMemory**. Let's see how to add them in the following sections.

Moq

Moq is arguably the most popular and friendly mocking framework for .NET. To better understand why we need it, we need to introduce the concept of mocking.

Mocking is a convenient feature that we can use in unit testing whenever the unit that we want to test has external dependencies that cannot be easily created within the testing project. The main purpose of a mocking framework is to create replacements objects that simulate the behavior of the real ones. **Moq** is a minimalistic framework that will do just that.

To install it, do the following:

1. From **Solution Explorer**, right-click on the `WorldCities.Test` project and choose **Manage NuGet Packages**.
2. Search for the `Moq` keyword.
3. Find and install the **Moq NuGet Package**.

Alternatively, just type the following command in the Visual Studio's **Package Manager Console**:

```
> Install-Package Moq
```

At the time of writing, we're using **Moq 4.13.1**, this being the latest stable version. To be sure that you are using this version as well, just add `-version 4.13.1` to the preceding command.



The latest **Moq** NuGet package, as well as all of the previous versions, are available here:

<https://www.nuget.org/packages/moq/>

That's it! We now need to install another NuGet package.

Microsoft.EntityFrameworkCore.InMemory

`Microsoft.EntityFrameworkCore.InMemory` is an in-memory database provider for Entity Framework Core that can be used for testing purposes. This is basically the same concept as the Angular in-memory Web API that we talked about in Chapter 4, *Data Model with Entity Framework Core*. In a nutshell, we can think of it as a convenient database mock.

To install it, do the following:

1. From **Solution Explorer**, right-click on the `WorldCities.Test` project and choose **Manage NuGet Packages**.
2. Search for the `Microsoft.EntityFrameworkCore.InMemory` keyword.
3. Find and install the **Microsoft.EntityFrameworkCore.InMemory** NuGet package.

Alternatively, just type the following command in the Visual Studio's **Package Manager Console**:

```
> Install-Package Microsoft.EntityFrameworkCore.InMemory
```

At the time of writing, we're using **Microsoft.EntityFrameworkCore.InMemory 3.1.1**, this being the latest stable version. To be sure that you are using this version as well, just add `-version 3.1.1` to the preceding command.



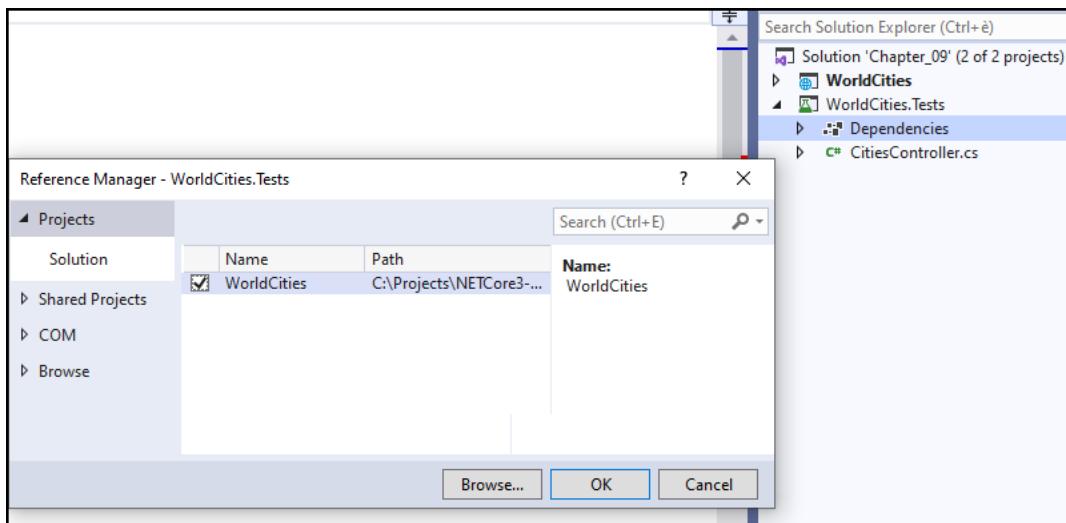
The latest `Microsoft.EntityFrameworkCore.InMemory` NuGet package, as well as all of the previous versions, are available here:
<https://www.nuget.org/packages/Microsoft.EntityFrameworkCore.InMemory/>

With this, we're all set.

Adding the WorldCities dependency reference

The next thing we need to do is to add a reference to the main project in our new `WorldCities.Test` project's dependencies so that we'll be able to import the required classes and types.

To do that, right-click on the **Dependencies** node of the new project to add a reference to the `WorldCities` project, as shown in the following screenshot, and press **OK**:



By doing this, our test project will be able to access (and hence test) the whole `WorldCities` code.

We're now ready to learn how **xUnit** actually works. As always, the best way to do this is to create our first unit test.

Our first test

In Standard Testing Development practice, which we're going to call STD from now on, unit tests are often used to ensure that our existing code is working properly. Once ready, those units will be protected against regression bugs and breaking changes.

Since our *back-end* code is a Web API, the first thing we can cover with our unit tests should be the individual Controller's method. However, instantiating our Controllers outside our web application's life cycle is not that simple, since they do have at least two important dependencies: `HttpContext` and `ApplicationDbContext`. Is there a way to instantiate them too in our `WorldCities.Test` project?

Thanks to `Microsoft.EntityFrameworkCore.InMemory`, this can be a rather easy task... as soon as we understand how to use it.

From **Solution Explorer**, open the `WorldCities.Test` project. Create a new `CitiesController_Test.cs` file in the project's root and fill it with the following content:

```
using Microsoft.EntityFrameworkCore;
using WorldCities.Controllers;
using WorldCities.Data;
using WorldCities.Data.Models;
using Xunit;

namespace WorldCities.Tests
{
    public class CitiesController_Tests
    {
        /// <summary>
        /// Test the GetCity() method
        /// </summary>
        [Fact]
        public async void GetCity()
        {
            #region Arrange
            // todo: define the required assets
            #endregion

            #region Act
            // todo: invoke the test
            #endregion

            #region Assert
            // todo: verify that conditions are met.
            #endregion
        }
    }
}
```

As we can see by looking at the highlighted regions, we have split the unit test into three code blocks, or phases:

- **Arrange:** Defines the assets required to run the test
- **Act:** Invokes the testing subject's behavior
- **Assert:** Verifies that the expected conditions are met by evaluating the behavior's return value or measuring it against some user-defined rules

Such an approach is known as the **Arrange, Act, Assert** pattern. This is a typical way to describe the various phases of software testing in TDD. However, there are also alternative names used to describe these same test phases; for example, BDD frameworks usually refer to them as *Given*, *When*, and *Then*.



TDD and BDD are two development practices that enforce a different coding approach when compared to **Standard Testing Development (STD)**. We'll talk more about these soon enough.

Regardless of the names, the important thing here is to understand the following key concepts:

- Separating the three phases increases the readability of the test.
- Executing the three phases in the proper order makes the test easier to understand.

Let's now take a look at how we have implemented the three phases.

Arrange

The `Arrange` phase is the place where we define the assets required to run the test. In our scenario, since we're going to test the functionality of `GetCity()` method of `CitiesController`, we need to provide our Controller with a suitable `ApplicationDbContext`.

However, since we're not testing `ApplicationDbContext` itself, instantiating the real thing wouldn't be advisable, at least for now. We don't want our test to fail just because the database is unavailable or the database connection is incorrect because these are different units and therefore should be checked by different unit tests. Moreover, we definitely can't allow our unit tests to operate against our actual data source: what if we want to test an update or a delete task?

The best thing we can do to test our Web API Controllers is to find a way to provide them with a replacement object that can behave just like our real `ApplicationDbContext`; in other words, a mock. This is where the `Microsoft.EntityFrameworkCore.InMemory` NuGet package that we installed early on might come in handy.

Here's how we can use it to properly implement the `Arrange` phase:

```
// ...existing code...

#region Arrange
var options = new DbContextOptionsBuilder<ApplicationDbContext>()
    .UseInMemoryDatabase(databaseName: "WorldCities")
    .Options;
using (var context = new ApplicationDbContext(options))
{
    context.Add(new City() {
        Id = 1,
        CountryId = 1,
        Lat = 1,
        Lon = 1,
        Name = "TestCity1"
    });
    context.SaveChanges();
}
City city_existing = null;
City city_notExisting = null;
#endregion

// ...existing code...
```

As we can see, we've used the `UseInMemoryDatabase` extension method provided by the `Microsoft.EntityFrameworkCore.InMemory` package to create a suitable `DbContextOptionsBuilder`. Once we have it, we can use it to instantiate an `ApplicationDbContext` session with an in-memory database instead of the SQL Server used by the `WorldCities` project.

Once created, that `context` can be populated by creating new cities, which is what we did in the preceding code, creating `TestCity1` with some random data. This will allow our `GetCity()` method of `CitiesController` to actually retrieve something, providing that we'll pass that city ID.

Other than that, we have defined two `City` objects that will contain the two specimens for this test.

Act

The Act phase is where the test takes place. It often consists of a single instruction that corresponds to the behavior of the unit that we want to check.

Here's the Act phase implementation:

```
// ...existing code...

#region Act
using (var context = new ApplicationDbContext(options))
{
    var controller = new CitiesController(context);
    city_existing = (await controller.GetCity(1)).Value;
    city_notExisting = (await controller.GetCity(2)).Value;
}
#endregion

// ...existing code...
```

As we can see, the entire implementation is enclosed by a `using` directive, which ensures that our in-memory `ApplicationDbContext` instance will be properly disposed of as soon as the phase ends.

The remainder of the code is quite self-explanatory. We have created a `CitiesController` instance using the in-memory context and we execute the `GetCity()` method two times:

- The first occasion is to retrieve an existing city (using the same `Id` that we used to populate our in-memory database with).
- The second occasion is to retrieve a non-existing city (using a different `Id`).

The two return values are then stored in the `city_existing` and `city_notExisting` variables. Ideally, the first one should contain `TestCity1`, which we have created in the Arrange phase, while the latter should be `null`.

Assert

The purpose of the `Assert` phase is to verify that the conditions that we expect are properly met by the values retrieved by the `Act` phase. To do this, we'll make use of the `Assert` class provided by `xUnit`, which contains various static methods that can be used to verify that these conditions are met.

Here's the `Assert` phase implementation:

```
#region Assert
Assert.True(
    city_existing != null
    && city_notExisting == null
);
#endregion
```

As we can see, we're just checking the values of the two variables that contain the return values of the two `GetCity()` method calls of `CitiesController` made in the `Act` phase. We reasonably expect `city_existing` not to be `null`, while `city_notExisting` should definitely be `null`.

Our test is now ready, so let's see how we can execute it.

Executing the test

Each unit test can be executed in two ways:

- **From the command line**, using the .NET Core CLI
- **From the Visual Studio GUI**, using the Visual Studio's built-in test runner (Test Explorer)

Let's quickly try both of these approaches.

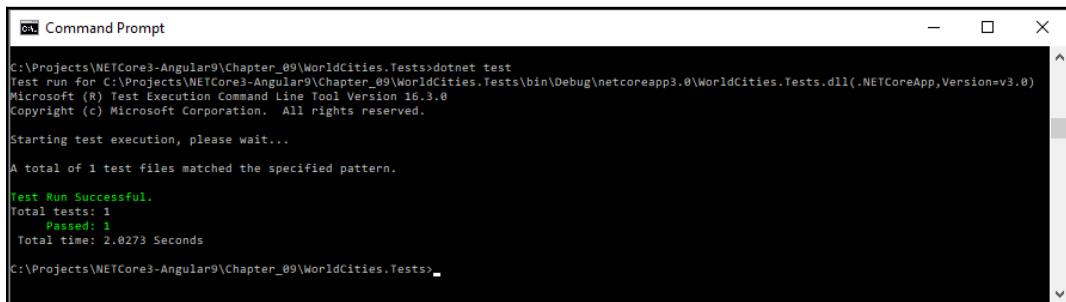
Using the CLI

To execute our test unit(s) by using the .NET CLI, perform the following steps:

1. Open Command Prompt.
2. Navigate to the `WorldCities.Tests` project root folder.
3. Execute the following command:

```
> dotnet test
```

If we have done everything correctly, we should see something like this:



The screenshot shows a Windows Command Prompt window titled "cmd Command Prompt". The output of the command `dotnet test` is displayed:

```
C:\Projects\NETCore3-Angular9\Chapter_09\WorldCities.Tests>dotnet test
Test run for C:\Projects\NETCore3-Angular9\Chapter_09\Worldcities.Tests\bin\Debug\netcoreapp3.0\WorldCities.Tests.dll(.NETCoreApp,Version=v3.0)
Microsoft (R) Test Execution Command Line Tool Version 16.3.0
Copyright (c) Microsoft Corporation. All rights reserved.

Starting test execution, please wait...

A total of 1 test files matched the specified pattern.

Test Run Successful.
Total tests: 1
    Passed: 1
Total time: 2.0273 Seconds

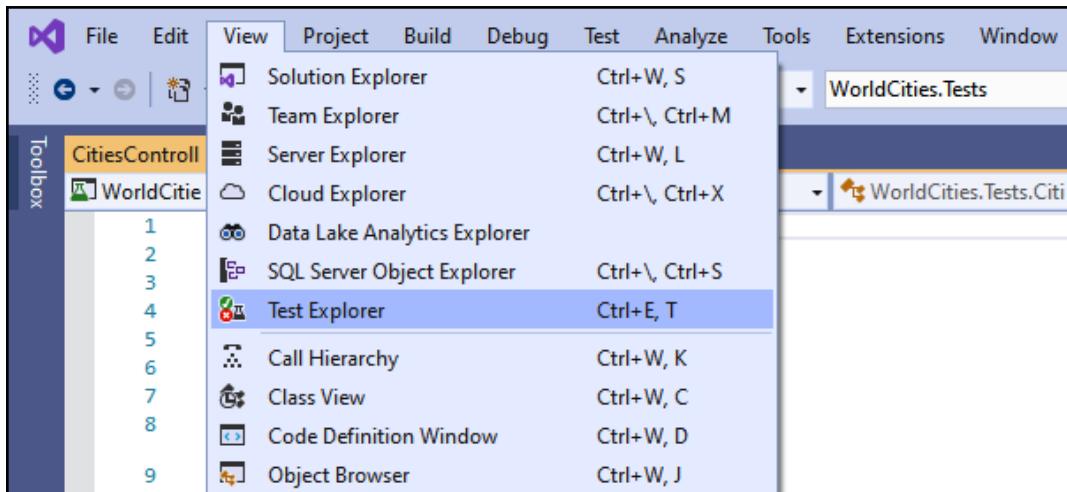
C:\Projects\NETCore3-Angular9\Chapter_09\WorldCities.Tests>
```

That's it. Our test is working and it does pass, meaning that the `GetCity()` method of `CitiesController` is behaving as expected.

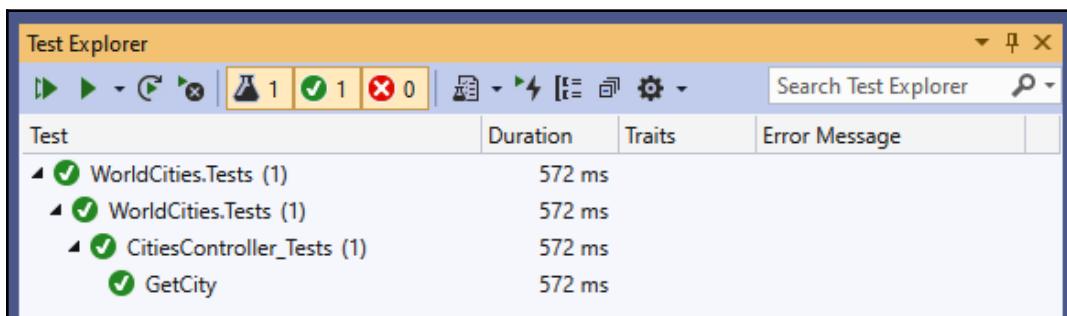
Using the Visual Studio Test Explorer

Being able to run our tests from the command line can be a great feature if we want to automate such kind of tasks. However, in most cases, we'll rather want to be able to run these tests directly from within the Visual Studio GUI.

Luckily enough, this is definitely possible thanks to the **Test Explorer** window, which can be activated by pressing `Ctrl + E, T` or from **Menu | View**, as shown in the following screenshot:



Once activated, the **Test Explorer** window should be accessible in the rightmost part of the Visual Studio GUI, just below the **Solution Explorer** window. From there, we can either run all tests or just the current test by pressing the first two green *play* icons placed at the top-left part of the panel, called **Run All** and **Run**, respectively (refer to the following screenshot):



Since we only have a single test, for now, either command will do the same thing: run our unit test and show the results using either a green check (success) or a red cross (failure).

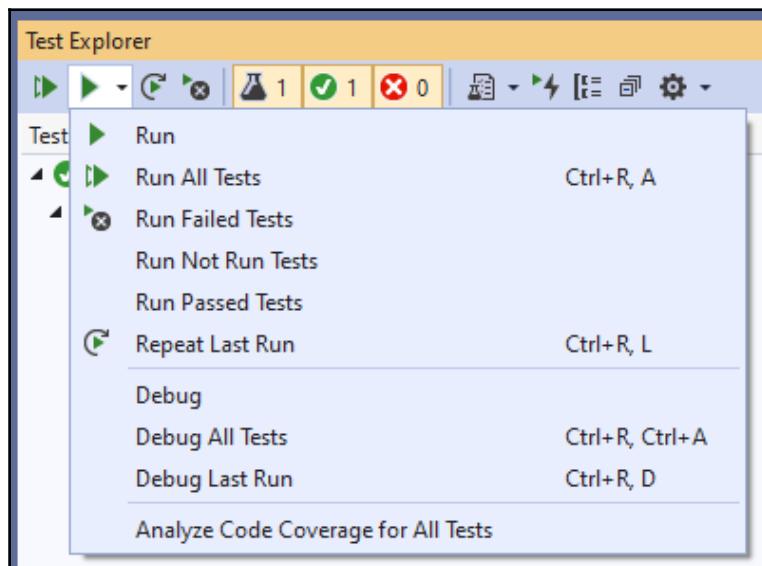


As we can see in the preceding screenshot, those green and/or red icons will be used to determine the combined results of the testing class, the namespace, and the whole assembly.

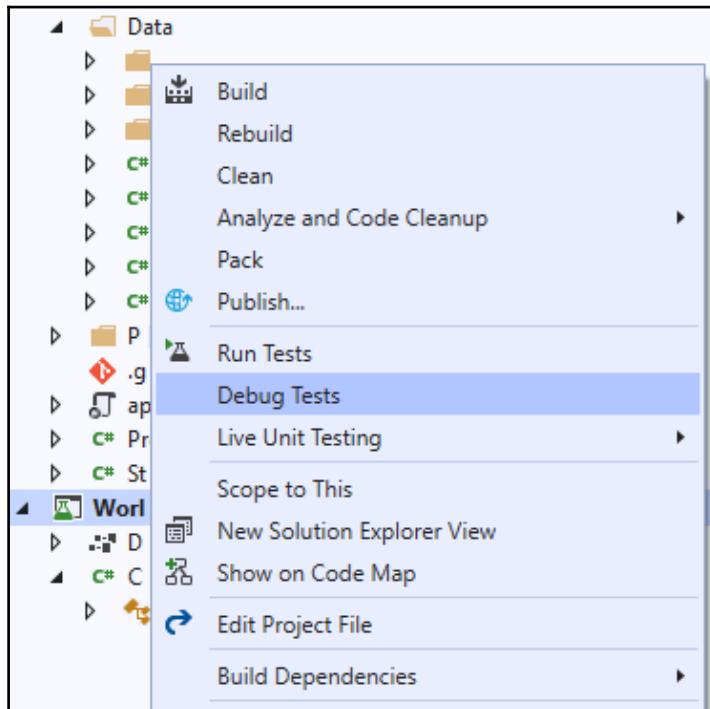
Before moving further, we should spend another couple of minutes learning how to debug these unit tests.

Debugging tests

If we click on the arrow handle next to the second **Run** icon in the top-left part of the **Test Explorer** window, we can see that there are a number of other possible commands we can give to our tests, including the **Debug**, **Debug All Tests**, and **Debug Last Run** (refer to the following screenshot):

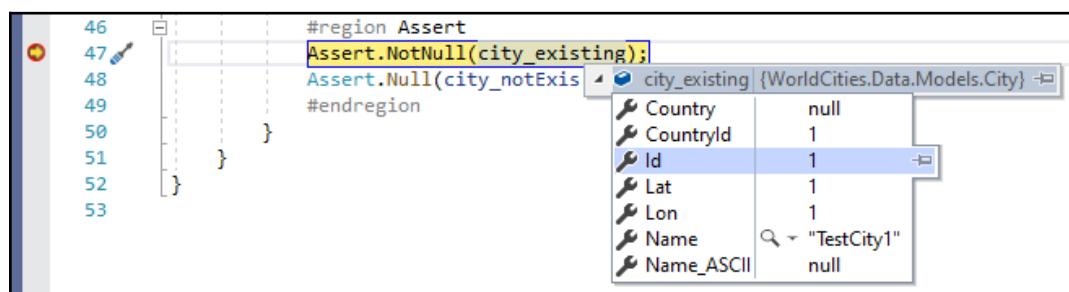


Alternatively, we can use the **Debug Tests** command that is shown when we right-click on the `WorldCities.Tests` project node from the **Solution Explorer** window:



Both commands will execute our test in debug mode, meaning that we can set breakpoints (or conditional breakpoints) and evaluate the results.

To quickly test it, set a breakpoint to the first line of the `Assert` region, then execute the preceding **Debug Tests** command, and wait for the hit:



There we go. Now, we know how to debug our unit tests. This can be very useful during the adoption phase when we still don't know how to properly use them and/or we're still learning the various xUnit.net commands.



Those readers who want to know more about xUnit.net for .NET Core and the unique unit test classes and methods provided by this package are strongly encouraged to check out the following URL:

<https://xunit.net/docs/getting-started/netcore/cmdline>

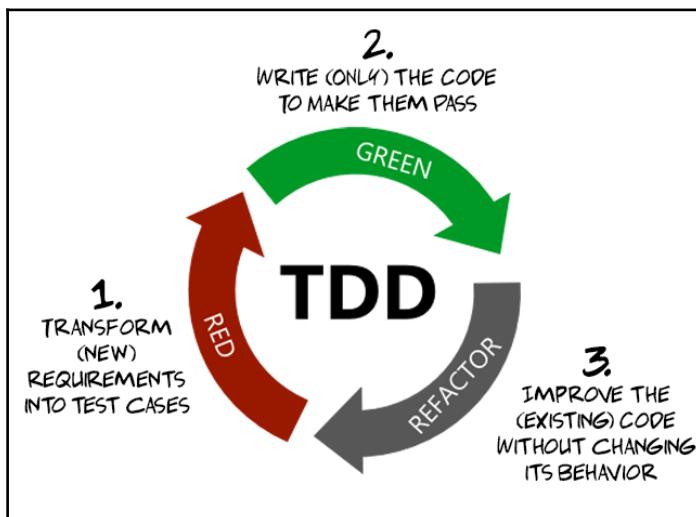
Before switching to the *front-end*, it might be worthwhile spending a couple of minutes familiarizing ourselves with the concepts of TDD and BDD since this is something that could greatly help us to create useful and relevant tests.

Test-Driven Development

TDD is more a programming practice than a testing approach, and it can be a very good practice, at least for certain scenarios.

In a nutshell, a software developer that adopts the TDD methodology will convert all of the software requirements into specific test cases, and then write the new code (or improve the existing code) so that the tests will pass.

Let's try to visualize the actual life cycle of these programming practices with the help of a small diagram:



As we can see, TDD is mostly a way of designing the code that requires developers to **start writing test cases that express what they intend the code to do before writing any actual code (RED)**. Once done, it asks them to **only write the code required to make the test cases pass (GREEN)**. Eventually, **when all of the test cases pass, the existing code can be improved (REFACTOR)**, until more test cases appear. This short development cycle is conventionally called **RED-GREEN-REFACTOR** and is the backbone of the TDD practice. It's worth noting that **RED** is always the initial step of any cycle since the tests will always fail at the start because their code that could allow them to pass is yet to be written.

Such a practice is very different from the STD practice, where we first generate the code and then (maybe) the tests. In other words, our source code can be (and therefore usually gets) written before (or even without) test cases. The main difference between the two approaches is that, in TDD, tests are requirement conditions that we need to fulfill while in STD, as we have already said a short while ago, they are mostly the proof that our existing code is working.

In the next chapter, when dealing with authentication and authorization, we'll try to create a couple of *back-end* unit tests using the TDD approach; after all, since the TDD practice requires the creation of test cases only when we have to implement additional requirements, the best way to use it is when we have some new features to add.

Behavior-Driven Development

BDD is an agile software development process that shares the same test-first approach of TDD but **emphasizes the end-user perspective results instead of focusing on implementation**.

To better understand the key differences between TDD and BDD, we can ask ourselves the following question:

What are we testing for?

That's a great question to ask when we're about to write some unit tests.

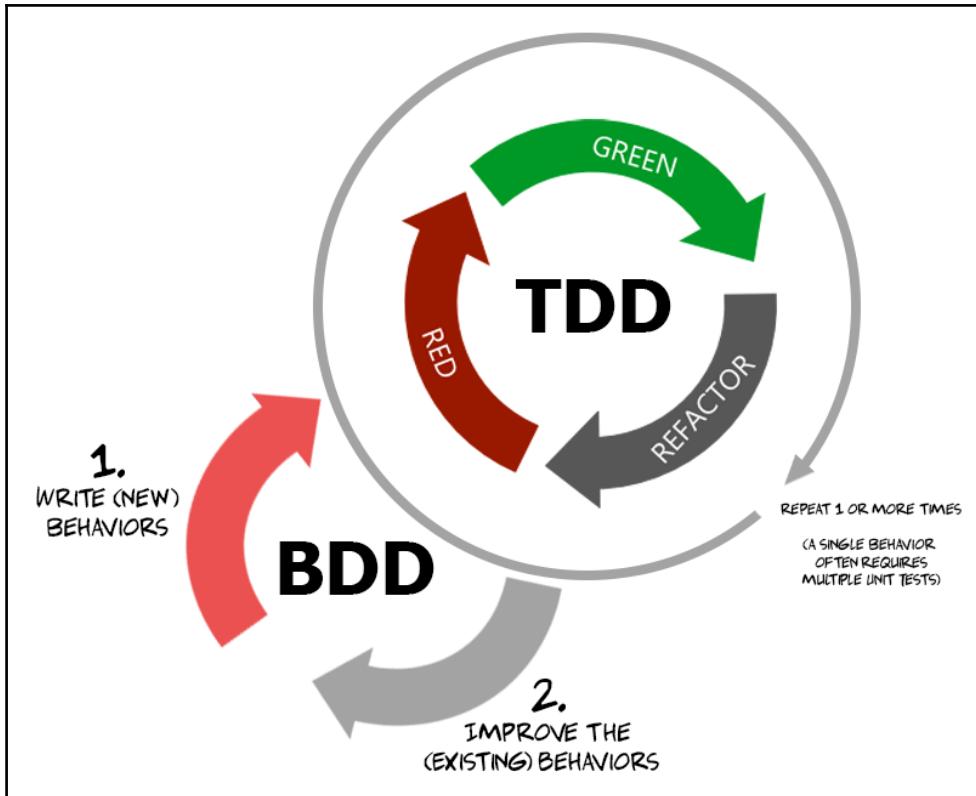
If we want to test the actual implementation of our methods/units, TDD might be the proper way to go. However, if we aim to figure out the end-user behavior of our application under specific circumstances, TDD might give us false positives, especially if the system evolves (as Agile-driven projects often do). More specifically, we could encounter a scenario where one or more units are passing their tests despite failing to deliver the expected end-user outcome.

In more general terms, we can say the following:

- TDD is meant to **enforce developers' control over the source code they write.**
- BDD aims to **satisfy both the developer and the end-user** (or customer).

Therefore, we can easily see how BDD supersedes TDD instead of replacing it.

Let's try to wrap up these concepts in a diagram:



As we can see, BDD acts just like an extension to TDD. Instead of writing the test cases, we start by writing a behavior. As soon as we do that, we will develop the required code for our application to be able to perform it (arguably using TDD), and then we move on to define additional behaviors or refactor the existing ones.

Since these behaviors are aimed at the end-user, they must also be written using understandable terms. For that very reason, the BDD tests are usually defined using a semi-formal format that is borrowed from Agile's user stories, with a strong narrative and an explicit contextualization. These user stories are generally meant to comply with the following structure:

- **Title:** An explicit title, such as *Editing an Existing City*
- **Narrative:** A descriptive section that uses the *Role/Feature/Benefit* pattern from Agile user stories, such as *As a user, I want to edit an existing city, so that I can change its values*
- **Acceptance criteria:** A description of the three test phases, using the *Given/When/Then* model, which is basically a more understandable version of the *Arrange/Act/Assert* cycle used in TDD, such as: **Given** a world cities database containing one or more cities; **When** the user selects a City; **Then** the app must retrieve it from the DB and display it on the front-end

As we can see, we just tried to describe the unit test we created a while ago using a typical BDD approach. Although it mostly works, it's evident that a single behavior might require multiple *back-end* and *front-end* unit tests. This lets us understand another distinctive feature of the BDD practice. The utmost importance of the *front-end* testing phase is the best way to test user behavior rather than an implementation spec.

All in all, BDD can be a great way to extend a standard TDD approach to design our tests in a way that their results can address a wider audience—provided we're able to properly design the required *front-end* and *back-end* tests.

In the next section, we're going to learn how we can do that.

Angular unit tests

Everything we have said in the previous sections of this chapter regarding the .NET Core testing purposes, meanings, and approaches are also valid for Angular.

Luckily enough, this time, we won't need to install anything since the .NET Core and Angular Visual Studio template that we've used to create our `WorldCities` project already contains everything we need to write app tests for our Angular application.

More specifically, we can already count on the following packages, which we've briefly introduced in Chapter 2, *Looking Around*:

- **Jasmine:** A JavaScript testing framework that fully supports the BDD approach that we talked about earlier
- **Karma:** A tool that lets us spawn browsers and run our Jasmine tests inside them (and show their results) from the command line
- **Protractor:** An end-to-end test framework that runs tests against Angular applications from within a real browser, interacting with it as if it were a real user

For additional information regarding Jasmine and Karma, check out the following guides:

Karma:

<https://karma-runner.github.io/>



Jasmine:

<https://jasmine.github.io/>

Protractor:

<https://www.protractortest.org/>

Angular Unit Test:

<https://angular.io/guide/testing>

In the following sections, we're going to do the following:

- **Review the testing configuration files** still present in our `WorldCities` Angular app
- **Introduce the TestBed interface**, one of the most important concepts of Angular testing
- **Explore Jasmine and Karma** to understand how they actually work
- **Create some .spec.ts files** to test our existing Components
- **Set up and configure some tests** for our Angular app

Let's get started!

General concepts

Conversely, from what we did in .NET Core, where we created our unit tests in separate `WorldCities.Tests` projects, all our *front-end* tests will be written in the same project that hosts our Angular app.

As a matter of fact, we've already seen one of these tests in [Chapter 2, Looking Around](#), when we explored the Angular folders for the first time. The test was written in the `counter.component.spec.ts` file, which we then deleted at the end of that chapter because we no longer required `CounterComponent`.

Luckily enough, we didn't delete the following files from the `/ClientApp/src/app/` folder:

- `karma.conf.js`: The application-specific Karma configuration file, containing information about the reporters, the browser to use, the TCP port, and so on
- `test.ts`: The Angular entry point for the project's unit test; this is where Angular initializes the testing environment, configures the `.spec.ts` extensions to identify the test files, and loads the required modules from the `@angular/core/testing` and `@angular/platform-browser-dynamic/testing` packages

That's a good thing because now we just need to write tests for our new Components. However, before doing that, it would be wise to spend a bit longer explaining how Angular testing actually works.

Introducing the TestBed interface

The **TestBed** interface is one of the most important concepts of the Angular testing approach. In a nutshell, a **TestBed** is a dynamically constructed Angular test module that emulates the behavior of an Angular **@NgModule**.

The **TestBed** concept was first introduced with Angular 2 as a convenient way to test a Component with a real DOM behind it. The **TestBed** interface significantly assists in this regard thanks to its support for injecting services (either real or mock) into our Components, as well as automatically binding Components and templates.

To better understand how a TestBed actually works and how we can use it, let's take a look at the TestBed implementation provided within the `counter.component.spec.ts` file that we deleted back in Chapter 2, *Looking Around*:

```
TestBed.configureTestingModule({
  declarations: [ CounterComponent ]
})
.compileComponents();
```

In the preceding code, we can see how the TestBed reproduces the behavior of a minimalistic `AppModule` file — the bootstrap `@NgModule` of an Angular app — with the sole purpose of compiling the Components that we need to test. It uses the Angular module system (which we've talked about in Chapter 3, *Front-end and Back-end Interactions*) to declare and compile `CounterComponent` so that we can use its source code in our tests.

Testing with Jasmine

Jasmine tests are usually constructed using the following three main APIs:

- `describe()`: A wrapping context used to create a group of tests (also called a *test suite*)
- `it()`: The declaration of a single test
- `expect()`: The expected result of a test

These APIs will be available within our `*.spec.ts` files in the form of static methods thanks to the built-in Angular integration with the Jasmine testing framework.

By keeping this in mind, let's create our first testing class file for our Angular app.

Our first Angular test suite

Let's now try to create our own test suite, and a corresponding TestBed, for one of our existing Angular Components. We'll use `CitiesComponent` since we know it very well.

Unfortunately, the Angular CLI doesn't (yet) provide a way to automatically generate `spec.ts` files for existing Component classes. However, there are a number of third-party libraries that generate the specs based on Angular CLI spec presets.



The most popular (and widely used) package that does that is called `ngx-spec` and is available on GitHub at the following URL:

<https://github.com/smnbbrv/ngx-spec>

However, we're not going to use it in our specific scenario; we'll create and implement our `spec.ts` files manually so that we can better understand how they work.

From **Solution Explorer**, create a new `/ClientApp/src/app/cities/cities.component.spec.ts` file and open it. Since we're going to write a fair amount of source code, it would be wise to separate it into multiple blocks.

The import section

Let's start by defining the required `import` statements:

```
import { async, ComponentFixture, TestBed } from
  '@angular/core/testing';
import { BrowserAnimationsModule } from
  '@angular/platform-browser/animations';
import { AngularMaterialModule } from '../angular-material.module';
import { of } from 'rxjs';

import { CitiesComponent } from './cities.component';
import { City } from './city';
import { CityService } from './city.service';
import { ApiResult } from '../base.service';

// ...to be continued...
```

As we can see, we added a bunch of modules that we already use in our `AppModule` and `CitiesComponent` classes. This is certainly anticipated since our `TestBed` will need to reproduce a suitable `@NgModule` for our tests to run.

The describe and beforeEach sections

Now that we have got all of our required references, let's see how we can use the `describe()` API to lay out our testing suite:

```
// ...existing code...

describe('CitiesComponent', () => {
  let fixture: ComponentFixture<CitiesComponent>;
  let component: CitiesComponent;

  // async beforeEach(): testBed initialization
  beforeEach(async(() => {

    // todo: initialize the required providers

    TestBed.configureTestingModule({
      declarations: [CitiesComponent],
      imports: [
        BrowserAnimationsModule,
        AngularMaterialModule
      ],
      providers: [
        // todo: reference the required providers
      ]
    })
    .compileComponents();
  }));

  // synchronous beforeEach(): fixtures and components setup
  beforeEach(() => {
    fixture = TestBed.createComponent(CitiesComponent);
    component = fixture.componentInstance;

    // todo: configure fixture/component/children/etc.
  });

  // todo: implement some tests
});
```

As we can see by looking at the preceding code, everything happens within a single `describe()` wrapping context, which represents our `CitiesComponent` test suite. All of the tests related to our `CitiesComponent` class will be implemented inside this suite.

The first thing we have done in the test suite is to define two important variables that will be used extensively in our tests:

- `fixture`: This property hosts a fixed state of `CitiesComponent` for running tests; we can use this fixture to interact with the instantiated Component and its child elements.
- `component`: This property will contain the `CitiesComponent` instance created from the preceding fixture.

Immediately after this, we defined two consecutive `beforeEach()` method calls. To better distinguish them, we have provided them with a different name using the inline comments:

- `async beforeEach()`, where the TestBed is created and initialized
- `synchronous beforeEach()`, where fixtures and Components are instantiated and configured

Inside `async beforeEach()`, we have defined a TestBed by declaring our `CitiesComponent` and importing its two required modules — `BrowserAnimationModule` and `AngularMaterialModule`. As we can see from the `todo` comments we've left, we'll also need to define and configure our providers (such as `CityService`), otherwise, `CitiesComponent` won't be able to inject them; we'll do that in a short while. Inside `synchronous beforeEach()`, we have instantiated our `fixture` and `component` variables. Since we'll likely have to properly set up them and/or configure some of our Component's child elements, we've left another `todo` comment there as well.

At the end of the file, there's another `todo` comment. This is where we'll get to implement our tests using `it()` and `expect()` APIs provided by the Jasmine framework.

Adding a mock CityService

Now, we're going to replace our first `todo` by implementing a *mock* `CityService` so that we can reference it within our `TestBed`.



As we already know from the *back-end* testing using .NET Core and xUnit, a mock is a replacement object that simulates the behavior of the real ones.

Just like .NET Core and xUnit, Jasmine provides multiple ways to set up mock objects. In the following paragraphs, we'll briefly review some of the most frequently used approaches.

Fake service class

We can create a fake `CityService`, which just returns whatever we want for our test. Once done, we can import it in the `.spec.ts` class and add it to the TestBed's providers list so that it will be called by our Component just like the real one.

Extending and overriding

Instead of creating a whole double class, we can just extend the real service and then override the methods we need in order to perform our tests. Once done, we can set up an instance of the extended class in our TestBed using the `@NgModule`'s `useValue` feature.

Interface instance

Instead of creating a new double or extended class, we can just instantiate the interface of our service, implementing just the method that we need for our tests. Once done, we can set up that instance in our TestBed using the `@NgModule`'s `useValue` feature.

Spy

This approach relies upon a Jasmine-specific feature called `spy`, which lets us take an existing class, function, or object and mock it so that we can control its return values. Since the real method won't be executed, a spy method will work just like an override, without having to create an extended class.

We can use such a feature to create a real instance of our service, spy the method that we want to override, and then set up that specific instance in our TestBed using the `@NgModule`'s `useValue` feature. Alternatively, we can use the `jasmine.createSpyObj()` static function to create a mock object with multiple spy methods that we can then configure in various ways.

Implementing the mock CityService

Which route should we take? Unfortunately, there's not a best answer for all scenarios, since the best approach often depends on the complexity of the features we want to test and/or how we want to structure our test suite.

Theoretically speaking, creating a whole **fake service class** is arguably the safest and versatile choice since we can fully customize our mock service return values. However, it can also be time-consuming and often unnecessary, as long as we're dealing with simple services and/or small-scale tests. Conversely, the **extend and override, interface, and spy** approaches are often a great way to address the basic requirements of most tests, yet they might give unexpected results in complex testing scenarios, unless we pay close attention to overriding/spying all of the required methods.

Everything considered, since our `CityService` is quite small and features a simple implementation with a small number of methods, we're going to use the `spy` approach, which seems to be the most apt one for our given scenario.

Let's go back to the `/ClientApp/src/cities/cities.components.spec.ts` file. Once there, the following line of code needs to be replaced:

```
// todo: initialize the required providers
```

The preceding line of code has to be replaced with the following code:

```
// Create a mock cityService object with a mock 'getData' method
let cityService = jasmine.createSpyObj<CityService>('CityService',
['getData']);

// Configure the 'getData' spy method
cityService.getData.and.returnValue(
  // return an Observable with some test data
  of<ApiResult<City>>(<ApiResult<City>>{
    data: [
      <City>{
        name: 'TestCity1',
        id: 1, lat: 1, lon: 1,
        countryId: 1, countryName: 'TestCountry1'
      },
      <City>{
        name: 'TestCity2',
        id: 2, lat: 1, lon: 1,
        countryId: 1, countryName: 'TestCountry1'
      },
      <City>{
```

```
        name: 'TestCity3',
        id: 3, lat: 1, lon: 1,
        countryId: 1, countryName: 'TestCountry1'
    }
],
totalCount: 3,
pageIndex: 0,
pageSize: 10
}));
```

That's it. Now, we can add our new mock `CityService` to the `TestBed` configuration, replacing the second `todo`:

```
// todo: reference the required providers
```

This is replaced with the highlighted lines of the following code:

```
// ...existing code...
```

```
TestBed.configureTestingModule({
  declarations: [CitiesComponent],
  imports: [
    BrowserAnimationsModule,
    AngularMaterialModule
  ],
  providers: [
    {
      provide: CityService,
      useValue: cityService
    }
  ]
})
.compileComponents();

// ...existing code...
```

That mock `CityService` will now be injected into `CitiesComponent`, thereby making us able to control the data returned for each test.

Alternative implementation using the interface approach

Here's how we could have implemented the mock `CityService` using the interface approach:

```
// Create a mock cityService object with a mock 'getData' method
let cityService = <CityService>{
  get: () => { return null; },
```

```
put: () => { return null; },
post: () => { return null; },
getCountries: () => { return null; },
isDupeCity: () => { return null; },
http: null,
baseUrl: null,
getData: () => {
    // return an Observable with some test data
    return of<ApiResult<City>>(<ApiResult<City>>{
        data: [
            <City>{
                name: 'TestCity1',
                id: 1, lat: 1, lon: 1,
                countryId: 1, countryName: 'TestCountry1'
            },
            <City>{
                name: 'TestCity2',
                id: 2, lat: 1, lon: 1,
                countryId: 1, countryName: 'TestCountry1'
            },
            <City>{
                name: 'TestCity3',
                id: 3, lat: 1, lon: 1,
                countryId: 1, countryName: 'TestCountry1'
            }
        ],
        totalCount: 3,
        pageIndex: 0,
        pageSize: 10
    });
}
```

```
};
```

As we can see, the code is rather similar, but implementing the interface requires additional code if we want to maintain the `<CityService>` type assertion. That's why we've used the `spy` approach instead.

Configuring the fixture and the Component

It's now time to remove the third `todo` in our `/ClientApp/src/cities/cities.components.spec.ts` class:

```
// todo: configure fixture/component/children/etc.
```

This needs to be replaced with the following highlighted lines:

```
// ...existing code...

// synchronous beforeEach(): fixtures and components setup
beforeEach(() => {
    fixture = TestBed.createComponent(CitiesComponent);
    component = fixture.componentInstance;

    component.paginator = jasmine.createSpyObj(
        "MatPaginator", ["length", "pageIndex", "pageSize"]
    );

    fixture.detectChanges();
});

// ...existing code...
```

The preceding code will perform the following steps directly before each test:

- Create a mock `MatPaginator` object instance.
- Trigger a change detection run on our Component.

As we might easily surmise, change detection isn't done automatically there, so we have to manually trigger it by calling the `detectChanges` method on our `fixture`. This will make our `ngOnInit()` method fire and populate the table with the cities. Since we're testing the Component behavior, that's definitely something to do before running our tests.



Creating the title test

We're finally ready to create our first test.

The last remaining `todo` line in our `/ClientApp/src/cities/cities.components.spec.ts` class needs to be replaced:

```
// todo: implement some tests
```

The preceding line of code needs to be replaced as follows:

```
it('should display a "Cities" title', async(() => {
    let title = fixture.nativeElement
        .querySelector('h1');
```

```
    expect(title.textContent).toEqual('Cities');
});
```

As we can see, we're finally using the `it()` and `expect()` Jasmine methods. The first one declares the meaning of our test, while the latter evaluates the Component's behavior against the expected one and determines the test result.

In this first test, we want to check that the Component displays a `Cities` title to the user. Since we know that our Component's template holds the title inside an `<H1>` HTML element, we can check it by performing a DOM query against `fixture.nativeElement`, the root Component element that contains all of the rendered HTML content.

Once we get the `title` element, we check its `textContent` property to see whether it's what we expect (`Cities`). This is what will make the test pass or fail.

Creating the cities tests

Before running our test suite, let's add another test.

Open the `/ClientApp/src/cities/cities.components.spec.ts` file again and add the following lines right below the previous test:

```
// ...existing code...

it('should contain a table with a list of one or more cities',
async(() => {
  let table = fixture.nativeElement
    .querySelector('table.mat-table');
  let tableRows = table
    .querySelectorAll('tr.mat-row');
  expect(tableRows.length).toBeGreaterThan(0);
}));

// ...existing code...
```

This time, we're checking the table that contains the list of cities. More precisely, we're counting the table body rows to ensure that the resulting number is greater than zero, meaning that the table has been filled with at least one city. To perform such a count, we're using the CSS classes that Angular Material assigns to its `MatTable` Component by default.

To better understand this, take a look at the following screenshot:

As we can see, the `mat-row` CSS class is only applied to the table body rows, while the table header rows have the `mat-header-row` class. Therefore, if the test passes, it definitely means that the Component created at least one row within the table.



IMPORTANT: It goes without saying that relying upon CSS classes applied by a third-party package to define our tests is not a good practice. We're doing that just to demonstrate what we can do with our current implementation. A safer approach for such DOM-based tests would arguably require defining custom CSS classes and checking for their presence instead.

Running the test suite

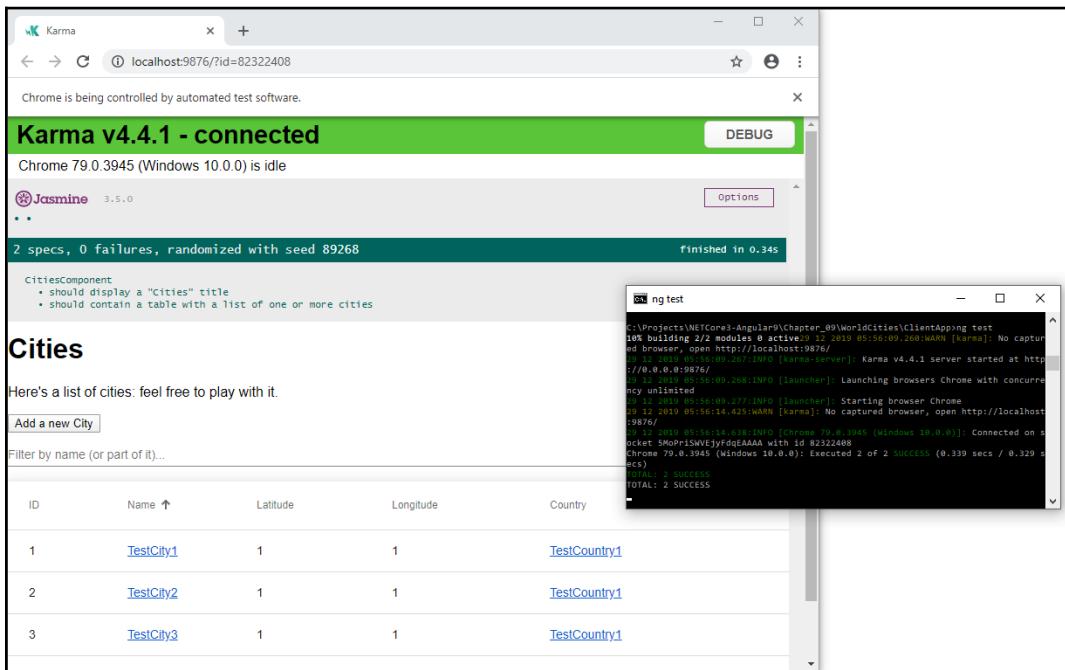
It's now time to run our test suite and see what we've got.

To do this, perform the following steps:

1. Open Command Prompt.
2. Navigate to the /ClientApp/ folder of the WorldCities app.
3. Execute the following command:

```
> ng test
```

This will launch the Karma test runner, which will open a dedicated browser to run the tests into. If we have done everything correctly, we should be able to see the following results:



That's it. Both tests passed. To be 100% certain that we did everything properly, let's now try to make them fail.

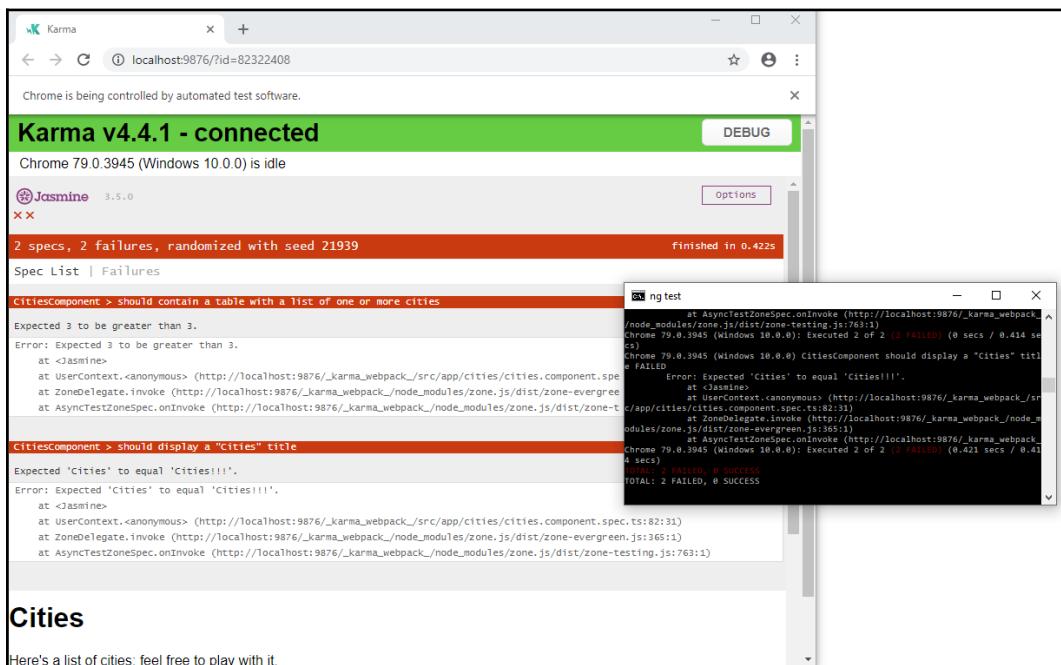
Open the /ClientApp/src/cities/cities.components.spec.ts file again and modify the test's source code in the following way (the updated lines are highlighted):

```
it('should display a "Cities" title', async(() => {
  let title = fixture.nativeElement
    .querySelector('h1');
  expect(title.textContent).toEqual('Cities!!!!');
```

```
});  
  
it('should contain a table with a list of one or more cities',  
async(() => {  
    let table = fixture.nativeElement  
        .querySelector('table.mat-table');  
    let tableRows = table  
        .querySelectorAll('tr.mat-row');  
    expect(tableRows.length).toBeGreaterThan(3);  
}));
```

Now, our first test will expect an incorrect title value, and the second is looking for more than three rows, which won't be the case since our mock `CityService` has been configured to serve three of them.

As soon as we save the file, the Karma test runner should automatically reload the testing page and show the updated results (refer to the following screenshot):



There we go. Now, we are experiencing two failures, just as expected. The Jasmine framework is also telling us what's wrong so that we can address the issues promptly.

Let's do this. Open the /ClientApp/src/cities/cities.components.spec.ts file and revert the test's source code back to how it was before:

```
it('should display a "Cities" title', async(() => {
  let title = fixture.nativeElement
    .querySelector('h1');
  expect(title.textContent).toEqual('Cities');
}));

it('should contain a table with a list of one or more cities',
async(() => {
  let table = fixture.nativeElement
    .querySelector('table.mat-table');
  let tableRows = table
    .querySelectorAll('tr.mat-row');
  expect(tableRows.length).toBeGreaterThan(0);
}));
```

That's it. Now that we have *tested* our test suite, we can close the test runner by pressing *Ctrl + C* on the ng test Terminal window and then choose *Y* (and hit *Enter*) to terminate the batch job.

With this, we've concluded our learning journey through *front-end* testing.

Summary

This chapter was entirely dedicated to the concepts of testing and unit testing. After a brief introduction, where we explained the meaning of these concepts and the various testing practices available, we spent some valuable time learning how to implement them properly.

We started focusing on *back-end* testing with the help of the xUnit.net testing tool. Such an approach required us to create a new test project, where we implemented our first *back-end* unit tests. While working at it, we learned the importance of some test-related concepts such as mocking, which we used to emulate the behavior of our ApplicationDbContext class to provide some in-memory data instead of using our SQL Server data source.

The *back-end* testing approach greatly helped us to understand the meaning of TDD and its similarities and differences vis-à-vis the BDD approach, which is a distinctive *front-end* testing practice.

Such a comparison guided us to Angular, where we used the **Jasmine** testing framework and the **Karma** test runner to develop some *front-end* tests. Here, we got the opportunity to learn some good testing practices as well as other important concepts strictly related to the Jasmine framework, such as TestBed, test suites, and spies. Eventually, we successfully saw our tests in action in our `WorldCities` app.

In the next chapter, we'll try to design some more tests when dealing with the authorization and authentication topics. The concepts that we learned here will definitely be very useful when having to implement the registration and login workflows.

Suggested topics

Unit Testing, xUnit, Moq, TDD, BDD, Mock, Stub, Fixture, Jasmine, Karma, Protractor, Spy, test suite, TestBed.

References

- *Getting Started with xUnit.net*: <https://xunit.net/docs/getting-started/netcore/cmdline>
- *Unit testing in .NET Core and .NET Standard*: <https://docs.microsoft.com/en-US/dotnet/core/testing/>
- *Unit test controller logic in ASP.NET Core*: <https://docs.microsoft.com/en-us/aspnet/core/mvc/controllers/testing>
- *The using statement (C#)*: <https://docs.microsoft.com/en-US/dotnet/csharp/language-reference/keywords/using-statement>
- *xUnit.net – Using .NET Core with the .NET SDK command line*: <https://xunit.net/docs/getting-started/netcore/cmdline>
- *Angular – Testing*: <https://angular.io/guide/testing>
- *Protractor: End-to-end testing for Angular*: <https://www.protractortest.org/>
- *Jasmine: Behavior-Driven JavaScript*: <https://jasmine.github.io/>

- *Karma: Spectacular Test Runner for JavaScript:* <https://karma-runner.github.io/latest/index.html>
- *Angular Testing: ComponentFixture:* <https://angular.io/api/core/testing/ComponentFixture>
- *Angular References: ngAfterViewInit:* <https://ngrefs.com/latest/core/ng-after-view-init>

10

Authentication and Authorization

Generally speaking, the term *authentication* refers to any process of verification that someone, be it a human being or an automated system, is who (or what) it claims to be. This is also true within the context of the **World Wide Web (WWW)**, where that same word is mostly used to denote any technique used by a website or service to collect a set of login information from a user agent, typically a web browser, and authenticate them using a membership and/or identity service.

Authentication should never be confused with *authorization*, as this is a different process and is in charge of a very different task. To give a quick definition, we can say that the purpose of authorization is to confirm that the requesting user is allowed to have access to the action they want to perform. In other words, while authentication is about who they are, authorization is about what they're allowed to do.

To better understand the difference between these two apparently similar concepts, we can think of two real-world scenarios:

- A free, yet registered account trying to gain access to a paid or premium-only service or feature; this is a common example of authenticated, yet not authorized access; we know who they are, yet they're not allowed to go there.
- An anonymous user trying to gain access to a publicly available page or file; this is an example of non-authenticated, yet authorized access; we don't know who they are, yet they can access public resources just like everyone else.

Authentication and authorization will be the main topics of this chapter, which we'll try to address both from theoretical and practical points of view. More precisely, we're going to do the following:

- **Discuss some typical scenarios** where authentication and authorization could either be required or not.
- **Introduce ASP.NET Core Identity**, a modern membership system that allows developers to add login functionality to their applications, as well as `IdentityServer`, middleware designed to add OIDC and OAuth 2.0 endpoints to any ASP.NET Core application.
- **Implement ASP.NET Core Identity and IdentityServer** to add login and registration functionalities to our existing `WorldCities` app.
- **Explore the Angular authorization API** provided by the .NET Core and Angular Visual Studio project template, which implements the `oidc-client` npm package to interact with the URI endpoints provided by the ASP.NET Core Identity system, as well as some key Angular features, such as **Route Guards** and **HTTP interceptors**, to handle the whole authorization flow.
- **Integrate the aforementioned back-end and front-end APIs** to our `WorldCities` project in order to give our users a satisfying authentication and authentication experience.

Let's do our best!

Technical requirements

In this chapter, we're going to need all technical requirements listed in the previous chapters, with the following additional packages:

- `Microsoft.AspNetCore.Identity.EntityFrameworkCore`
- `Microsoft.AspNetCore.ApiAuthorization.IdentityServer`
- `Microsoft.AspNetCore.Identity.UI`

As always, it's advisable to avoid installing them straight away: we're going to bring them in during the chapter to better contextualize their purposes within our project.

The code files for this chapter can be found at https://github.com/PacktPublishing/ASP-.NET-Core-3-and-Angular-9-Third-Edition/tree/master/Chapter_10/

To auth, or not to auth

As a matter of fact, implementing authentication and/or authorization logic isn't mandatory for most web-based applications or services; there are a number of websites that still don't do that, mostly because they serve content that can be accessed by anyone at any time. This used to be pretty common among most corporate, marketing, and informative websites until some years ago; that was before their owners learned how important it is to build a network of registered users and how much these "loyal" contacts are worth nowadays.

We don't need to be experienced developers to acknowledge how much the WWW has changed in the last few years; each and every website, regardless of its purpose, has an increasing and more or less legitimate interest in tracking their users nowadays, giving them the chance to customize their navigation experience, interacting with their social networks, collecting email addresses, and so on. None of the preceding can be done without an authentication mechanism of some sort.

There are billions of websites and services that require authentication to work properly, as most of their content and/or intents depend upon the actions of registered users: forums, blogs, shopping carts, subscription-based services, and even collaborative tools such as wikis.

Long story short, the answer is yes; as long as we want to have users performing **Create, Read, Update and Delete (CRUD)** operations within our client app, there is no doubt that we should implement some kind of authentication and authorization procedure. If we're aiming for a production-ready **Single-Page Application (SPA)** featuring some user interactions of any kind, we definitely want to know who our users are in terms of names and email addresses. It is the only way to determine who will be able to view, add, update, or delete our records, not to mention perform administrative-level tasks, keep track of our users, and so on.

Authentication

Since the origin of the WWW, the vast majority of authentication techniques rely upon **HTTP/HTTPS implementation standards**, and all of them work more or less in the following way:

1. A non-authenticated user agent asks for content that cannot be accessed without some kind of permission.
2. The web application returns an authentication request, usually in form of an HTML page containing an empty web form to complete.

3. The user agent fills in the web form with their credentials, usually a username and a password, and then sends it back with a `POST` command, which is most likely issued by a click on a **Submit** button.
4. The web application receives the `POST` data and calls the aforementioned server-side implementation that will try to authenticate the user with the given input and return an appropriate result.
5. If the result is successful, the web application will authenticate the user and store the relevant data somewhere, depending on the chosen authentication method: sessions/cookies, tokens, signatures, and so on (we'll talk about them later on). Conversely, the result will be presented to the user as a readable outcome inside an error page, possibly asking them to try again, contact an administrator, or something else.

This is still the most common approach nowadays. Almost all websites we can think of are using it, albeit with a number of big or small differences regarding security layers, state management, **JSON Web Tokens (JWT)** or other RESTful tokens, basic or digest access, single sign-on properties, and more.

Third-party authentication

Being forced to have a potentially different username and password for each website visit can be frustrating, other than requiring the users to develop custom password storage techniques that might lead to security risks. In order to overcome this issue, a large number of IT developers started to look around for an alternative way to authenticate users that could replace the standard authentication technique based on usernames and passwords with an authentication protocol based on trusted third-party providers.

The rise and fall of OpenID

Among the first successful attempts to implement a third-party authentication mechanism was the first release of **OpenID**, an open and decentralized authentication protocol promoted by the non-profit OpenID Foundation. Available since 2005, it was quickly and enthusiastically adopted by some big players such as Google and Stack Overflow, who originally based their authentication providers on it.

Here's how it works in a few words:

- Whenever our application receives an OpenID authentication request, it opens a transparent connection interface through the requesting user and a trusted, third-party authentication provider (for example, the **Google Identity Provider**); the interface can be a popup, an AJAX, populated modal windows, or an API call, depending on the implementation.
- The user sends their username and password to the aforementioned third-party provider, who performs the authentication accordingly and communicates the result to our application by redirecting the user to where they came from, along with a security token that can be used to retrieve the authentication result.
- Our application consumes the token to check the authentication result, authenticating the user in the event of success or sending an error response in the event of failure.

Despite the great enthusiasm between 2005 and 2009, with a good number of relevant companies publicly declaring their support for OpenID and even joining the foundation—including PayPal and Facebook—the original protocol didn't live up to its great expectations: legal controversies, security issues, and, most importantly, the massive popularity surge of the social networks with their improper—yet working—**OAuth-based** social logins within the 2009–2012 period basically killed it.



Those who don't know what OAuth is, have some patience; we'll get there soon enough.

OpenID Connect

In a desperate attempt to keep their flag flying after the takeover of the **OAuth/OAuth2** social logins, the OpenID Foundation released the third generation of the OpenID technology in February 2014; this was called **OpenID Connect (OIDC)**.

Despite the name, the new installment has little or nothing to do with its ancestors; it's merely an authentication layer built upon the OAuth2 authorization protocol. In other words, it's little more than a standardized interface to help developers using OAuth2 as an authentication framework in a less improper way, which is kind of funny, considering that OAuth2 played a major role in taking out OpenID 2.0 in the first place.

The choice of giving up on OpenID in favor of OIDC has been highly criticized in 2014; however, after more than 3 years, we can definitely say that OIDC can still provide a useful, standardized way to obtain user identities. It allows developers to request and receive information about authenticated users and sessions using a convenient, RESTful-based JSON interface; it features an extensible specification that also supports some promising optional features such as encryption of identity data, auto-discovery of OpenID providers, and even session management. In short, it's still useful enough to be used instead of relying on pure OAuth2.

For additional information about OpenID, we strongly suggest reading the following specifications from the OpenID Foundation official website:



OpenID Connect:

http://openid.net/specs/openid-connect-core-1_0.html.

OpenID 2.0 to OIDC migration guide:

http://openid.net/specs/openid-connect-migration-1_0.html.

Authorization

In most standard implementations, including those featured by ASP.NET, the authorization phase kicks in right after authentication, and it's mostly based on permissions or roles; any authenticated user might have their own set of permissions and/or belong to one or more roles and thus be granted access to a specific set of resources. These *role-based* checks are usually set by the developer in a declarative fashion within the application source code and/or configuration files.

Authorization, as we said, shouldn't be confused with authentication, despite the fact that it can be easily exploited to perform an implicit authentication as well, especially when it's delegated to a third-party actor.

Third-party authorization

The best-known third-party authorization protocol nowadays is the 2.0 release of OAuth, also known as OAuth2, which supersedes the former release (OAuth 1 or simply OAuth) originally developed by Blaine Cook and Chris Messina in 2006.

We already talked a lot about it for good reasons: OAuth 2 has quickly become the industry-standard protocol for authorization and is currently used by a gigantic number of community-based websites and social networks, including Google, Facebook, and Twitter. It basically works like this:

- Whenever an existing user requests a set of permissions to our application via OAuth, we open a transparent connection interface between them and a third-party authorization provider that is trusted by our application (for example, Facebook).
- The provider acknowledges the user and, if they have the proper rights, responds by entrusting them with a temporary, specific access key.
- The user presents the access key to our application and will be granted access.

We can clearly see how easy it is to exploit this authorization logic for authentication purposes as well; after all, if Facebook says I can do something, shouldn't it also imply that I am who I claim to be? Isn't that enough?

The short answer is no. It might be the case for Facebook because their OAuth 2 implementation implies that subscribers receiving the authorization must have authenticated themselves to Facebook first; however, this assurance is not written anywhere. Considering how many websites are using it for authentication purposes, we can assume that Facebook won't likely change their actual behavior, yet we have no guarantees about it.

Theoretically speaking, these websites can split their authorization system from their authentication protocol at any time, thus leading our application's authentication logic to an unrecoverable state of inconsistency. More generally, we can say that presuming something is from something else is almost always a bad practice, unless that assumption lies upon very solid, well-documented, and (most importantly) highly guaranteed grounds.

Proprietary versus third-party

Theoretically speaking, it's possible to entirely delegate the authentication and/or authorization tasks to existing external, third-party providers such as those we mentioned before; there are a lot of web and mobile applications that proudly follow this route nowadays. There are a number of undeniable advantages in using such an approach, including the following:

- **No user-specific DB tables/data models**, just some provider-based identifiers to use here and there as reference keys.
- **Immediate registration**, since there's no need to fill in a registration form and wait for a confirmation email—no username, no password. This will be appreciated by most users and will probably increase our conversion rates as well.
- **Few or no privacy issues**, as there's no personal or sensitive data on the application server.
- **No need to handle usernames and passwords** and implement automatic recovery processes.
- **Fewer security-related issues** such as form-based hacking attempts or brute-force login attempts.

Of course, there are also some downsides:

- **There won't be an actual user base**, so it will be difficult to get an overview of active users, get their email address, analyze statistics, and so on.
- **The login phase might be resource-intensive**, since it will always require an external, back-and-forth secure connection with a third-party server.
- **All users will need to have (or open) an account with the chosen third-party provider(s)** in order to log in.
- **All users will need to trust our application** because the third-party provider will ask them to authorize it to access their data.
- **We will have to register our application with the provider** in order to be able to perform a number of required or optional tasks, such as receiving our public and secret keys, authorizing one or more URI initiators, and choosing the information we want to collect.

Taking all these pros and cons into account, we can say that relying on third-party providers might be a great time-saving choice for small-scale apps, including ours; however, building our own account management system seems to be the only way to overcome the aforementioned governance and control-based flaws undeniably brought by that approach.

In this book, we'll explore both these routes, in an attempt to get the most—if not the best—of both worlds. In this chapter, we'll create an **internal membership provider** that will handle authentication and provide its very own set of authorization rules; in the following chapter, we'll further leverage that same implementation to demonstrate how we can give our users the chance to log in using a sample third-party auth provider (Facebook) and use its SDK and API to fetch the data that we need to create our corresponding internal users, thanks to the built-in features provided by the ASP.NET Core Identity package.

Proprietary auth with .NET Core

The authentication patterns made available by ASP.NET Core are basically the same as those supported by the previous versions of ASP.NET:

- **No authentication**, if we don't feel like implementing anything or if we want to use (or develop) a self-made auth interface without relying upon the ASP.NET Core Identity system
- **Individual User Accounts**, when we set up an internal database to store user data using the standard ASP.NET Core Identity interface
- **Azure Active Directory**, which implies using a token-based set of API calls handled by the **Azure AD Authentication Library (ADAL)**
- **Windows authentication**, only viable for local-scope applications within Windows domains or Active Directory trees

However, the implementation patterns introduced by the ASP.NET Core team during the past few years are constantly evolving in order to match the latest security practices available.

All the aforementioned approaches—excluding the first one—are handled by the **ASP.NET Core Identity system**, a membership system that allows us to add authentication and authorization functionalities to our application.



For additional info about the ASP.NET Core Identity APIs, check out the following URL:

<https://docs.microsoft.com/en-us/aspnet/core/security/authentication/identity>

Starting with .NET Core 3.0, ASP.NET Core Identity has been integrated with a new API authorization mechanism to handle authentication in SPAs: this new feature is based on `IdentityServer`, a piece of open source OIDC and OAuth 2.0 middleware that has been part of the .NET Foundation since .NET Core 3.0.



Further information about `IdentityServer` can be retrieved from the official documentation website, which is available at the following URLs:

<https://identityserver.io/>
<http://docs.identityserver.io/en/latest/>

With ASP.NET Core Identity, we can easily implement a login mechanism that will allow our users to create an account and log in with a username and a password. On top of that, we can also give them the chance to use an external login provider—as long as it's supported by the framework; as of today, the list of available providers includes Facebook, Google, Microsoft Account, Twitter, and more.

In this section, we're going to do the following:

- **Introduce the ASP.NET Core Identity Model**, the framework provided by ASP.NET Core to manage and store user accounts.
- **Set up an ASP.NET Core Identity implementation** by installing the required NuGet packages to our existing `WorldCities` app.
- **Extend the ApplicationDbContext** using the Individual User Accounts authentication type.
- **Configure the Identity service** in our application's `Startup` class.
- **Update the existing SeedController** by adding a method to create our default users with the .NET Identity API providers.

Right after that, we'll also consider a couple of words about the ASP.NET Core **Task Asynchronous Programming (TAP)** model.

The ASP.NET Core Identity Model

ASP.NET Core provides a unified framework to manage and store user accounts that can be easily used in any .NET Core application (even non-web ones); this framework is called **ASP.NET Core Identity** and provides a set of APIs that allows developers to handle the following tasks:

- Design, set up, and implement user registration and login functionalities.
- Manage users, passwords, profile data, roles, claims, tokens, email confirmation, and so on.
- Support external (third-party) login providers such as Facebook, Google, Microsoft Account, Twitter, and more.

The ASP.NET Core Identity source code is open source and available on GitHub at <https://github.com/aspnet/AspNetCore/tree/master/src/Identity>.

It goes without saying that the ASP.NET Core Identity requires a persistent data source to store (and retrieve) the identity data (usernames, passwords, and profile data), such as a SQL Server database: for that very reason, it features built-in integration mechanisms with the Entity Framework Core.

This means that, in order to implement our very own identity system, we'll basically extend what we did in [Chapter 4, Data Model with Entity Framework Core](#); more specifically, we'll update our existing `ApplicationDbContext` to support the additional entity classes required to handle users, roles, and so on.

Entity types

The ASP.NET Core Identity platform strongly relies upon the following entity types, each one of them representing a specific set of records:

- `User`: The users of our application
- `Role`: The roles that we can assign to each user
- `UserClaim`: The claims that a user possesses
- `UserToken`: The authentication token that a user might use to perform auth-based tasks (such as logging in)
- `UserLogin`: The login account associated with each user
- `RoleClaim`: The claims that are granted to all users within a given role
- `UserRole`: The lookup table to store the relationship between users and their assigned roles

These entity types are related to each other in the following ways:

- Each `User` can have many `UserClaim`, `UserLogin`, and `UserToken` entities (*one-to-many*).
- Each `Role` can have many associated `RoleClaim` entities (*one-to-many*).
- Each `User` can have many associated `Role` entities, and each `Role` can be associated with many `User` entities (*many-to-many*).

The many-to-many relationship requires a join table in the database, which is represented by the `UserRole` entity.

Luckily enough, we won't have to manually implement all these entities from scratch, because ASP.NET Core Identity provides some default **Common Language Runtime (CLR)** types for each one of them:

- `IdentityUser`
- `IdentityRole`
- `IdentityUserClaim`
- `IdentityUserToken`
- `IdentityUserLogin`
- `IdentityRoleClaim`
- `IdentityUserRole`

These types can be used as *base classes* for our own implementation, whenever we need to explicitly define an identity-related entity model; moreover, most of them don't have to be implemented in most common authentication scenarios, since their functionalities can be handled at a higher level thanks to the ASP.NET Core Identity sets of APIs, which can be accessed from the following classes:

- `RoleManager<TRole>`: Provides the APIs for managing roles
- `SignInManager<TUser>`: Provides the APIs for signing users in and out (login and logout)
- `UserManager<TUser>`: Provides the APIs for managing users

Once the ASP.NET Core Identity service has been properly configured and set up, these providers can be injected into our .NET Controllers using **dependency injection (DI)**, just like we did with `ApplicationDbContext`; in the following section, we'll see how we can do that.

Setting up ASP.NET Core Identity

In Chapter 1, *Getting Ready*, and in Chapter 3, *Front-end and Back-end Interactions*, when we created our `HealthCheck` and `WorldCities` .NET Core projects, we always made the choice to go with an empty project featuring no authentication. That was because we didn't want Visual Studio to install **ASP.NET Core Identity** within our application's startup files right from the start. However, now that we'll use it, we need to manually perform the required setup steps.

Adding the NuGet packages

Enough with the theory, let's put the plan into action.

From **Solution Explorer**, right-click on the `WorldCities` tree node, then select **Manage NuGet packages**, look for the following two packages, and install them:

- `Microsoft.AspNetCore.Identity.EntityFrameworkCore`
- `Microsoft.AspNetCore.ApiAuthorization.IdentityServer`

Alternatively, open the **Package Manager Console** and install them with the following commands:

```
> Install-Package Microsoft.AspNetCore.Identity.EntityFrameworkCore  
> Install-Package Microsoft.AspNetCore.ApiAuthorization.IdentityServer
```

At the time of writing, the latest version for both of them is **3.1.1**; as always, we are free to install a newer version, as long as we know how to adapt our code accordingly to fix potential compatibility issues.

Creating ApplicationUser

Now that we have installed the required identity libraries, we need to create a new `ApplicationUser` entity class with all the features required by the ASP.NET Core Identity service to use it for auth purposes. Luckily enough, the package comes with a built-in `IdentityUser` base class that can be used to extend our own implementation, thus granting it all that we need.

From **Solution Explorer**, navigate to the `/Data/Models/` folder, then create a new `ApplicationUser.cs` class and fill its content with the following code:

```
using Microsoft.AspNetCore.Identity;
using System;
using System.Collections.Generic;
using System.Linq;
using System.Threading.Tasks;

namespace WorldCities.Data.Models
{
    public class ApplicationUser : IdentityUser
    {
    }
}
```

As we can see, we don't need to implement anything there, at least for the time being: we'll just extend the `IdentityUser` base class, which already contains everything we need for now.

Extending ApplicationDbContext

In order to support the .NET Core authentication mechanism, our existing `ApplicationContext` needs to be extended from a different database abstraction base class that supports ASP.NET Core Identity and `IdentityServer`.

Open the `/Data/ApplicationDbContext.cs` file and update its contents accordingly (updated lines are highlighted):

```
using IdentityServer4.EntityFramework.Options;
using Microsoft.AspNetCore.ApiAuthorization.IdentityServer;
using Microsoft.EntityFrameworkCore;
using Microsoft.Extensions.Options;
using WorldCities.Data.Models;

namespace WorldCities.Data
{
    public class ApplicationDbContext :
        ApiAuthorizationDbContext<ApplicationUser>
    {
        #region Constructor
        public ApplicationDbContext(
            DbContextOptions options,
            IOptions<OperationalStoreOptions> operationalStoreOptions)
            : base(options, operationalStoreOptions)
        {
        }
}
```

```
}

#endregion Constructor

#region Methods
protected override void OnModelCreating(ModelBuilder
    modelBuilder)
{
    base.OnModelCreating(modelBuilder);

    // Map Entity names to DB Table names
    modelBuilder.Entity<City>().ToTable("Cities");
    modelBuilder.Entity<Country>().ToTable("Countries");
}
#endregion Methods

#region Properties
public DbSet<City> Cities { get; set; }
public DbSet<Country> Countries { get; set; }
#endregion Properties
}
}
```

As we can see from the preceding code, we changed the current `DbContext` base class with the new `ApiAuthorizationDbContext` base class; the new class strongly relies on the `IdentityServer` middleware, which also required a change in the constructor signature to accept some options that are required for properly configuring the operational context.



For additional information about the .NET authentication and authorization system for SPA, ASP.NET Core Identity API, and the .NET Core `IdentityServer`, check out the following URL:

<https://docs.microsoft.com/en-us/aspnet/core/security/authentication/identity-api-authorization>

Adjusting our unit tests

As soon as we save the new `ApplicationContext` file, our existing `CitiesController_Tests.cs` class in the `WorldCities.Tests` project will likely throw a compiler error, as shown in the following screenshot:

```

10  namespace WorldCities.Tests
11  {
12      public class CitiesController_Tests
13      {
14          /// <summary>
15          /// Test the GetCity() method
16          /// </summary>
17          [Fact]
18          public async void GetCity()
19          {
20              #region Arrange
21              var options = new DbContextOptionsBuilder<ApplicationContext>()
22                  .UseInMemoryDatabase(databaseName: "WorldCities")
23                  .Options;
24
25              using (var context = new ApplicationContext(options))
26              {
27                  context.Add(new City()
28                  {
29                      Id = 1,
30                      CountryId = 1,
31                      Lat = 1,
32                      Lon = 1,
33                      Name = "TestCity1"
34                  });
35                  context.SaveChanges();
36              }
37          }
38      }
39  }

```

The reason for that is well explained in the **Error List** panel: the constructor signature of `ApplicationContext` changed, requiring an additional parameter that we don't pass here.



It's worth noting that this issue doesn't affect our main application's Controllers since `ApplicationContext` is injected through DI there.

To quickly fix that, update the `CitiesController_Tests.cs` existing source code in the following way (new and updated lines are highlighted):

```

using IdentityServer4.EntityFramework.Options;

// ...existing code...

var storeOptions = Options.Create(new OperationalStoreOptions());

```

```
using (var context = new ApplicationDbContext(options, storeOptions))  
    // ...existing code...
```

Now the error should disappear (and the test should still pass).

Configuring the ASP.NET Core Identity middleware

Now that we're done with all the prerequisites, we can open the `Startup.cs` file and add the following highlighted lines in the `ConfigureServices` method to set up the middleware required by the ASP.NET Core Identity system:

```
// ...existing code...  
  
// This method gets called by the runtime. Use this method to add  
// services to the container.  
public void ConfigureServices(IServiceCollection services)  
{  
    services.AddControllersWithViews()  
        .AddJsonOptions(options => {  
            // set this option to TRUE to indent the JSON output  
            options.JsonSerializerOptions.WriteIndented = true;  
            // set this option to NULL to use PascalCase instead of  
            // CamelCase (default)  
            // options.JsonSerializerOptions.PropertyNamingPolicy = null;  
        });  
  
    // In production, the Angular files will be served from  
    // this directory  
    services.AddSpaStaticFiles(configuration =>  
    {  
        configuration.RootPath = "ClientApp/dist";  
    });  
  
    // Add EntityFramework support for SqlServer.  
    services.AddEntityFrameworkSqlServer();  
  
    // Add ApplicationDbContext.  
    services.AddDbContext<ApplicationDbContext>(options =>  
        options.UseSqlServer(  
            Configuration.GetConnectionString("DefaultConnection")  
        )  
    );  
  
    // Add ASP.NET Core Identity support
```

```
services.AddDefaultIdentity< ApplicationUser >(options =>
{
    options.SignIn.RequireConfirmedAccount = true;
    options.Password.RequireDigit = true;
    options.Password.RequireLowercase = true;
    options.Password.RequireUppercase = true;
    options.Password.RequireNonAlphanumeric = true;
    options.Password.RequiredLength = 8;
})
    .AddRoles< IdentityRole >()
    .AddEntityFrameworkStores< ApplicationDbContext >();

services.AddIdentityServer()
    .AddApiAuthorization< ApplicationUser, ApplicationDbContext >();

services.AddAuthentication()
    .AddIdentityServerJwt();
}

// ...existing code...
```

And then, in the `Configure` method, add the following highlighted lines:

```
// ...existing code...

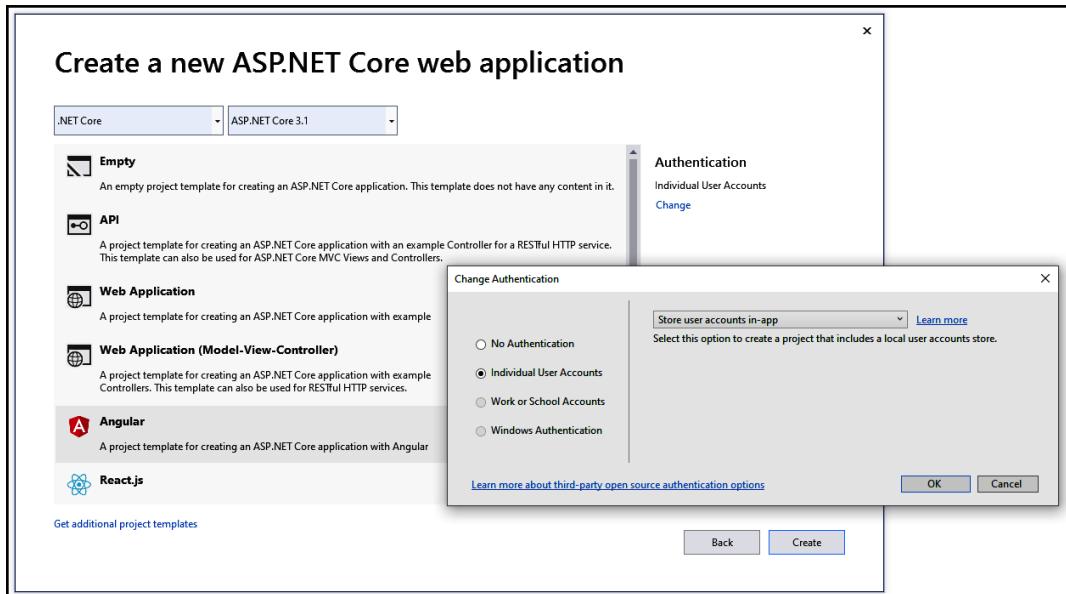
app.UseRouting();

app.UseAuthentication();
app.UseIdentityServer();
app.UseAuthorization();

app.UseEndpoints(endpoints =>

// ...existing code...
```

The preceding code strictly resembles the default .NET Core Identity implementation for SPA projects. If we created a new **ASP.NET Core web application** using the Visual Studio wizard, selecting the **Individual User Accounts** authentication method (see the following screenshot), we would end up with the same code, with some minor differences:



In the opposite way to the default implementation, in our code, we took the chance to override some of the default password policy settings to demonstrate how we can configure the Identity service to better suit our needs.

Let's take another look at the preceding code, emphasizing the changes (highlighted lines):

```
options.SignIn.RequireConfirmedAccount = true;
options.Password.RequireLowercase = true;
options.Password.RequireUppercase = true;
options.Password.RequireDigit = true;
options.Password.RequireNonAlphanumeric = true;
options.Password.RequiredLength = 8;
```

As we can see, we didn't change the `RequireConfirmedAccount` default settings, which require a confirmed user account (verified through email) to sign in. What we did instead was explicitly set our password strength requirements so that all our user's passwords would need to have the following:

- At least one lowercase letter
- At least one uppercase letter
- At least one digit character
- At least one non-alphanumeric character
- A minimum length of eight characters

That will grant our app a decent level of authentication security, should we ever want to make it publicly accessible on the web. Needless to say, we can change these settings depending on our specific needs; a development sample could probably live with more relaxed settings, as long as we don't make it available to the public.

It's worth noting that the preceding code will require a reference to the new identity-related packages that we installed a moment ago:

```
// ...existing code...

using Microsoft.AspNetCore.Authentication;
using Microsoft.AspNetCore.Identity;

// ...existing code...
```

Furthermore, we'll also need to reference the namespace that we used for our data models, since we're now referencing the `ApplicationUser` class:

```
// ...existing code...

using WorldCities.Data.Models;

// ...existing code...
```

Now that we have properly configured our `Setup` class, we need to do the same with `IdentityServer` .

Configuring IdentityServer

In order to properly set up the `IdentityServer` middleware, we need to add the following lines to our existing `appSettings.json` configuration file (new lines are highlighted):

```
{
  "ConnectionStrings": {
    "DefaultConnection": "(your connection string)"
  },
  "Logging": {
    "LogLevel": {
      "Default": "Information",
      "Microsoft": "Warning",
      "Microsoft.Hosting.Lifetime": "Information"
    }
  },
  "IdentityServer": {
```

```
    "Clients": {
        "WorldCities": {
            "Profile": "IdentityServerSPA"
        }
    },
    "Key": {
        "Type": "Development"
    }
},
"AllowedHosts": "*"
}
```

As we can see, we added a single client for `IdentityServer`, which will be our Angular app. The "`IdentityServerSPA`" profile indicates the application type and it's used internally to generate the server defaults for that type—in our scenario, an SPA is hosted alongside `IdentityServer` as a single unit.

Here are the defaults that `IdentityServer` will load for our application type:

- The `redirect_uri` defaults to `/authentication/login-callback`.
- The `post_logout_redirect_uri` defaults to `/authentication/logout-callback`.
- The set of scopes includes the `openID`, `Profile`, and every scope defined for the APIs in the app.
- The set of allowed OIDC response types is `id_token token` or each of them individually (`id_token`, `token`).
- The allowed response mode is *fragment*.

Other available profiles include the following:

- **SPA:** An SPA that is not hosted with `IdentityServer`
- **IdentityServerJwt:** An API that is hosted alongside `IdentityServer`
- **API:** An API that is not hosted with `IdentityServer`

Before going further, we need to perform another `IdentityServer` related update to our `appSettings.Development.json` file.

Updating the appSettings.Development.json file

As we know from Chapter 2, *Looking Around*, the `appSettings.Development.json` file is used to specify additional configuration key/value pairs (and/or override the existing ones) for the *development* environment. This is precisely what we need to do now since the `IdentityServer` requires some development-specific settings that shouldn't be put in production.

Open the `appSettings.Development.json` file and add the following content (new lines are highlighted):

```
{  
    "Logging": {  
        "LogLevel": {  
            "Default": "Debug",  
            "System": "Information",  
            "Microsoft": "Information"  
        },  
        "IdentityServer": {  
            "Key": {  
                "Type": "Development"  
            }  
        }  
    }  
}
```

The "Key" element that we added in the preceding code describes the key that will be used to sign tokens; for the time being, since we're still in development, that key type will work just fine. However, when we want to deploy our app to production, we'll need to provision and deploy a real key alongside our app. When we come to that, we'll have to add a "Key" element to our `appSettings.json` production file and configure it accordingly; we'll talk more about this in Chapter 12, *Windows and Linux Deployment*.

Until then, it's better to avoid adding it in the production settings to prevent our web app from running in insecure mode.



For additional information about the `IdentityServer` and its configuration parameters, check out the following URL:

<https://docs.microsoft.com/en-us/aspnet/core/security/authentication/identity-api-authorization>

Now we're ready to create our users.

Revising SeedController

The best way to create a new user from scratch would be from `SeedController`, which implements the *seeding mechanism* that we set up in Chapter 4, *Data Model with Entity Framework Core*; however, in order to interact with the .NET Core Identity APIs required to do that, we need to inject them using DI, just like we already did with `ApplicationDbContext`.

Adding RoleManager and UserManager through DI

From **Solution Explorer**, open the `/Controllers/SeedController.cs` file of the `WorldCities` project and update its content accordingly with the following code (new/updated lines are highlighted):

```
using Microsoft.AspNetCore.Identity;

// ...existing code...

public class SeedController : ControllerBase
{
    private readonly ApplicationDbContext _context;
    private readonly RoleManager<IdentityRole> _roleManager;
    private readonly UserManager< ApplicationUser > _userManager;
    private readonly IWebHostEnvironment _env;

    public SeedController(
        ApplicationDbContext context,
        RoleManager<IdentityRole> roleManager,
        UserManager< ApplicationUser > userManager,
        IWebHostEnvironment env)
    {
        _context = context;
        _roleManager = roleManager;
        _userManager = userManager;
        _env = env;
    }

    // ...existing code...
}
```

As we can see, we added the `RoleManager<TRole>` and `UserManager<TUser>` providers that we talked about early on; we did that using DI, just like we did with `ApplicationDbContext` and `IWebHostEnvironment` back in Chapter 4, *Data Model with Entity Framework Core*. We'll see how we can use these new providers to create our users and roles soon enough.

Now, let's define the following method at the end of the /Controllers/SeedController.cs file, right below the existing Import() method:

```
// ...existing code...

[HttpGet]
public async Task<ActionResult> CreateDefaultUsers()
{
    throw new NotImplementedException();
}

// ...existing code...
```

In the opposite way to what we usually do, we're not going to implement this method straight away; we'll take this chance to embrace the **Test-Driven Development** (TDD) approach, which means that we'll start with creating a (failing) unit test.

Defining the CreateDefaultUser() unit test

From **Solution Explorer**, create a new /SeedController_Tests.cs file in the WorldCities.Tests project; once done, fill its content with the following code:

```
using IdentityServer4.EntityFramework.Options;
using Microsoft.AspNetCore.Hosting;
using Microsoft.AspNetCore.Identity;
using Microsoft.AspNetCore.Identity.EntityFrameworkCore;
using Microsoft.EntityFrameworkCore;
using Microsoft.Extensions.Logging;
using Microsoft.Extensions.Options;
using Moq;
using System;
using WorldCities.Controllers;
using WorldCities.Data;
using WorldCities.Data.Models;
using Xunit;

namespace WorldCities.Tests
{
    public class SeedController_Tests
    {
        /// <summary>
        /// Test the CreateDefaultUsers() method
        /// </summary>
        [Fact]
        public async void CreateDefaultUsers()
        {
```

```
#region Arrange
// create the option instances required by the
// ApplicationDbContext
var options = new
    DbContextOptionsBuilder<ApplicationDbContext>()
        .UseInMemoryDatabase(databaseName: "WorldCities")
        .Options;
var storeOptions = Options.Create(new
    OperationalStoreOptions());

// create a IWebHost environment mock instance
var mockEnv = new Mock<IWebHostEnvironment>().Object;

// define the variables for the users we want to test
 ApplicationUser user_Admin = null;
 ApplicationUser user_User = null;
 ApplicationUser user_NotExisting = null;
#endregion

#region Act

// create a ApplicationDbContext instance using the
// in-memory DB
using (var context = new ApplicationDbContext(options,
    storeOptions))
{
    // create a RoleManager instance
    var roleStore = new RoleStore<IdentityRole>(context);
    var roleManager = new RoleManager<TIdentityRole>(
        roleStore,
        new IRoleValidator<TIdentityRole>[0],
        new UpperInvariantLookupNormalizer(),
        new Mock<IdentityErrorDescriber>().Object,
        new Mock<ILogger<RoleManager<TIdentityRole>>>()
            .Object);

    // create a UserManager instance
    var userStore = new
        UserStore<ApplicationUser>(context);
    var userManager = new UserManager<TIdentityUser>(
        userStore,
        new Mock<IOptions<IdentityOptions>>().Object,
        new Mock<IPasswordHasher<TIdentityUser>>().Object,
        new IUserValidator<TIdentityUser>[0],
        new IPasswordValidator<TIdentityUser>[0],
        new UpperInvariantLookupNormalizer(),
        new Mock<IdentityErrorDescriber>().Object,
        new Mock<IServiceProvider>().Object,
```

```
        new Mock<ILogger<UserManager<TIDentityUser>>>()
            .Object);

        // create a SeedController instance
        var controller = new SeedController(
            context,
            roleManager,
            userManager,
            mockEnv
        );

        // execute the SeedController's CreateDefaultUsers()
        // method to create the default users (and roles)
        await controller.CreateDefaultUsers();

        // retrieve the users
        user_Admin = await userManager.FindByEmailAsync(
            "admin@email.com");
        user_User = await userManager.FindByEmailAsync(
            "user@email.com");
        user_NotExisting = await userManager.FindByEmailAsync(
            "notexisting@email.com");
    }
    #endregion

    #region Assert
    Assert.True(
        user_Admin != null
        && user_User != null
        && user_NotExisting == null
    );
    #endregion
}
}
}
```

As we can see, we are creating *real instances* (not *mocks*) of the `RoleManager` and `UserManager` providers, since we'll need them to actually perform some read/write operations to the *in-memory* database that we have defined in the options of `ApplicationDbContext`; this basically means that these providers will perform their job for real, but everything will be done on the in-memory database instead on the SQL Server data source. That's an ideal scenario for our tests.

At the same time, we still made good use of the Moq package library to create a number of *mocks* to emulate a number of parameters required to instantiate `RoleManager` and `UserManager`. Luckily enough, most of them are internal objects that won't be needed to perform our current tests; for those that are required, we had to create a real instance.



For example, for both providers, we were forced to create a real instance of `UpperInvariantLookupNormalizer`—which implements the `ILookupNormalizer` interface—because it's being used internally by `RoleManager` (to lookup for existing *roles*) as well as the `UserManager` (to lookup for existing *usernames*); if we had mocked it instead, we would've hit some nasty runtime errors while trying to make these tests pass.

While we are here, it could be useful to move the `RoleManager` and `UserManager` generation logic to a separate helper class, so that we'll be able to use it in other tests without having to repeat it every time.

From **Solution Explorer**, create a new `IdentityHelper.cs` file in the `WorldCities.Tests` project; once done, fill its content with the following code:

```
using Microsoft.AspNetCore.Identity;
using Microsoft.Extensions.Logging;
using Microsoft.Extensions.Options;
using Moq;
using System;
using System.Collections.Generic;
using System.Text;

namespace WorldCities.Tests
{
    public static class IdentityHelper
    {
        public static RoleManager<TIdentityRole>
            GetRoleManager<TIdentityRole>(
                IRoleStore<TIdentityRole> roleStore) where TIdentityRole : IdentityRole
        {
            return new RoleManager<TIdentityRole>(
                roleStore,
                new IRoleValidator<TIdentityRole>[0],
                new UpperInvariantLookupNormalizer(),
                new Mock<IdentityErrorDescriber>().Object,
                new Mock<	ILogger<RoleManager<TIdentityRole>>>()
                    .Object);
        }
    }
}
```

```
    }

    public static UserManager<TIDentityUser>
    GetUserManager<TIDentityUser>(
        IUserStore<TIDentityUser> userStore) where TIDentityUser :
        IdentityUser
    {
        return new UserManager<TIDentityUser>(
            userStore,
            new Mock<IOptions<IdentityOptions>>().Object,
            new Mock<IPasswordHasher<TIDentityUser>>().Object,
            new IUserValidator<TIDentityUser>[0],
            new IPasswordValidator<TIDentityUser>[0],
            new UpperInvariantLookupNormalizer(),
            new Mock<IdentityErrorDescriber>().Object,
            new Mock<IServiceProvider>().Object,
            new Mock<ILogger<UserManager<TIDentityUser>>>(
                ).Object);
    }
}
```

As we can see, we created two methods—`GetRoleManager` and `GetUserManager`—that we can use to create these providers for other tests.

Now we can call these two methods from `SeedController` by updating its code in the following way (updated lines are highlighted):

```
// ...existing code...

// create a RoleManager instance
var roleManager = IdentityHelper.GetRoleManager(
    new RoleStore<IdentityRole>(context));

// create a UserManager instance
var userManager = IdentityHelper.GetUserManager(
    new UserStore<ApplicationUser>(context));

// ...existing code...
```

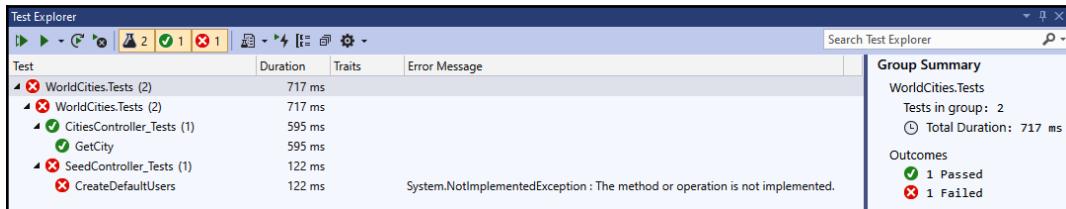
With this, our unit test is ready; we just need to execute it to see it fail.

To do that, right-click the `WorldCities.Test` node from **Solution Explorer** and select **Run Tests**.



Alternatively, just switch to the **Test Explorer** window and use the topmost buttons to run the tests from there.

If we did everything correctly, we should be able to see our `CreateDefaultUsers()` test failing, just like in the following screenshot:



That's it; all we have to do now is to implement the `CreateDefaultUsers()` method of `SeedController` to make the preceding test pass.

Implementing the `CreateDefaultUsers()` method

Add the following method at the end of the `/Controllers/SeedController.cs` file, right below the existing `Import()` method:

```
// ...existing code...

[HttpGet]
public async Task<ActionResult> CreateDefaultUsers()
{
    // setup the default role names
    string role_RegisteredUser = "RegisteredUser";
    string role_Administrator = "Administrator";

    // create the default roles (if they doesn't exist yet)
    if (await _roleManager.FindByNameAsync(role_RegisteredUser) == null)
        await _roleManager.CreateAsync(new
            IdentityRole(role_RegisteredUser));

    if (await _roleManager.FindByNameAsync(role_Administrator) == null)
        await _roleManager.CreateAsync(new
            IdentityRole(role_Administrator));

    // create a list to track the newly added users
```

```
var addedUserList = new List<ApplicationUser>();

// check if the admin user already exist
var email_Admin = "admin@email.com";
if (await _userManager.FindByNameAsync(email_Admin) == null)
{
    // create a new admin ApplicationUser account
    var user_Admin = new ApplicationUser()
    {
        SecurityStamp = Guid.NewGuid().ToString(),
        UserName = email_Admin,
        Email = email_Admin,
    };

    // insert the admin user into the DB
    await _userManager.CreateAsync(user_Admin, "MySecr3t$");

    // assign the "RegisteredUser" and "Administrator" roles
    await _userManager.AddToRoleAsync(user_Admin,
        role_RegisteredUser);
    await _userManager.AddToRoleAsync(user_Admin,
        role_Administrator);

    // confirm the e-mail and remove lockout
    user_Admin.EmailConfirmed = true;
    user_Admin.LockoutEnabled = false;

    // add the admin user to the added users list
    addedUserList.Add(user_Admin);
}

// check if the standard user already exist
var email_User = "user@email.com";
if (await _userManager.FindByNameAsync(email_User) == null)
{
    // create a new standard ApplicationUser account
    var user_User = new ApplicationUser()
    {
        SecurityStamp = Guid.NewGuid().ToString(),
        UserName = email_User,
        Email = email_User
    };

    // insert the standard user into the DB
    await _userManager.CreateAsync(user_User, "MySecr3t$");

    // assign the "RegisteredUser" role
    await _userManager.AddToRoleAsync(user_User,
```

```
        role_RegisteredUser);

        // confirm the e-mail and remove lockout
        user_User.EmailConfirmed = true;
        user_User.LockoutEnabled = false;

        // add the standard user to the added users list
        addedUserList.Add(user_User);
    }

    // if we added at least one user, persist the changes into the DB
    if (addedUserList.Count > 0)
        await _context.SaveChangesAsync();

    return new JsonResult(new
    {
        Count = addedUserList.Count,
        Users = addedUserList
    });
}

// ...existing code...
```

The code is quite self-explanatory, and it has a lot of comments explaining the various steps; however, here's a convenient summary of what we just did:

- We started by defining some default role names (`RegisteredUsers` for the standard registered users, `Administrator` for the administrative-level ones).
- We created a logic to check whether these roles already exist. If they don't exist, we create them. As expected, both tasks have been performed using `RoleManager`.
- We defined a user list local variable to track the newly added users, so that we can output it to the user in the JSON object we'll return at the end of the action method.
- We created a logic to check whether a user with the `admin@email.com` username already exists; if it doesn't, we create it and assign it both the `RegisteredUser` and `Administrator` roles, since it will be a standard user *and also* the administrative account of our app.

- We created a logic to check whether a user with the `user@email.com` username already exists; if it doesn't, we create it and assign it the `RegisteredUser` role.
- At the end of the action method, we configured the JSON object that we'll return to the caller; this object contains a count of the added users and a list containing them, which will be serialized into a JSON object that will show their entity values.



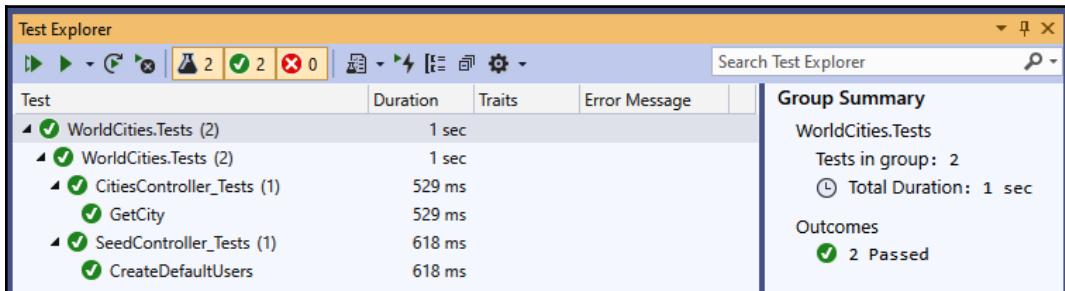
The `Administrator` and `RegisteredUser` roles we just implemented here will be the core of our authorization mechanism; all of our users will be assigned to at least one of them. Note how we assigned both of them to the `Admin` user to make them able to do everything a standard user can do, plus more: all the other users only have the latter, so they'll be unable to perform any administrative-level task—as long as they're not provided with the `Administrator` role.

Before moving on, it's worth noting that we're using the user's email address for both the `Email` and `UserName` fields. We did that on purpose, because those two fields in the ASP.NET Core Identity system are used interchangeably by default: whenever we add a user using the default APIs, the `Email` provided is saved in the `UserName` field as well, even if they are two separate fields in the `AspNetUsers` database table. Although this behavior can be changed, we're going to stick to the default settings so that we'll be able to use the default settings without changing them throughout the whole ASP.NET Identity system.

Rerunning the unit test

Now that we have implemented the test, we can rerun the `CreateDefaultUsers()` test and see whether it passes. As usual, we can do that by right-clicking the `WorldCities.Test` root node from **Solution Explorer** and select **Run Tests**, or from within the **Test Explorer** panel.

If we did everything correctly, we should see something like this:



That's it; now we're finally done updating our project's classes.

A word on `async` tasks, `awaits`, and deadlocks

As we can see by looking at the preceding `CreateDefaultUsers()` method, all the ASP.NET Core Identity system API's relevant methods are *asynchronous*, meaning that they return an *async task* rather than a given return value; for that very reason, since we need to execute these various tasks one after another, we had to prepend all of them with the `await` keyword.

Here's an example of `await` usage taken from the preceding code:

```
await _userManager.AddToRoleAsync(user_Admin, role_RegisteredUser);
```

The `await` keyword, as the name implies, awaits the completion of the `async` task before going forward. It's worth noting that such an expression does not block the thread on which it is executing; instead, it causes the compiler to sign up the rest of the `async` method as a continuation on the awaited task, thus returning the thread control to the caller. Eventually, when the task completes, it invokes its continuation, thus resuming the execution of the `async` method where it left off.



That's the reason why the `await` keyword can only be used within `async` methods; as a matter of fact, the preceding logic requires the caller to be `async` as well, otherwise, it wouldn't work.

Alternatively, we could have used the `Wait()` method, in the following way:

```
_userManager.AddToRoleAsync(user_Admin, role_RegisteredUser).Wait();
```

However, we didn't do that—for good reasons. In the opposite way to the `await` keyword, which tells the compiler to *asynchronously wait* for the `async` task to complete, the parameterless `Wait()` method will *block the calling thread* until the `async` task has completed execution; therefore, the calling thread will unconditionally wait until the task completes.

To better explain how such techniques impact our .NET Core application, we should spend a little time to better understand the concept of `async` tasks, as they are a pivotal part of the ASP.NET Core TAP model.

One of the first things we should learn when working with sync methods invoking `async` tasks in ASP.NET is that when the top-level method awaits a task, its current execution context gets blocked until the task completes. This won't be a problem unless that context allows only one thread to run at a time, which is precisely the case of `AspNetSynchronizationContext`. If we combine these two things, we can easily see that *blocking an `async` method* (that is, a method returning an `async` task) will expose our application to a high risk of *deadlock*.

A *deadlock*, from a software development perspective, is a dreadful situation that occurs whenever a process or thread enters a waiting state indefinitely, usually because the resource it's waiting for is held by another waiting process. In any legacy ASP.NET web application, we would face a deadlock every time we're blocking a task, simply because that task, in order to complete, will require the same execution context of the invoking method, which is kept blocked by that method until the task completes!

Luckily enough, we're not using legacy ASP.NET here; we're using .NET Core, where the legacy ASP.NET pattern based upon the `SynchronizationContext` has been replaced by a *contextless* approach layered upon a versatile, deadlock-resilient thread pool.

This basically means that *blocking the calling thread* using the `Wait()` method isn't that problematic anymore; therefore, if we switched our `await` keywords with it, our method would still run and complete just fine. However, by doing so, we would basically use synchronous code to perform asynchronous operations, which is generally considered a bad practice; moreover, we would lose all the benefits brought by asynchronous programming, such as performance and scalability.

For all those reasons, the `await` approach is definitely the way to go there.

For additional information regarding threads, async tasks awaits, and asynchronous programming in ASP.NET, we highly recommend checking out the outstanding articles written by Stephen Cleary on the topic, which will greatly help in understanding some of the most tricky and complex scenarios that we could face when developing with these technologies. Some of them were written a while ago, yet they never really age:

<https://blog.stephencleary.com/2012/02/async-and-await.html>



<https://blogs.msdn.microsoft.com/pfxteam/2012/04/12/asyncawait-faq/>

<http://blog.stephencleary.com/2012/07/dont-block-on-async-code.html>

<https://msdn.microsoft.com/en-us/magazine/jj991977.aspx>

<https://blog.stephencleary.com/2017/03/aspnetcore-synchronization-context.html>

Also, we strongly suggest checking out this excellent article about asynchronous programming with `async` and `await` at
<https://docs.microsoft.com/en-us/dotnet/csharp/programming-guide/concepts/async/index>

Updating the database

It's time to create a new migration and reflect the code changes to the database by taking advantage of the Code-first approach we chose in Chapter 4, *Data Model with Entity Framework Core*.

Here's a list of what we're going to do in this section:

- **Add the identity migration** using the `dotnet-ef` command, just like we did in Chapter 4, *Data Model with Entity Framework Core*.
- **Apply the migration to the database**, updating it without altering the existing data or performing a drop and recreate
- **Seed the data** using the `CreateDefaultUsers()` method of `SeedController` that we implemented early on.

Let's get to work.

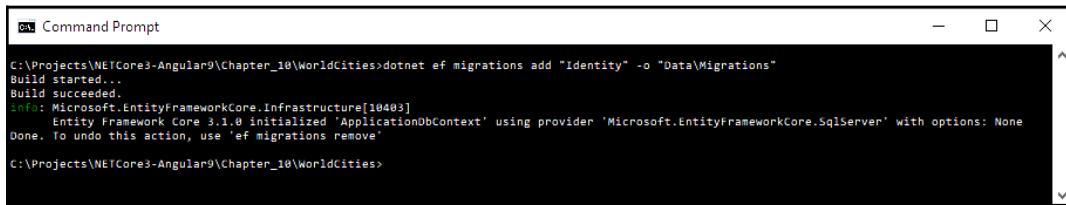
Adding identity migration

The first thing we need to do is to add a new migration to our data model to reflect the changes that we have implemented by extending the `ApplicationDbContext` class.

To do that, open a command line or PowerShell prompt and go to our `WorldCities` project's root folder, then write the following:

```
dotnet ef migrations add "Identity" -o "Data\Migrations"
```

A new migration should then be added to the project, as shown in the following screenshot:



```
C:\Projects\NETCore3-Angular9\Chapter_10\WorldCities>dotnet ef migrations add "Identity" -o "Data\Migrations"
Build started...
Build succeeded.
[Info: Microsoft.EntityFrameworkCore.Infrastructure[10403]
      Entity Framework Core 3.1.0 initialized 'ApplicationDbContext' using provider 'Microsoft.EntityFrameworkCore.SqlServer' with options: None
Done. To undo this action, use 'ef migrations remove'
C:\Projects\NETCore3-Angular9\Chapter_10\WorldCities>
```

The new migration files will be autogenerated in the `\Data\Migrations\` folder.

Those who experience issues while creating migrations can try to clear the `\Data\Migrations\` folder before running the preceding `dotnet-ef` command.



For additional information regarding EF Core migrations, and how to troubleshoot them, check out the following guide:

<https://docs.microsoft.com/en-us/ef/core/managing-schemas/migrations/>

Applying the migration

The next thing to do is to apply the new migration to our database. We can choose between two options:

- **Updating the existing data model schema** while keeping all its data as it is
- **Dropping and recreating the database** from scratch

As a matter of fact, the whole purpose of the EF Core migration feature is to provide a way to incrementally update the database schema while preserving existing data in the database; for that very reason, we're going to follow the former path.

Before applying migrations, it's always advisable to perform a full database backup; this advice is particularly important when dealing with production environments. For small databases such as the one currently used by our `WorldCities` web app, it would take a few seconds.



For additional information about how to perform a full backup of a SQL Server database, read the following guide:

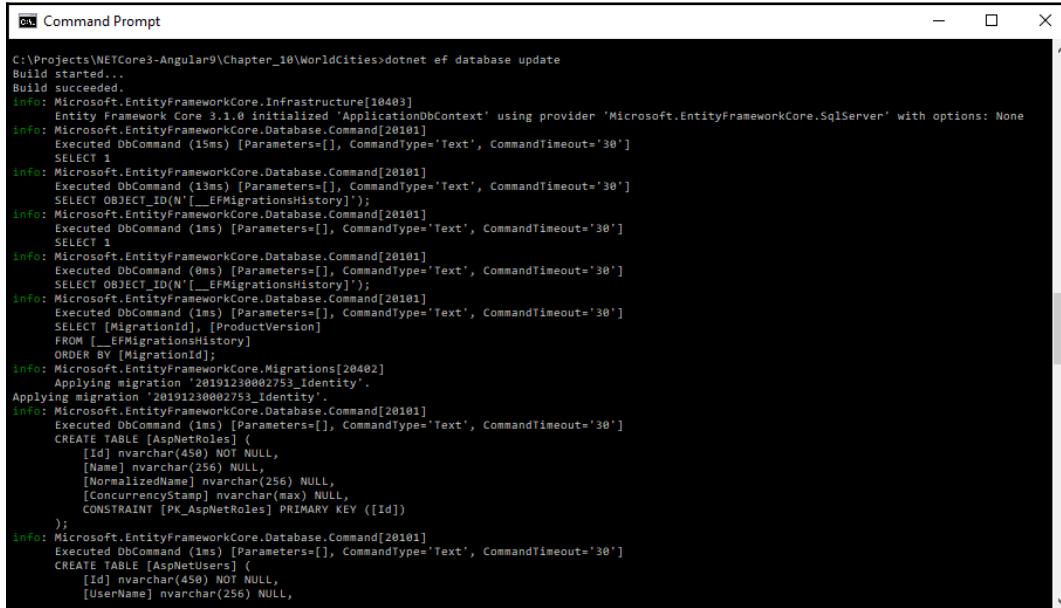
<https://docs.microsoft.com/en-us/sql/relational-databases/backup-restore/create-a-full-database-backup-sql-server>

Updating the existing data model

To apply the migration to the existing database schema without losing the existing data, run the following command from our `WorldCities` project's root folder:

```
dotnet ef database update
```

The `dotnet ef` tool will then apply the necessary updates to our SQL database schema and output the relevant information—as well as the actual SQL queries—in the console buffer, as shown in the following screenshot:

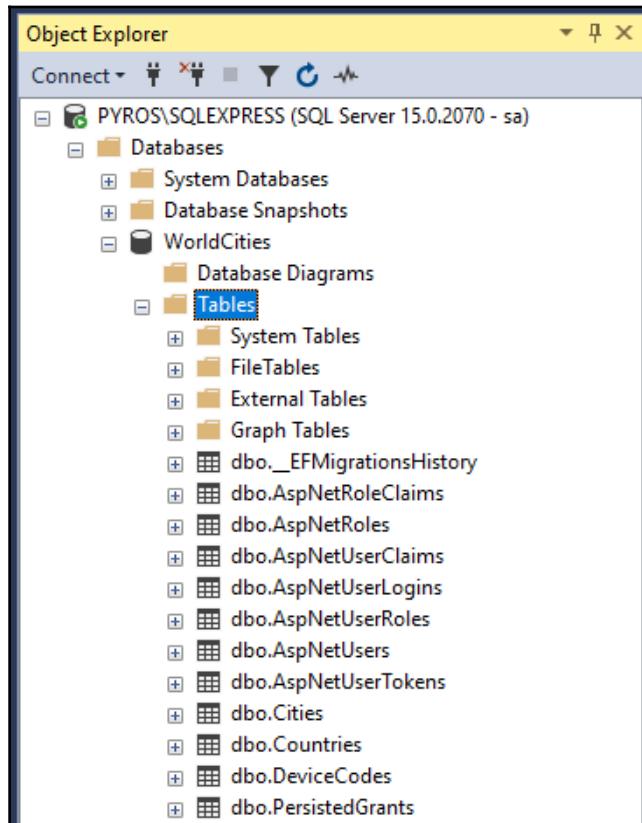


The screenshot shows a Windows Command Prompt window titled "Command Prompt". The path "C:\Projects\NETCore3-Angular9\Chapter_10\WorldCities" is displayed at the top. The command entered is "dotnet ef database update". The output shows the migration process, including the creation of the "AspNetRoles" and "AspNetUsers" tables with their respective columns and constraints.

```
C:\Projects\NETCore3-Angular9\Chapter_10\WorldCities>dotnet ef database update
Build started...
Build succeeded.
Info: Microsoft.EntityFrameworkCore.Infrastructure[10403]
      Entity Framework Core 3.1.0 initialized 'ApplicationDbContext' using provider 'Microsoft.EntityFrameworkCore.SqlServer' with options: None
Info: Microsoft.EntityFrameworkCore.Database.Command[20101]
      Executed DbCommand [15ms] [Parameters=[], CommandType='Text', CommandTimeout='30']
      SELECT 1
Info: Microsoft.EntityFrameworkCore.Database.Command[20101]
      Executed DbCommand [13ms] [Parameters=[], CommandType='Text', CommandTimeout='30']
      SELECT OBJECT_ID(N'[_EFMigrationsHistory']')
Info: Microsoft.EntityFrameworkCore.Database.Command[20101]
      Executed DbCommand [1ms] [Parameters=[], CommandType='Text', CommandTimeout='30']
      SELECT 1
Info: Microsoft.EntityFrameworkCore.Database.Command[20101]
      Executed DbCommand [0ms] [Parameters=[], CommandType='Text', CommandTimeout='30']
      SELECT OBJECT_ID(N'[_EFMigrationsHistory']')
Info: Microsoft.EntityFrameworkCore.Database.Command[20101]
      Executed DbCommand [1ms] [Parameters=[], CommandType='Text', CommandTimeout='30']
      SELECT [MigrationId], [ProductVersion]
      FROM [_EFMigrationsHistory]
      ORDER BY [MigrationId];
Info: Microsoft.EntityFrameworkCore.Migrations[20402]
      Applying migration '20191230002753_Identity'.
Info: Microsoft.EntityFrameworkCore.Database.Command[20101]
      Executed DbCommand [1ms] [Parameters=[], CommandType='Text', CommandTimeout='30']
      CREATE TABLE [AspNetRoles] (
          [Id] nvarchar(450) NOT NULL,
          [Name] nvarchar(256) NULL,
          [Normalized Name] nvarchar(256) NULL,
          [ConcurrencyStamp] nvarchar(max) NULL,
          CONSTRAINT [PK_AspNetRoles] PRIMARY KEY ([Id])
      );
Info: Microsoft.EntityFrameworkCore.Database.Command[20101]
      Executed DbCommand [1ms] [Parameters=[], CommandType='Text', CommandTimeout='30']
      CREATE TABLE [AspNetUsers] (
          [Id] nvarchar(450) NOT NULL,
          [UserName] nvarchar(256) NULL,
```

Once the task has been completed, we should connect to our database using the **SQL Server Management Studio** tool that we installed back in [Chapter 4, Data Model with Entity Framework Core](#)—and check for the presence of the new identity-related tables.

If everything went well, we should be able to see the new identity tables together with our existing `Cities` and `Countries` tables:



As we can easily guess, these tables are still empty; to populate them we'll have to run the `CreateDefaultUsers()` method of `SeedController`, which is something that we're going to do in a short while.

Dropping and recreating the data model from scratch

For completeness, let's spend a little time looking at how to recreate our data model and **database schema (db schema)** from scratch. Needless to say, if we opt for that route, we will lose all our existing data. However, we could always reload everything using the `Import()` method of `SeedController`, hence it wouldn't be a great loss; as a matter of fact, we would only lose what we did during our CRUD-based tests in Chapter 4, *Data Model with Entity Framework Core*.

Although performing a DB drop and recreate is not the suggested approach—especially considering that we've adopted the *migration* pattern precisely to avoid such a scenario—it can be a decent workaround whenever we lose control of our migrations, provided that we entirely back up the data before doing that and, most importantly, know how to restore everything afterward.



Although it might seem a horrible way to fix things, that's definitely not the case; we're still in the development phase, hence we can definitely allow a full database refresh.

Should we choose to take this route, here are the `dotnet-eF` console commands to use:

```
> dotnet ef database drop  
> dotnet ef database update
```

The `drop` command should ask for a Y/N confirmation before proceeding; when it does, hit the Y key and let it happen. When the drop and update tasks are both done, we can run our project in debug mode and pay a visit to the `Import()` method of `SeedController`; once done, we should have an updated database with ASP.NET Core Identity support.

Seeding the data

Regardless of the option we chose to update the database, we now have to repopulate it.

Hit *F5* to run the project in debug mode, then manually input the following URL in the browser's address

bar: <https://localhost:44334/api/Seed/CreateDefaultUsers>.

And let the `CreateDefaultUsers()` method of `SeedController` work its magic.

Once done, we should be able to see the following JSON response:

```
{
  "count": 2,
  "users": [
    {
      "id": "70577f19-4693-46ef-9b24-ce2bdadd72e8",
      "userName": "Admin",
      "normalizedUserName": "ADMIN",
      "email": "admin@email.com",
      "normalizedEmail": "ADMIN@EMAIL.COM",
      "emailConfirmed": true,
      "passwordHash": "AQAAAAEAACcQAAAAEhIn6CBJPMV4EW56JNjZ7YUKPUamsY5P10yEsti1maWUzIuaXthrBIYdD7nDBc8GQ==",
      "securityStamp": "IEUDIDDXUGXZCLINKEM5552HGZ3FTDRC",
      "concurrencyStamp": "138d5351-07e1-4222-9cb1-f559d77abf95",
      "phoneNumber": null,
      "phoneNumberConfirmed": false,
      "twoFactorEnabled": false,
      "lockoutEnd": null,
      "lockoutEnabled": false,
      "accessFailedCount": 0
    },
    {
      "id": "f0fa0aca-8be6-4b98-8048-f6257e30b7db",
      "userName": "User",
      "normalizedUserName": "USER",
      "email": "user@email.com",
      "normalizedEmail": "USER@EMAIL.COM",
      "emailConfirmed": true,
      "passwordHash": "AQAAAAEAACcQAAAAEOwRqSq0SWJbN9JlV8eZT3A0W4N\u002B\u002BnieSeoFBAVF1\u002B\u002BrBPDpa/pJXU\u002BsjvGh1Xjk19A==",
      "securityStamp": "7C5FZHLOUSUNTSE554TZG3F52VSEYNQW",
      "concurrencyStamp": "cae3053d-f118-43ac-ac61-f33ac90f14c",
      "phoneNumber": null,
      "phoneNumberConfirmed": false,
      "twoFactorEnabled": false,
      "lockoutEnd": null,
      "lockoutEnabled": false,
      "accessFailedCount": 0
    }
  ]
}
```

This output already tells us that our first two users have been created and stored in our data model. However, we can confirm that by connecting to our database using the SQL Server Management Studio tool and taking a look at the `dbo.AspNetUsers` table (see the following screenshot):

The screenshot shows the Microsoft SQL Server Management Studio interface. In the Object Explorer on the left, under the database 'PYROS\SQLEXPRESS (SQL Server 15.0.2070 - sa)', the 'Tables' node is expanded, showing tables like `dbo.AspNetUsers`, `dbo.AspNetRoles`, etc. In the center pane, there are two queries in a query editor window:

```
SELECT *  
FROM [WorldCities].[dbo].[AspNetUsers];  
  
SELECT *  
FROM [WorldCities].[dbo].[AspNetRoles];
```

The bottom pane displays the results of the first query, which shows two rows of user data:

	Id	UserName	NormalizedUserName	Email	NormalizedEmail	EmailConfirmed
1	7057719-4633-46ef-9b24-ce2bdadd72e8	admin@email.com	ADMIN@EMAIL.COM	admin@email.com	ADMIN@EMAIL.COM	1
2	f0fa0aca-9be6-4b98-8048-f6257e30b7db	user@email.com	USER@EMAIL.COM	user@email.com	USER@EMAIL.COM	1

Below this, another results grid shows the second query's output:

	Id	Name	NormalizedName	ConcurrencyStamp
1	90586e0ba34474a-845c-46db-5c2fcbe6	RegisteredUser	REGISTEREDUSER	c65a4545-0ee0-4906-80e1-fb1c1c239
2	b6ddcb37-3833-4fe4-8555-6b55c0db5497	Administrator	ADMINISTRATOR	a01b4893-e461-4fdc-8744-0790f355e6

A status bar at the bottom indicates: 'Query executed successfully.' and 'PYROS\SQLEXPRESS (15.0 RTM) | sa (67) | WorldCities | 00:00:00 | 4 rows'.

As we can see, we used the following T-SQL queries to check for the existing users and roles:

```
SELECT *  
FROM [WorldCities].[dbo].[AspNetUsers];  
  
SELECT *  
FROM [WorldCities].[dbo].[AspNetRoles];
```

Bingo! Our ASP.NET Core Identity system implementation is up, running, and fully integrated with our data model; now we just need to implement it within our Controllers and hook it up with our Angular client app.

Authentication methods

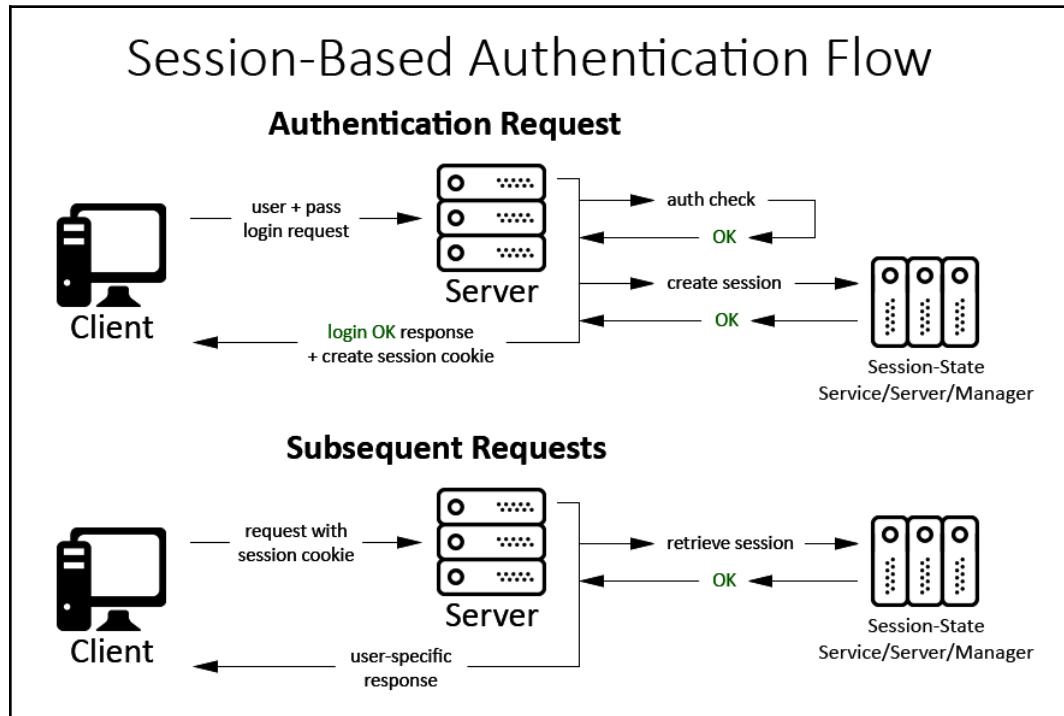
Now that we have updated our database to support the ASP.NET Core Identity authentication workflow and patterns, we should spend some valuable time choosing which authentication method to adopt; more precisely, since we've already implemented the .NET Core `IdentityServer`, to properly understand whether the default authentication method that it provides for SPA—JWT tokens—is safe enough to use or whether we should change it to a more secure mechanism.

As we most certainly know, the HTTP protocol is *stateless*, meaning that whatever we do during a request/response cycle will be lost before the subsequent request, including the authentication result. The only way we have to overcome this is to store that result somewhere, along with all its relevant data, such as user ID, login date/time, and last request time.

Sessions

Since a few years ago, the most common and traditional method to do this was to store that data on the server using either a memory-based, disk-based or external session manager. Each session can be retrieved using a unique ID that the client receives with the authentication response, usually inside a session cookie, that will be transmitted to the server on each subsequent request.

Here's a brief diagram showing the **Session-Based Authentication Flow**:



This is still a very common technique used by most web applications. There's nothing wrong with adopting this approach, as long as we are okay with its widely acknowledged downsides, such as the following:

- **Memory issues:** Whenever there are many authenticated users, the web server will consume more and more memory. Even if we use a file-based or external session provider, there will nonetheless be an intensive I/O, TCP, or socket overhead.
- **Scalability issues:** Replicating a session provider in a scalable architecture (*IIS web farm, load-balanced cluster* and the like) might not be an easy task and will often lead to bottlenecks or wasted resources.

- **Cross-domain issues:** Session cookies behave just like standard cookies, so they cannot be easily shared between different origins/domains. These kinds of problems can often be solved with some workarounds, yet they will often lead to insecure scenarios to make things work.
- **Security issues:** There is a wide range of detailed literature on security-related issues involving sessions and session cookies: XSS attacks, cross-site request forgery, and a number of other threats that won't be covered here for the sake of simplicity. Most of them can be mitigated by some countermeasures, yet they can be difficult to handle for junior or novice developers.

As these issues have arisen over the years, there's no doubt that most analysts and developers have put a lot of effort into figuring out different approaches.

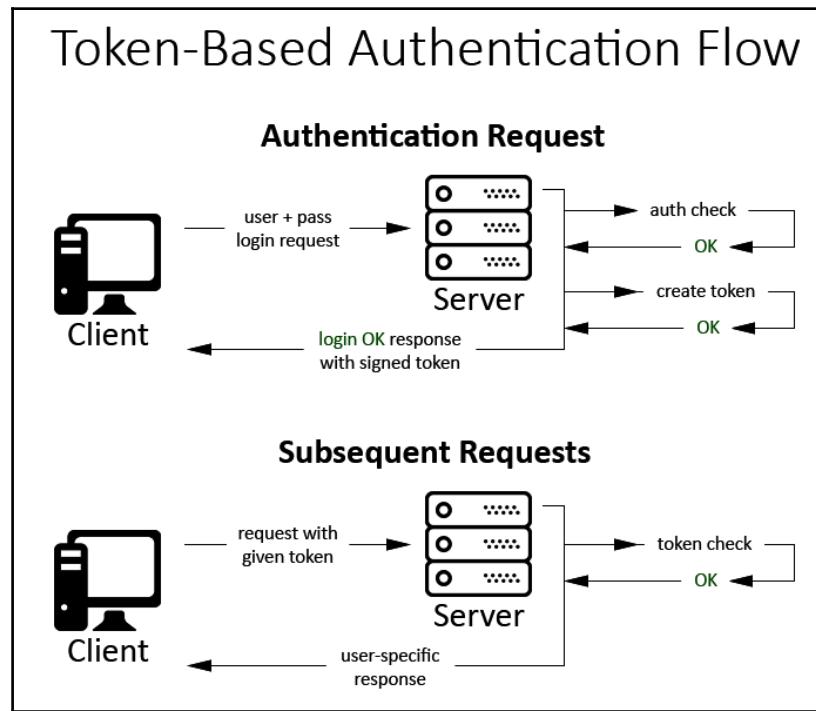
Tokens

Token-based authentication has been increasingly adopted by **Single-Page Applications (SPAs)** and mobile apps in the last few years for a number of undeniably good reasons that we'll try to briefly summarize here.

The most important difference between session-based authentication and token-based authentication is that the latter is *stateless*, meaning that we won't be storing any user-specific information on the server memory, database, session provider, or other data containers of any sort.

This single aspect solves most of the downsides that we pointed out earlier for session-based authentication. We won't have sessions, so there won't be an increasing overhead; we won't need a session provider, so scaling will be much easier. Also, for browsers supporting `LocalStorage`, we won't even be using cookies, so we won't get blocked by *cross-origin* restrictive policies and, hopefully, we'll get around most security issues.

Here's a typical **Token-Based Authentication Flow**:



In terms of client-server interaction, these steps don't seem much different from the Session-Based Authentication Flow diagram; apparently, the only difference is that we'll be issuing and checking tokens instead of creating and retrieving sessions. The real deal is happening (or not happening) at the server side. We can immediately see that the token-based auth flow does not rely on a stateful session-state server, service, or manager. This will easily translate into a considerable boost in terms of performance and scalability.

Signatures

This is a method used by most modern API-based cloud-computing and storage services, including **Amazon Web Services (AWS)**. In contrast to session-based and token-based approaches, which rely on a transport layer that can be theoretically accessed by or exposed to a third-party attacker, signature-based authentication performs a hash of the whole request using a previously shared private key. This ensures that no intruder or man-in-the-middle can ever act as the requesting user, as they won't be able to sign the request.

Two-factor

This is the standard authentication method used by most banking and financial accounts, being arguably the most secure one.

The implementation may vary, but it always relies on the following base workflow:

- The user performs a standard login with a username and password.
- The server identifies the user and prompts them with an additional, user-specific request that can be only satisfied by something obtained or obtainable through a different channel: an OTP password sent by SMS, a unique authentication card with a number of answer codes, a dynamic PIN generated by a proprietary device or a mobile app, and so on.
- If the user gives the correct answer, they are authenticated using a standard session-based or token-based method.

Two-Factor Authentication (2FA) has been supported by ASP.NET Core since its 1.0 release, which implemented it using an SMS verification (SMS 2FA); however, starting with ASP.NET Core 2, the SMS 2FA approach was deprecated in favor of a **Time-based One-time Password Algorithm (TOTP)**, which became the industry-recommended approach to implement 2FA in web applications.

For additional information about SMS 2FA, check out the following URL:

<https://docs.microsoft.com/en-us/aspnet/core/security/authentication/2fa>



For additional information about TOTP 2FA, take a look at the following URL:

<https://docs.microsoft.com/en-us/aspnet/core/security/authentication/identity-enable-qrcodes>

Conclusions

After reviewing all these authentication methods, we can definitely say that the token-based authentication approach provided by `IdentityServer` seems to be a great choice for our specific scenario.

Our current implementation is based on **JSON Web Tokens (JWT)**, a JSON-based open standard explicitly designed for native web applications, available in multiple languages, such as .NET, Python, Java, PHP, Ruby, JavaScript/NodeJS, and PERL. We've chosen it because it's becoming a de facto standard for token authentication, as it's natively supported by most technologies.



For additional information about JSON Web Tokens, check out the following URL:

<https://jwt.io/>

Implementing authentication in Angular

In order to handle JWT-based token authentication, we need to set up our ASP.NET *back-end* and our Angular *front-end* to handle all the required tasks.

In the previous sections, we spent a good amount of time configuring the .NET Core Identity services as well as `IdentityServer`, meaning that we're halfway done; as a matter of fact, we're almost done with the *server-side* tasks. At the same time, we did nothing at the *front-end* level: the two sample users that we created in the previous section—`admin@email.com` and `user@email.com`—have no way to log in, and there isn't a registration form for creating new ones.

Now, here's some (very) good news: the Visual Studio Angular template that we used to set up our apps comes with built-in support for the auth API that we've just added to our *back-end*, and the best part of it is that it actually works very well!

However, we've also got some bad news: since we chose to *not* add any authentication method to our projects when we created them, all the Angular modules, Components, services, interceptors, and tests that would have handled this task *have been excluded* from our Angular app; as a consequence of that initial choice, when we started to explore our pre-made Angular app back in Chapter 2, *Looking Around*, we only had the `counter` and `fetch-data` Components to play with.

As a matter of fact, we've chosen to exclude the authorization Components for a reason: since we used that template as a sample application to learn more about the Angular structure, we didn't want to complicate our life early on by bringing in all the authentication and authorization stuff.

Luckily enough, all those missing classes can be easily retrieved and implemented in our current `WorldCities` project... which is precisely what we're going to do in this section.

More specifically, here's a list of our upcoming tasks:

- **Creating a brand new .NET Core and Angular project**, which we'll use as a *code repository* to copy the auth-related Angular classes from; the new project name will be `AuthSample`.
- **Exploring the Angular authorization APIs** to understand how they work.
- **Testing the login and registration forms** provided by the aforementioned APIs from the `AuthSample` project.

By the end of the section, we should be able to register new users, as well as log in with existing users, using the *front-end* authorization APIs shipped with the `AuthSample` app.

Creating the AuthSample project

The first thing we're going to do is create a new .NET Core and Angular web application project. As a matter of fact, it's the third time we're doing this: we created the `HealthCheck` project in Chapter 1, *Getting Ready*, and then the `WorldCities` project in Chapter 3, *Front-end and Back-end Interactions*; therefore, we already know most of what we have to do.

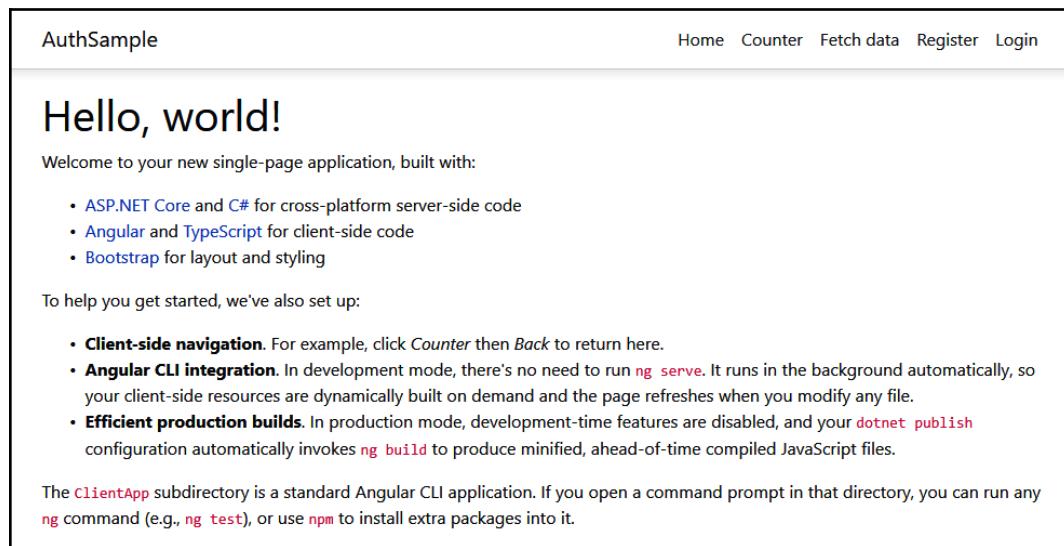
The name of our third project will be `AuthSample`; however, the required tasks to create it will be slightly different (and definitely easier) from the last time we did this:

1. Create a new project with the `dotnet new angular -o AuthSample -au Individual` command.
2. Edit the `/ClientApp/package.json` file to update the existing npm package versions to the same version we're currently using in the existing `HealthCheck` and `WorldCities` Angular apps (see Chapter 2, *Looking Around*, for details on how to do this).

That's it. As we can see, this time we added the `-au` switch (a shortcut for `--auth`), which will include all the auth-related classes that we purposely missed when creating the `HealthCheck` and `WorldCities` projects; moreover, we didn't have to delete or update anything other than the npm package versions: the built-in Angular Components, as well as the *back-end* classes and libraries, are more than enough to explore the auth-related code we've been missing until now.

Troubleshooting the AuthSample project

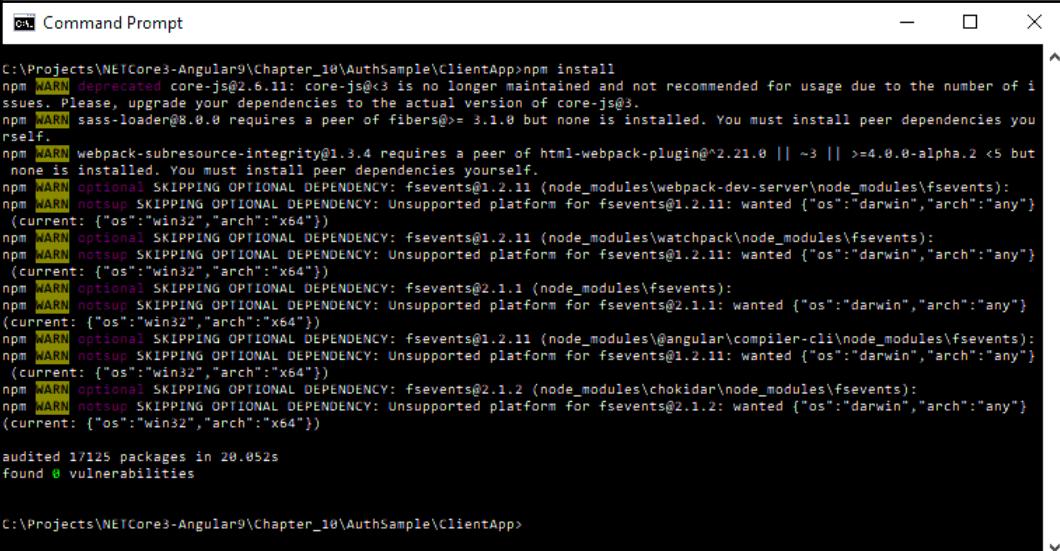
After updating the npm packages, the first thing we should do is to launch the project in debug mode and ensure that the home page is properly working (see the following screenshot):



If we run into package conflicts, JavaScript errors, or other npm-related issues, we can try to execute the following npm commands from the `/ClientApp/` folder to update them all and verify the package cache:

```
> npm install  
> npm cache verify
```

This is shown in the following screenshot:



The screenshot shows a Windows Command Prompt window titled "Command Prompt". The command entered was "npm install". The output of the command is displayed, showing numerous warnings from npm regarding deprecated packages and missing peer dependencies. Key messages include:

```
C:\Projects\NETCore3-Angular9\Chapter_10\AuthSample\ClientApp>npm install
npm WARN deprecated core-js@2.6.11: core-js@3 is no longer maintained and not recommended for usage due to the number of issues. Please, upgrade your dependencies to the actual version of core-js@3.
npm WARN sass-loader@8.0.0 requires a peer of fibers@>= 3.1.0 but none is installed. You must install peer dependencies yourself.
npm WARN webpack-subresource-integrity@1.3.4 requires a peer of html-webpack-plugin@^2.21.0 || ~3 || >=4.0.0-alpha.2 <5 but none is installed. You must install peer dependencies yourself.
npm WARN optional SKIPPING OPTIONAL DEPENDENCY: fsevents@1.2.11 (node_modules\webpack-dev-server\node_modules\fsevents):
npm WARN notsup SKIPPING OPTIONAL DEPENDENCY: Unsupported platform for fsevents@1.2.11: wanted {"os":"darwin","arch":"any"}
(current: {"os":"win32","arch":"x64"})
npm WARN optional SKIPPING OPTIONAL DEPENDENCY: fsevents@1.2.11 (node_modules\watchpack\node_modules\fsevents):
npm WARN notsup SKIPPING OPTIONAL DEPENDENCY: Unsupported platform for fsevents@1.2.11: wanted {"os":"darwin","arch":"any"}
(current: {"os":"win32","arch":"x64"})
npm WARN optional SKIPPING OPTIONAL DEPENDENCY: fsevents@2.1.1 (node_modules\fsevents):
npm WARN notsup SKIPPING OPTIONAL DEPENDENCY: Unsupported platform for fsevents@2.1.1: wanted {"os":"darwin","arch":"any"}
(current: {"os":"win32","arch":"x64"})
npm WARN optional SKIPPING OPTIONAL DEPENDENCY: fsevents@1.2.11 (node_modules\@angular\compiler-cli\node_modules\fsevents):
npm WARN notsup SKIPPING OPTIONAL DEPENDENCY: Unsupported platform for fsevents@1.2.11: wanted {"os":"darwin","arch":"any"}
(current: {"os":"win32","arch":"x64"})
npm WARN optional SKIPPING OPTIONAL DEPENDENCY: fsevents@2.1.2 (node_modules\chokidar\node_modules\fsevents):
npm WARN notsup SKIPPING OPTIONAL DEPENDENCY: Unsupported platform for fsevents@2.1.2: wanted {"os":"darwin","arch":"any"}
(current: {"os":"win32","arch":"x64"})

audited 17125 packages in 20.052s
found 0 vulnerabilities
```

C:\Projects\NETCore3-Angular9\Chapter_10\AuthSample\ClientApp>

Although Visual Studio should automatically update the npm packages as soon as we update the package .json file on disk, sometimes the auto-update process fails to work properly: when this happens, manual execution of the preceding npm commands from the command line is a convenient way to fix these kinds of issues.

In case we experience some *back-end* runtime errors, it could be wise to briefly review the .NET Code against what we did in the previous chapters—and also in this chapter—to fix any issue related to the template's source code, third-party references, NuGet package versions, and so on. As always, the GitHub repository provided by this book will greatly help us to troubleshoot our own code; be sure to check it out!

Exploring the Angular authorization APIs

In this section, we're going to take an extensive look at the authorization APIs provided by the .NET Core and Angular Visual Studio project template: a set of functionalities that rely upon the **oidc-client** library to allow an Angular app to interact with the URI endpoints provided by the ASP.NET Core Identity system.



The **oidc-client** library is an open source solution that provides OIDC and OAuth2 protocol support for client-side, browser-based JavaScript client applications, including user session support and access token management; its npm package reference is already present in the package.json file of our `WorldCities` app, therefore we won't have to manually add it.

For additional info about the **oidc-client** library, check out the following URL:

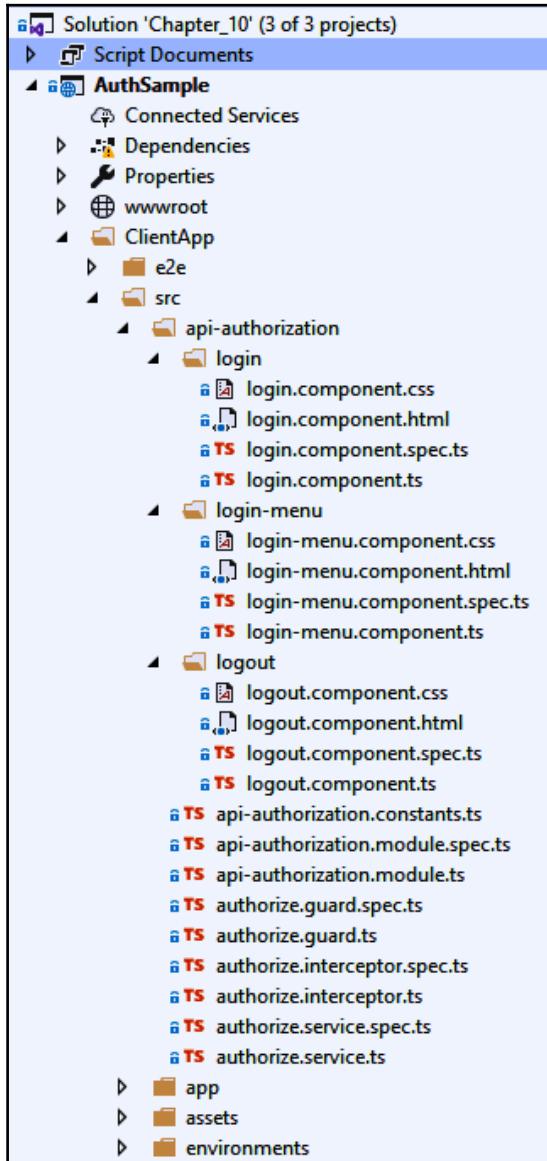
<https://github.com/IdentityModel/oidc-client-js>

As we'll be able to see, these APIs make use of some important Angular features—such as Route Guards and HTTP interceptors—to handle the authorization flow through the HTTP request/response cycle.

Let's start with a quick overview of the Angular app shipped with our new `AuthSample` project. If we observe the various files and folders within the `/ClientApp/` directory, we can immediately see that we're dealing with the same sample app that we already explored back in [Chapter 2, Looking Around](#), before trimming it down to better suit our needs.

However, there's an additional folder that wasn't there at the time: we're talking about the `/ClientApp/src/app/authorization-api/` folder, which basically contains everything we missed back then—the Angular *front-end* implementation of the .NET Core Identity APIs and `IdentityServer` hook points.

Inside that folder there are a number of interesting files and subfolders, as shown in the following screenshot:



Thanks to the knowledge we gained on the Angular architecture, we can easily understand the main role of each one of them:

- The first three subfolders—`/login/`, `/login-menu/`, and `/logout/`—contain three *Components*, each one with their TypeScript class, HTML template, CSS file, and test suite.
- The `api-authorization.constants.ts` file contains a bunch of common *interfaces* and *constants* that are referenced and used by the other classes.
- The `api-authorization.module.ts` file is an `NgModule`, that is, a container for the authorization APIs common feature set, just like the `AngularMaterialModule` that we created in our `WorldCities` app back in Chapter 5, *Fetching and Displaying Data*. If we open it, we can see that it contains some auth-specific routing rules.
- The `authorize.guard.ts` file introduces the concept of **Route Guards**, which is something that we've yet to learn; we'll talk more about this in a short while.
- The `authorize.interceptor.ts` file implements an **HTTP interceptor** class—another mechanism that we don't know yet; again, we'll talk more about this soon enough.
- The `authorize.service.ts` file contains the *Data Service* that will handle all the HTTP requests and responses; we know their role and how they work from Chapter 7, *Code Tweaks and Data Services*, where we implemented our `CityService` and `CountryService` for our `WorldCities` app.

We've yet to mention the various `.spec.ts` files; as we learned in Chapter 9, *ASP.NET Core and Angular Unit Testing*, we know that they are the corresponding *test units* for the class files they share their names with.

Route Guards

As we learned in Chapter 2, *Looking Around*, the Angular Router is the service that allows our users to navigate through the various *views* of our app; each view updates the *front-end* and (possibly) calls the *back-end* to retrieve content.

If we think about it, we can see how the Angular Router is the *front-end* counterpart of the ASP.NET Core Routing interface, which is responsible for mapping request URIs to *back-end* endpoints and dispatching incoming requests to those endpoints. Since both these modules share the same behavior, they also have similar requirements that we have to take care of when we implement an authentication and authorization mechanism to our app.

Throughout the previous chapters, we've defined a lot of routes on the *back-end* as well as on the *front-end* to grant our users access to the various ASP.NET Core action methods and Angular views that we've implemented. If we think about it, we can see how all of these routes share a common feature: *anyone can access them*. To put it in other words, *any user is free to go anywhere within our web app*: they can edit cities and countries, they can interact with our `SeedController` to execute its database-seeding tasks, and so on.

It goes without saying that such behavior, although being acceptable in development, is highly undesirable in any production scenario: when the app goes live, we would definitely want to protect some of these routes by restricting them to authorized users only; in other words, to *guard* them.

Route Guards are a mechanism to properly enforce such requirement; they can be added to our route configuration to return values that can control the router's behavior in the following way:

- If a Route Guard returns `true`, the navigation process continues.
- If it returns `false`, the navigation process stops.
- If it returns a `UrlTree`, the navigation process is canceled and replaced by a new navigation to the given `UrlTree`.

Available Guards

The following Route Guards are currently available in Angular:

- `CanActivate`: Mediates navigation to a given *route*
- `CanActivateChild`: Mediates navigation to a given *child route*
- `CanDeactivate`: Mediates navigation away from the current *route*
- `Resolve`: Performs some arbitrary operations (such as custom data retrieval tasks) before activating the *route*
- `CanLoad`: Mediates navigation to a given asynchronous *module*

Each one of them is available through a *superclass* that acts as a *common interface*: whenever we want to create our own guard, we'll just have to extend the corresponding superclass and implement the relevant method(s).

Any route can be configured with multiple guards: `CanDeactivate` and `CanActivateChild` guards will be checked first, from the deepest child route to the top; right after that, the router will check `CanActivate` guards from the top down to the deepest child route; once done, `CanLoad` routes will be checked for asynchronous modules. If any of these guards returns `false`, the navigation will be stopped and all pending guards will be canceled.

Let's now take a look at the `/ClientApp/src/api-authorization/authorize.guard.ts` file to see which route guards have been implemented by the *front-end* authorization API shipped with the `AuthSample` Angular app (relevant lines are highlighted):

```
import { Injectable } from '@angular/core';
import { CanActivate, ActivatedRouteSnapshot, RouterStateSnapshot,
  Router } from '@angular/router';
import { Observable } from 'rxjs';
import { AuthorizeService } from './authorize.service';
import { tap } from 'rxjs/operators';
import { ApplicationPaths, QueryParameterNames } from
  './api-authorization.constants';

@Injectable({
  providedIn: 'root'
})
export class AuthorizeGuard implements CanActivate {
  constructor(private authorize: AuthorizeService, private router: Router) {}
  canActivate (
    _next: ActivatedRouteSnapshot,
    state: RouterStateSnapshot): Observable<boolean> | Promise<boolean> | boolean {
    return this.authorize.isAuthenticated()
      .pipe(tap(isAuthenticated =>
        this.handleAuthorization(isAuthenticated, state)));
  }
  private handleAuthorization(isAuthenticated: boolean, state: RouterStateSnapshot) {
    if (!isAuthenticated) {
      this.router.navigate(ApplicationPaths.LoginPathComponents, {
        queryParams: {
          [QueryParameterNames.ReturnUrl]: state.url
        }
      });
    }
  }
}
```

```
        }
    );
}
}
```

As we can see, we're dealing with a guard that extends the `CanActivate` interface. As we can reasonably expect from an authorization API, that guard is checking the `isAuthenticated()` method of the `AuthorizeService` (which is *injected* in the constructor through DI) and conditionally allows or blocks the navigation based on it; no wonder its name is `AuthorizeGuard`.

Once they have been created, guards can be bound to the various routes from within the route configuration itself, which provides a property for each guard type; if we take a look inside the `/ClientApp/src/app/app.module.ts` file of the `AuthSample` app, where the main routes are configured, we can easily identify the *guarded* route:

```
// ...

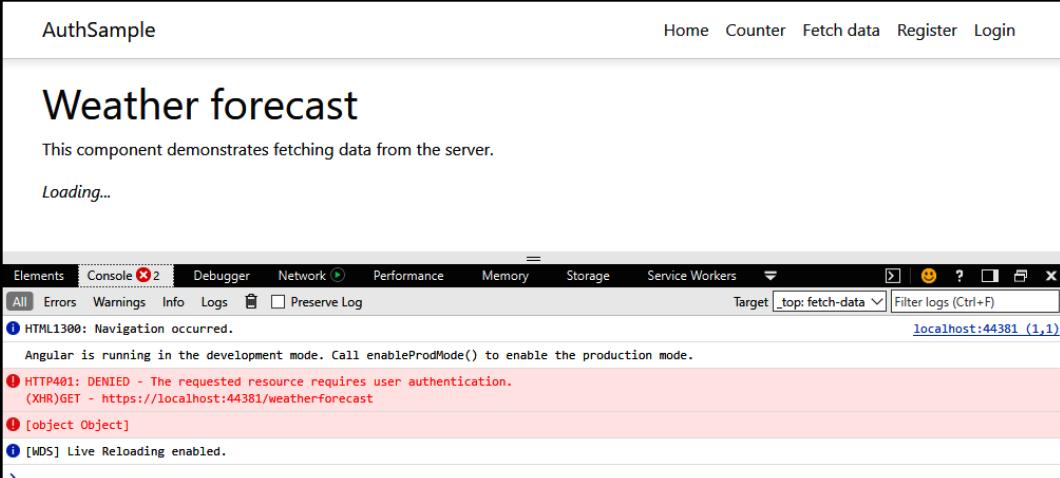
RouterModule.forRoot([
  { path: '', component: HomeComponent, pathMatch: 'full' },
  { path: 'counter', component: CounterComponent },
  { path: 'fetch-data', component: FetchDataComponent, canActivate:
    [AuthorizeGuard] },
])
// ...
```

This means that the `fetch-data` view, which brings the user to the `FetchDataComponent`, can only be activated by authenticated users: let's quickly give it a try to see if it works as expected.

Press **F5** to run the `AuthSample` app in debug mode, then try to navigate to the **Fetch data** view by clicking the corresponding link to the top-right menu. Since we're not an authenticated user, we should be redirected to the **Log in** view, as shown in the following screenshot:

The screenshot shows the `AuthSample` application's login interface. At the top, there is a header bar with the title "AuthSample" on the left and "Register" and "Login" links on the right. Below the header, the main content area has a heading "Log in". On the left side, there is a section titled "Use a local account to log in." followed by input fields for "Email" and "Password", and a "Remember me?" checkbox. To the right of these fields is another section titled "Use another service to log in." with a note stating "There are no external authentication services configured. See [this article](#) for details on setting up this ASP.NET application to support logging in via external services." At the bottom of the page, there are links for "Forgot your password?", "Register as a new user", and a copyright notice "© 2019 - AuthSample".

It seems that the Route Guard is working: if we now manually edit the `/ClientApp/src/app/app.module.ts` file, remove the `canActivate` property from the `fetch-data` route, and try again, we'll see that we'll be able to access that view without issues:



The screenshot shows a browser's developer tools open to the 'Console' tab. The URL in the target field is 'localhost:44381 (1,1)'. The log output is as follows:

- HTML1300: Navigation occurred.
- Angular is running in the development mode. Call enableProdMode() to enable the production mode.
- HTTP401: DENIED - The requested resource requires user authentication.
(XHR)GET - https://localhost:44381/weatherforecast
- [object Object]
- [MD5] Live Reloading enabled.

... Or maybe not.

As we can see from the **Console** log, even if the *front-end* allowed us to pass, the HTTP request issued to the *back-end* seems to have hit a 401 Unauthorized Error. What happened? The answer is really simple: by manually removing the Route Guard, we were able to *hack* our way through the Angular *front-end* routing system, but the .NET Core *back-end* routing also features a similar protection against unauthorized access that can't be avoided from the client side.

Such protection can be easily seen by opening the `/Controllers/WeatherForecastController.cs` file and looking at the existing class attributes (relevant line highlighted):

```
// ...  
  
[Authorize]  
[ApiController]  
[Route("[controller]")]  
public class WeatherForecastController : ControllerBase  
  
// ...
```

In .NET Core Controllers, route authorization is controlled through the `AuthorizeAttribute` attribute. More specifically, the Controller or action method that the `[Authorize]` attribute is applied to requires the authorization level specified by its parameters: if no parameters are given, applying the `AuthorizeAttribute` attribute to a Controller or action will limit the access to *authenticated* users only.

Now we know why we are unable to fetch that data from the *back-end*; if we remove (or comment out) that attribute, we will finally be able to, as shown in the following screenshot:

The screenshot shows a web application titled "AuthSample". The navigation bar includes links for Home, Counter, Fetch data, Register, and Login. The main content area displays a heading "Weather forecast" and a subtitle "This component demonstrates fetching data from the server." Below this is a table with five rows, each representing a weather forecast entry. The columns are labeled Date, Temp. (C), Temp. (F), and Summary. The data is as follows:

Date	Temp. (C)	Temp. (F)	Summary
2020-01-01T00:48:44.8869247+01:00	-20	-3	Chilly
2020-01-02T00:48:44.8869586+01:00	16	60	Cool
2020-01-03T00:48:44.8869765+01:00	24	75	Sweltering
2020-01-04T00:48:44.8869958+01:00	53	127	Hot
2020-01-05T00:48:44.8870115+01:00	29	84	Freezing

Before proceeding, let's put the *front-end* Route Guard and the *back-end* `AuthorizeAttribute` back in their place; we need them to be there to properly test our navigation after performing an actual login and obtaining the authorization to access those resources.

However, before doing that, we have to finish our exploration journey; in the next section, we'll introduce another important Angular concept that we haven't talked about yet.

For further information about Route Guards and their role in the Angular Routing workflow, check out the following URLs:



<https://angular.io/guide/router#guards>

<https://docs.microsoft.com/en-us/aspnet/core/fundamentals/routing>

HttpInterceptors

The Angular `HttpInterceptor` interface provides a standardized mechanism to intercept and/or transform outgoing HTTP requests or incoming HTTP responses; *interceptors* are quite similar to the ASP.NET *middleware* that we introduced in [Chapter 2, Looking Around](#), and then played within [Chapter 3, Front-end and Back-end Interactions](#), except that they work at the *front-end* level.

Interceptors are a major feature of Angular since they can be used for a number of different tasks: they can inspect and/or log our app's HTTP traffic, modifying the requests, caching the responses, and so on; they are a convenient way to centralize all these tasks so that we don't have to implement them explicitly on our *Data Services* and/or within the various `HttpClient`-based method calls. Moreover, they can also be chained, meaning that we can have multiple interceptors working together in a forward-and-backward chain of request/response handlers.

The `AuthorizeInterceptor` class shipped with the Angular authentication APIs we are exploring features a lot of inline comments that greatly help us to understand how it actually works.

To take a look at its source code, open the `/ClientApp/src/api-authorization/authorize.interceptor.ts` file (relevant lines are highlighted):

```
import { Injectable } from '@angular/core';
import { HttpInterceptor, HttpRequest, HttpHandler, HttpEvent } from '@angular/common/http';
import { Observable } from 'rxjs';
import { AuthorizeService } from './authorize.service';
import { mergeMap } from 'rxjs/operators';

@Injectable({
  providedIn: 'root'
})
export class AuthorizeInterceptor implements HttpInterceptor {
  constructor(private authorize: AuthorizeService) { }

  intercept(req: HttpRequest<any>, next: HttpHandler): Observable<HttpEvent<any>> {
    return this.authorize.getAccessToken()
      .pipe(mergeMap(token => this.processRequestWithToken(token, req,
      next)));
  }

  // Checks if there is an access_token available in the authorize
  // service and adds it to the request in case it's targeted at
  // the same origin as the single page application.
}
```

```
private processRequestWithToken(token: string, req:  
  HttpRequest<any>,  
  next: HttpHandler) {  
  if (!token && this.isSameOriginUrl(req)) {  
    req = req.clone({  
      setHeaders: {  
        Authorization: `Bearer ${token}`  
      }  
    });  
  }  
  
  return next.handle(req);  
}  
  
private isSameOriginUrl(req: any) {  
  // It's an absolute url with the same origin.  
  if (req.url.startsWith(`${window.location.origin}/`)) {  
    return true;  
  }  
  
  // It's a protocol relative url with the same origin.  
  // For example: //www.example.com/api/Products  
  if (req.url.startsWith(`//${window.location.host}/`)) {  
    return true;  
  }  
  
  // It's a relative url like /api/Products  
  if (/^\/[^\/].*/.test(req.url)) {  
    return true;  
  }  
  
  // It's an absolute or protocol relative url that  
  // doesn't have the same origin.  
  return false;  
}  
}
```

As we can see, the `AuthorizeInterceptor` implements the `HttpInterceptor` interface by defining an `intercept` method. That method's job is to intercept *all* the outgoing HTTP requests and conditionally add the JWT Bearer token to their HTTP headers; this condition is determined by the `isSameOriginUrl()` internal method, which will return `true` only if the request is addressed to an URL with the same *origin* of the Angular app.

Just like any other Angular class, the `AuthorizeInterceptor` needs to be properly configured within an `NgModule` in order to work; since it needs to inspect *any* HTTP request—including those not part of the authorization API—it has been configured in the `AppModule`, the root-level `NgModule`, or the `AuthSample` app.

To see the actual implementation, open the `/ClientApp/src/app/app.module.ts` file and look at the `providers` section:

```
// ...  
  
providers: [  
  { provide: HTTP_INTERCEPTORS, useClass: AuthorizeInterceptor, multi:  
    true }  
,  
  
// ...
```

The `multi: true` property that we can see in the preceding code is a required setting, because `HTTP_INTERCEPTORS` is a multi-provider token that is expecting to *inject* an array of multiple values, rather than a single one.

For additional information about HTTP interceptors, take a look at the following URLs:



<https://angular.io/api/common/http/HttpInterceptor>

https://angular.io/api/common/http/HTTP_INTERCEPTORS

The authorization Components

Let's now take a look to the various Angular Components included in the `/api-authorization/` folder.

LoginMenuComponent

The role of `LoginMenuComponent`, located in the `/ClientApp/src/api-authorization/login-menu/` folder, is to be included within `NavMenuComponent` (which we already know well) to add the `Login` and `Logout` actions to the existing navigation options.

We can check it out by opening the `/ClientApp/src/app/nav-menu/nav-menu.component.html` file and checking for the presence of the following line:

```
<app-login-menu></app-login-menu>
```

This is the root element of `LoginMenuComponent`; therefore, `LoginMenuComponent` is implemented as a *child Component* of `NavMenuComponent`. However, if we look at its TypeScript file source code, we can see that it has some unique features strictly related to its tasks (relevant lines are highlighted):

```
import { Component, OnInit } from '@angular/core';
import { AuthorizeService } from '../authorize.service';
import { Observable } from 'rxjs';
import { map, tap } from 'rxjs/operators';

@Component({
  selector: 'app-login-menu',
  templateUrl: './login-menu.component.html',
  styleUrls: ['./login-menu.component.css']
})
export class LoginMenuComponent implements OnInit {
  public isAuthenticated: Observable<boolean>;
  public userName: Observable<string>;

  constructor(private authorizeService: AuthorizeService) { }

  ngOnInit() {
    this.isAuthenticated = this.authorizeService.isAuthenticated();
    this.userName = this.authorizeService.getUser().pipe(map(u => u &&
      u.name));
  }
}
```

As we can see, the Component uses `authorizeService` (injected in the constructor through DI) to retrieve the following information about the visiting user:

- Whether that user is authenticated or not
- That user's username

The two values are stored in the `isAuthenticated` and `userName` local variables, which are then used by the template file to determine the Component's behavior.

To better understand that, let's take a look at the `/ClientApp/src/api-authentication/login-menu/login-menu.component.html` template file (relevant lines highlighted):

```
<ul class="navbar-nav" *ngIf="isAuthenticated | async">
  <li class="nav-item">
    <a class="nav-link text-dark"
       [routerLink]="/authentication/profile"
       title="Manage">Hello {{ userName | async }}</a>
  </li>
  <li class="nav-item">
    <a class="nav-link text-dark"
       [routerLink]="/authentication/logout"
       [state]'{ local: true }' title="Logout">Logout</a>
  </li>
</ul>
<ul class="navbar-nav" *ngIf="!(isAuthenticated | async)">
  <li class="nav-item">
    <a class="nav-link text-dark"
       [routerLink]="/authentication/register">Register</a>
  </li>
  <li class="nav-item">
    <a class="nav-link text-dark"
       [routerLink]="/authentication/login">Login</a>
  </li>
</ul>
```

We can immediately see how the presentation layer is determined by two `ngIf` structural directives in the following way:

- If the user is *authenticated*, it will show the `Hello <username>` welcome message and the `Logout` link.
- If the user is *not authenticated*, it will show the `Register` and `Login` links.

That's a widely used approach to implement a login/logout menu; as we can see, all the links are pointing to the IdentityServer endpoint URIs that will transparently handle each task.

LoginComponent

LoginComponent performs various tasks required to properly handle the user's login process; consequently, any Angular Component and/or .NET Core Controller that wants to restrict its access to authenticated users should perform an HTTP redirect to this Component's route; as we can see by looking at the source code of the Component's defining method, if the incoming request provides a `returnUrl` query parameter, the Component will redirect the user back to it after performing the login:

```
//...

private async login(returnUrl: string): Promise<void> {
  const state: INavigationState = { returnUrl };
  const result = await this.authService.signIn(state);
  this.message.next(undefined);
  switch (result.status) {
    case AuthenticationResultStatus.Redirect:
      break;
    case AuthenticationResultStatus.Success:
      await this.navigateToReturnUrl(returnUrl);
      break;
    case AuthenticationResultStatus.Fail:
      await this.router.navigate(
        ApplicationPaths.LoginFailedPathComponents,
        queryParams: { [QueryParameterNames.Message]: result.message }
      );
      break;
    default:
      throw new Error(`Invalid status result ${result as any}.status.`);
  }
}

// ...
```

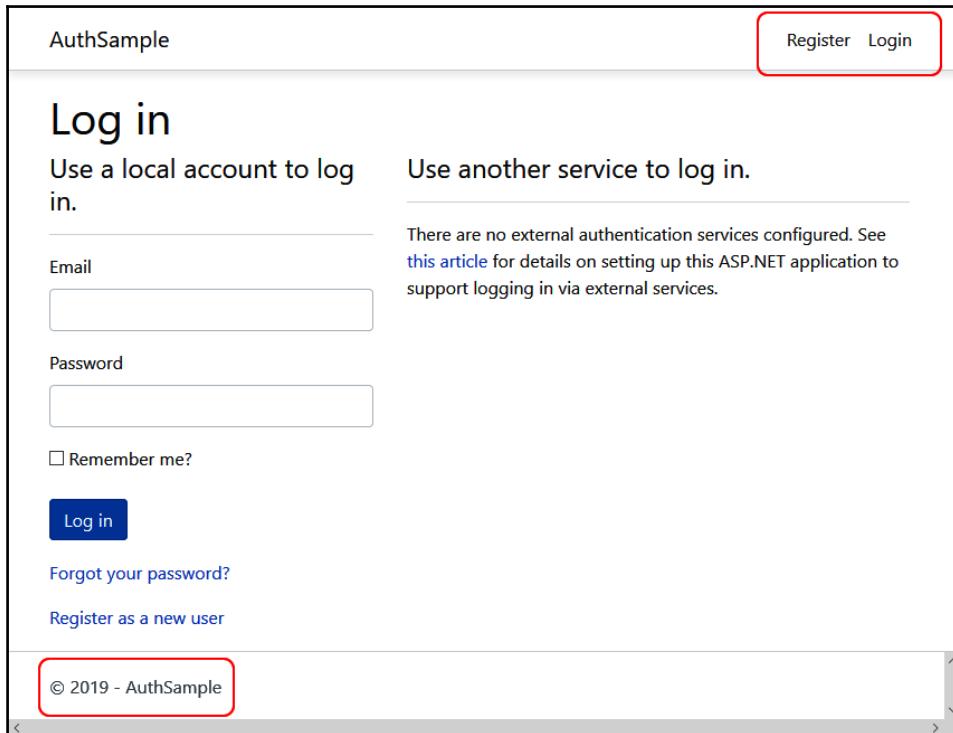
The LoginComponent TypeScript source code is rather long, but it's very understandable as long as we keep in mind its main job: passing the user's authentication information to the .NET Core IdentityServer using the default endpoint URIs and return the results back to the client; it basically acts like a *front-end* to *back-end* authentication proxy.

If we take a look at its template file, this role will become even more evident:

```
<p>{{ message | async }}</p>
```

That's it. As a matter of fact, this Component does have very tiny template, simply because it will mostly redirect the user to some *back-end* pages that loosely mimic the visual style of our Angular Components (!).

To quickly confirm that, hit *F5* to run the `AuthSample` project in debug mode and visit the **Log in** view, then look carefully at the UI elements highlighted in the following screenshot:



The two elements that we highlighted using the red squares don't match with the rest of our Angular app's GUI: the top-right menu is missing the **Counter** and the **Fetch data** options, and the footer doesn't even exist; both of them have been generated from the *back-end*, just like the rest of the **Log in** view's HTML content.

As a matter of fact, the Authentication API implementation shipped with the .NET Core and Angular template is designed to work in the following way: both the login and registration forms are handled by the *back-end*, with `LoginComponent` playing a hybrid role—half a request handler, half a UI proxy.



It's worth noting that these built-in *Login* and *Registration* pages provided by the ASP.NET Core *back-end* can be fully customized in their UI and/or behavior to make them compatible with the Angular app's look and feel: see the *Installing the ASP.NET Core Identity UI package* and *Customizing the default Identity UI* sections within this chapter for further details on how to do this.

This technique might seem a *hack*—and it actually is, at least to a certain extent, but it's a very smart one, since it *transparently* (well, not so much) works around a lot of the security, performance, and compatibility issues of most login mechanisms featuring a *pure front-end* implementation, while saving developers a lot of time.



In one of my previous books (*ASP.NET Core 2 and Angular 5*), I chose to purposely avoid the `.NET Core IdentityServer` and manually implement the registration and login workflows from the *front-end*: however, the .NET Core mixed approach has greatly improved in the last 2 years and now offers a great alternative to the standard, Angular-based implementation, thanks to a solid and highly configurable interface.

Those who prefer to use the former method can take a look at the GitHub repository of the *ASP.NET Core 2 and Angular 5* book, (Chapter_08 onward), which is still fully compatible with the latest Angular versions:

<https://github.com/PacktPublishing/ASP.NET-Core-2-and-Angular-5/>

If we don't like the *redirect to back-end* approach, the *built-in* authorization API features an alternative implementation that replaces the full-page HTTP redirects with popups.

To activate it, open the `/ClientApp/src/api-authorization/authorize.service.ts` file and change the `popupDisabled` internal variable value from `true` to `false`, as shown in the following code:

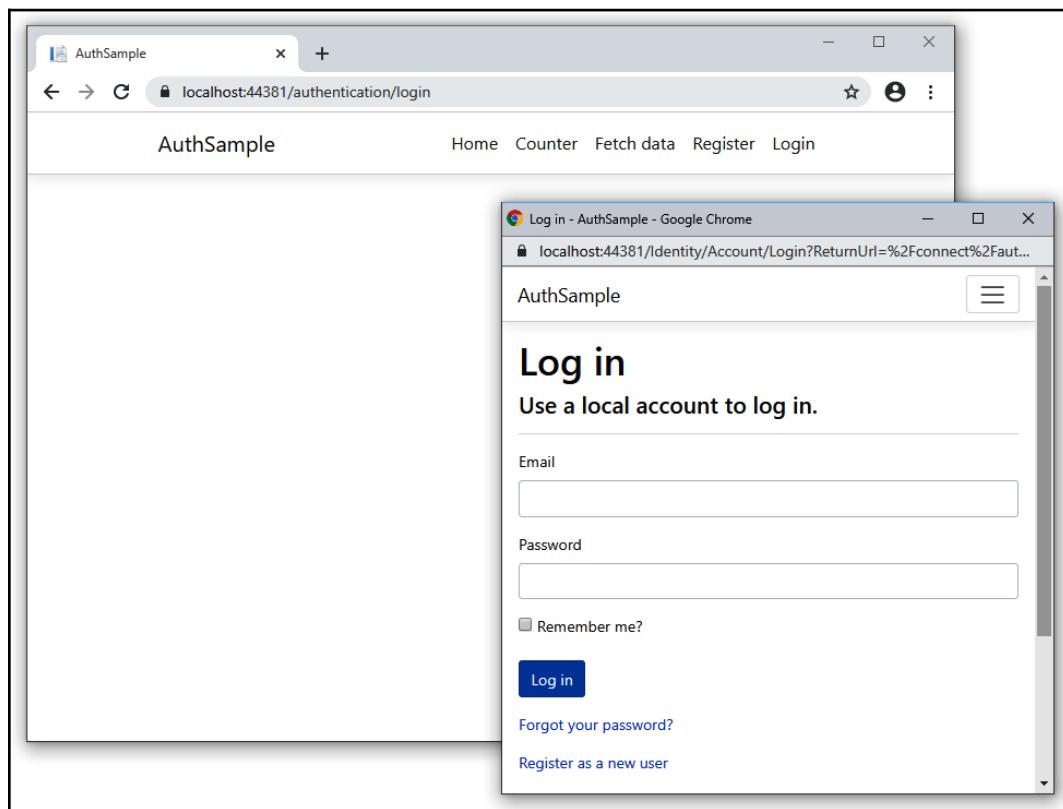
```
// ...  
  
export class AuthorizeService {  
    // By default pop ups are disabled because they don't work properly  
    // on Edge. If you want to enable pop up authentication simply set  
    // this flag to false.  
  
    private popUpDisabled = false;
```

```
private userManager: UserManager;
private userSubject: BehaviorSubject<IUser | null> = new
BehaviorSubject(null);

// ...
```

If we prefer to implement the auth feature through popups, we can change the preceding Boolean value to `false` and then test the outcome by launching our `AuthSample` project in debug mode.

Here's what the popup login page will look like:



However, as the inline comments say, popups don't work properly on Microsoft Edge (and even the other browsers don't like them); for this reason, the *back-end-generated* pages are arguably a better choice—especially if we can customize them, as we'll see later on.

LogoutComponent

LogoutComponent is the counterpart of LoginComponent, as it handles the task of disconnecting our users and bringing them back to the home page.

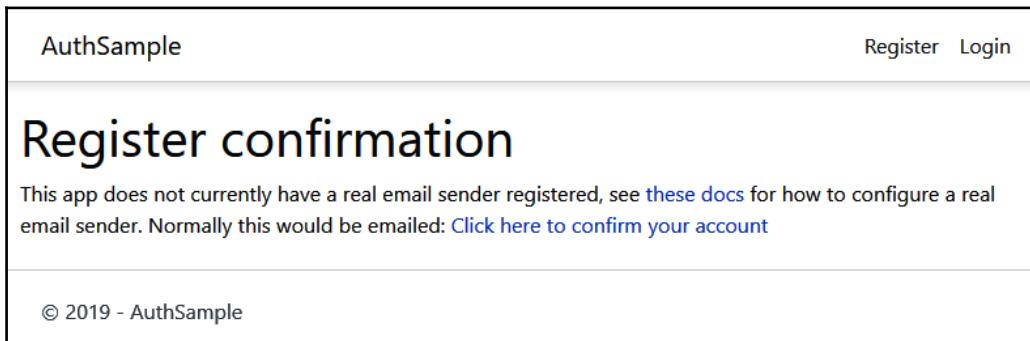
There's not much to say there, because it works in a similar way to its sibling, redirecting the user to the .NET Core Identity system endpoint URIs and then bringing it back to the Angular app using the returnUrl parameter. The main difference is that there are no *back-end* pages this time, since the logout workflow doesn't require a user interface.

Testing registration and login

Now we're ready to test the registration and login workflow of the AuthSample Angular app; let's start with the registration phase, since we don't have any registered user here yet.

Hit *F5* to run the project in debug mode, then navigate to the **Register** view: insert a valid email, a password that matches the required password strength settings, and hit the **Register** button.

As soon as we do that, we should see the following message:



Click the confirmation link to create the account, then wait for a full-page reload.

As a matter of fact, all these redirects and reloads performed by this implementation definitely break the SPA pattern that we talked about in Chapter 1, *Getting Ready*.



However, when we compared the pros and cons of the Native Web Application, SPA and Progressive Web Application approaches, we told ourselves that we would have definitely adopted some strategic HTTP round-trips and/or other redirect techniques whenever we could use a microservice to lift off some workload from our app; that's precisely what we are doing right now.

When we're taken back to the **Log in** view, we can finally enter the credentials chosen a moment ago and perform the login.

Once done, we should be welcomed by the following screen:

The screenshot shows a web browser window with the title "AuthSample". The navigation bar includes links for "Home", "Counter", "Fetch data", "Hello user@email.com", and "Logout". The main content area displays the message "Hello, world!" and a welcome message: "Welcome to your new single-page application, built with:". Below this, there is a bulleted list of technologies used: ".ASP.NET Core and C#" for cross-platform server-side code, "Angular and TypeScript" for client-side code, and "Bootstrap" for layout and styling. Further down, another bulleted list provides tips for getting started: "Client-side navigation", "Angular CLI integration", and "Efficient production builds". At the bottom, a note states: "The ClientApp subdirectory is a standard Angular CLI application. If you open a command prompt in that directory, you can run any ng command (e.g., `ng test`), or use `npm` to install extra packages into it."

Here we go; we can see that we've logged in because the UI behavior of `LoginMenuComponent` has changed, meaning that its `isAuthenticated` internal variable now evaluates to `true`.

With this, we're done with our `AuthSample` app: now that we've understood how the *front-end* authorization API shipped with the .NET Core and Angular Visual Studio template actually works, we're going to bring it to our `WorldCities` app.

Implementing the Auth API in the WorldCities app

In this section, we're going to implement the authorization API provided with the `AuthSample` app to our `WorldCities` app. Here's what we're going to do in detail:

- **Import the front-end authorization APIs** from the `AuthSample` app to the `WorldCities` app and integrate them to our existing Angular code.
- **Adjust the existing back-end source code** to properly implement the authentication features.
- **Test the login and registration forms** from the `WorldCities` project.

By the end of the section, we should be able to log in with our existing users, as well as create new users, from the `WorldCities` app.

Importing the front-end Authorization APIs

The first thing we need to do in order to import the *front-end* authorization APIs to our `WorldCities` Angular app is to copy the whole `/ClientApp/src/api-authorization/` folder from the `AuthSample` app. There are no drawbacks in doing this, so we can just do that using the Visual Studio **Solution Explorer** using the copy and paste GUI commands (or *Ctrl + C / Ctrl + V*, if you prefer to use keyboard shortcuts).

Once done, we need to integrate the new *front-end* capabilities with the existing code.

AppModule

The first file we have to modify is the `/ClientApp/src/api-authorization/api-authorization.constants.ts` file, which contains a literal reference to the app name on the first line of its contents:

```
export const ApplicationName = 'AuthSample';  
// ...
```

Change `'AuthSample'` to `'WorldCities'`, leaving the rest of the file as it is.

AppModule

Right after that, we need to update the `/ClientApp/src/app/app.module.ts` file, where we need to add the required references to the authorization API's classes:

```
// ...

import { ApiAuthorizationModule } from 'src/api-authorization/api-
authorization.module';
import { AuthorizeGuard } from 'src/api-
authorization/authorize.guard';
import { AuthorizeInterceptor } from 'src/api-
authorization/authorize.interceptor';

// ...

imports: [
  BrowserModule.withServerTransition({ appId: 'ng-cli-universal' }),
  HttpClientModule,
  FormsModule,
  ApiAuthorizationModule,
  RouterModule.forRoot([
    {
      path: '',
      component: HomeComponent,
      pathMatch: 'full'
    },
    {
      path: 'cities',
      component: CitiesComponent
    },
    {
      path: 'city/:id',
      component: CityEditComponent,
      canActivate: [AuthorizeGuard]
    },
    {
      path: 'city',
      component: CityEditComponent,
      canActivate: [AuthorizeGuard]
    },
    {
      path: 'countries',
      component: CountriesComponent
    },
    {
      path: 'country/:id',
      component: CountryEditComponent,
```

```
        canActivate: [AuthorizeGuard]
    },
{
    path: 'country',
    component: CountryEditComponent,
    canActivate: [AuthorizeGuard]
}
]),
BrowserAnimationsModule,
AngularMaterialModule,
ReactiveFormsModule
],
providers: [
    CityService,
    CountryService,
    { provide: HTTP_INTERCEPTORS, useClass: AuthorizeInterceptor,
      multi: true }
],
bootstrap: [AppComponent]
})
export class AppModule { }
```

As we can see, other than adding the required references, we took the chance to protect our edit Components using `AuthorizeGuard`, so that they will become accessible only to *registered* users.

NavMenuComponent

Now we need to integrate `LoginMenuComponent` to our existing `NavMenuComponent`, just like in the `AuthSample` app.

Open the `/ClientApp/src/app/nav-menu/nav-menu.component.html` template file and add a reference to the menu within its content accordingly:

```
<header>
<nav class="navbar navbar-expand-sm navbar-toggleable-sm
    navbar-light bg-white border-bottom box-shadow mb-3"
>
<div class="container">
    <a class="navbar-brand" [routerLink]="['/']">WorldCities</a>
    <button
        class="navbar-toggler"
        type="button"
        data-toggle="collapse"
        data-target=".navbar-collapse"
        aria-label="Toggle navigation"
```

```
[attr.aria-expanded]="isExpanded"
(click)="toggle() "
>
<span class="navbar-toggler-icon"></span>
</button>
<div
  class="navbar-collapse collapse d-sm-inline-flex
  flex-sm-row-reverse"
  [ngClass]="{ show: isExpanded }"
>
<app-login-menu></app-login-menu>
<ul class="navbar-nav flex-grow">
  <li
    class="nav-item"
    [routerLinkActive]=["link-active"]
    [routerLinkActiveOptions]={ exact: true }"
  >
    <a class="nav-link text-dark"
      [routerLink]=["/'"]>Home</a>
<!-- ...existing code... -->
```

Now we can switch to the *back-end* code.

Adjusting the back-end code

Let's start by importing `OidcConfigurationController`. The `AuthSample` project comes with a dedicated .NET Core API Controller to provide the URI endpoint that will serve the OIDC configuration parameters that the client needs to use.

Copy the `AuthSample` project's `/Controllers/OidcConfigurationController.cs` file to the `WorldCities` project's `/Controllers/` folder, then open the copied file and change its namespace accordingly:

```
// ...
namespace AuthSample.Controllers

// ...
```

Change `AuthSample.Controllers` to `WorldCities.Controllers` and go ahead.

Installing the ASP.NET Core Identity UI package

Remember when we talked about the login and registration pages generated from the *back-end* a short while ago? These are provided by the `Microsoft.AspNetCore.Identity.UI` package, which contains the default **Razor Pages** built-in UI for the .NET Core Identity framework. Since it's not installed by default, we need to manually add it to our `WorldCities` project using NuGet.

From **Solution Explorer**, right-click on the `WorldCities` tree node, then select **Manage NuGet packages**, look for the following package, and install it:

```
Microsoft.AspNetCore.Identity.UI
```

Alternatively, open **Package Manager Console** and install it with the following command:

```
> Install-Package Microsoft.AspNetCore.Identity.UI
```

At the time of writing, this package's latest available version is **3.1.1**; as always, we are free to install a newer version, as long as we know how to adapt our code accordingly to fix potential compatibility issues.

Customizing the default Identity UI

It's worth noting that we can replace the default *Login* and *Registration* views provided by **Microsoft.AspNetCore.Identity.UI** package via the *identity scaffolder* tool, which can be used to selectively add the source code contained in the **Identity Razor Class Library (RCL)** to our project; once generated, that source code can be modified and/or customized to change its appearance (and/or behavior) to better suit our needs.



Generated (and modified) code will automatically take precedence over the default code in the Identity RCL.

To gain full control of the UI and not use the default RCL, see the following guides:

- <https://docs.microsoft.com/en-us/aspnet/core/security/authentication/scaffold-identity>
- <https://docs.microsoft.com/en-us/aspnet/core/security/authentication/scaffold-identity#full>
- <https://docs.microsoft.com/en-us/aspnet/core/razor-pages/ui-class>

For the sake of simplicity, we won't be using this technique to alter the UI and/or behavior of the built-in *Login* and *Registration* pages: we'll just keep them as they are.

Mapping Razor Pages to EndpointMiddleware

Now that we're (internally) using some Razor Pages, we need to map them to the *back-end* routing system, otherwise, our .NET Core app won't forward the HTTP requests to them.

To do that, open the `WorldCities` project's `Startup.cs` file and add the following highlighted line in the `EndpointMiddleware` configuration block:

```
// ...  
  
app.UseEndpoints(endpoints =>  
{  
    endpoints.MapControllerRoute(  
        name: "default",  
        pattern: "{controller}/{action=Index}/{id?}");  
  
    endpoints.MapRazorPages();  
});  
  
// ...
```

That's it; now we're finally ready to log in.

Securing the back-end action methods

Before testing our authentication and authorization implementation, we should spend two more minutes to protect our *back-end* routes just like we did with the *front-end* ones. As we already know, we can do that using `AuthorizeAttribute`, which can restrict access to Controllers and/or action methods to the registered users only.

To effectively shield our .NET Core Web API against unauthorized access attempts, it can be wise to use it on the `PUT`, `POST`, and `DELETE` methods of all our Controllers in the following way:

1. Open the `/Controllers/CitiesController.cs` file and add the `[Authorize]` attribute to the `PutCity`, `PostCity`, and `DeleteCity` methods:

```
using Microsoft.AspNetCore.Authorization;

// ...

[Authorize]
[HttpPut("{id}")]
public async Task<IActionResult> PutCity(int id, City city)

// ...

[Authorize]
[HttpPost]
public async Task<ActionResult<City>> PostCity(City city)

[Authorize]
[HttpDelete("{id}")]
public async Task<ActionResult<City>> DeleteCity(int id)

// ...
```

2. Open the `/Controllers/CountriesController.cs` file and add the `[Authorize]` attribute to the `PutCountry`, `PostCountry`, and `DeleteCountry` methods:

```
using Microsoft.AspNetCore.Authorization;

// ...

[Authorize]
[HttpPut("{id}")]
public async Task<IActionResult> PutCountry(int id, Country
country)

// ...

[Authorize]
[HttpPost]
public async Task<ActionResult<Country>> PostCountry(Country
country)
```

```
// ...  
  
[Authorize]  
[HttpDelete("{id}")]  
public async Task<ActionResult<Country>> DeleteCountry(int id)  
  
// ...
```



Don't forget to add a reference to the using `Microsoft.AspNetCore.Authorization` namespace at the top of both files.

Now all these action methods are protected against unauthorized access, as they will accept only requests coming from registered and logged-in users; those who don't have it will receive a 401 – Unauthorized HTTP error response.

Testing login and registration

In this chapter, we're going to repeat the login and registration phases we already did for the `AuthSample` app a short while ago. However, this time, we'll do the login first, since we already have some existing users thanks to the `CreateDefaultUsers()` method of `SeedController`.

Launch the `WorldCities` app in debug mode by hitting *F5*. Once done, navigate to the login screen and insert the email and password of one of our existing users.



If we didn't change them at the time, the sample values that we used in `SeedController` should be the following: email: `user@email.com` and password: `MySecr3t$`.

If we did everything correctly, we should see a screen like the one shown in the following screenshot:

The screenshot shows a web browser window with the title "WorldCities". In the top right corner, there is a navigation bar with links for "Home", "Cities", "Countries", "Hello user@email.com", and "Logout". The main content area features a large heading "Hello, world!". Below it, a paragraph reads "Welcome to your new single-page application, built with:" followed by a bulleted list: "• ASP.NET Core and C# for cross-platform server-side code", "• Angular and TypeScript for client-side code", and "• Bootstrap for layout and styling". Further down, another section titled "To help you get started, we've also set up:" contains a bulleted list: "• Client-side navigation. For example, click *Counter* then *Back* to return here.", "• Angular CLI integration. In development mode, there's no need to run `ng serve`. It runs in the background automatically, so your client-side resources are dynamically built on demand and the page refreshes when you modify any file.", and "• Efficient production builds. In production mode, development-time features are disabled, and your `dotnet publish` configuration automatically invokes `ng build` to produce minified, ahead-of-time compiled JavaScript files.". At the bottom of the content area, a note states: "The `ClientApp` subdirectory is a standard Angular CLI application. If you open a command prompt in that directory, you can run any `ng` command (e.g., `ng test`), or use `npm` to install extra packages into it."

Right after that, we can try the registration workflow to register a new user, such as `test@email.com`; if our login path worked so well, there's no reason why this action shouldn't succeed as well.

We did it! Now our `WorldCities` app contains fully-featured authorization and authentication APIs.

As a matter of fact, we're still missing some key features, such as the following:

- The **email verification** step right after the registration phase, which would require an email sender
- The **password change** and **password recovery** features, also requiring the aforementioned email sender
- Some **external authentication services** such as Facebook, Twitter, and so on (that is, **social login**)

Now that we have implemented the ASP.NET Core Identity services, implementing an email sender to take care of the preceding features would be a rather easy task, especially if we use an external service such as **SendGrid**.



For additional information, check out the following guide:

<https://docs.microsoft.com/en-us/aspnet/core/security/authentication/accconfirm>

However, that's definitely more than enough for our sample app; we're ready to move on to the next topic.

Summary

At the start of this chapter, we introduced the concepts of authentication and authorization, acknowledging the fact that most applications, including ours, do require a mechanism to properly handle authenticated and non-authenticated clients as well as authorized and unauthorized requests.

We took some time to properly understand the similarities and differences between authentication and authorization as well as the pros and cons of handling these tasks using our own internal provider or delegating them to third-party providers such as Google, Facebook, and Twitter. We also found out that, luckily enough, the ASP.NET Core Identity services, together with the `IdentityServer` API support, provide a convenient set of features that allow us to achieve the best of both worlds.

To be able to use it, we added the required packages to our project and did what was needed to properly configure them, such as performing some updates in our `Startup` and `ApplicationDbContext` classes and creating a new `ApplicationUser` entity; right after implementing all the required changes, we added a new EF Core migration to update our database accordingly.

We briefly enumerated the various web-based authentication methods available nowadays: sessions, tokens, signatures, and two-factor strategies of various sorts. After careful consideration, we chose to stick with the token-based approach using JWT that `IdentityServer` provides by default for the SPA clients, it being a solid and well-known standard for any *front-end* framework.

Since the default .NET Core and Angular project template provided by Visual Studio features a built-in ASP.NET Core Identity system and IdentityServer support for Angular, we created a brand new project—which we called `AuthSample`—to test it out. We spent some time reviewing its main features, such as Route Guards, HTTP interceptors, HTTP round-trips to the *back-end*, and so on; while doing that, we took the time to implement the required *front-end* and *back-end* authorization rules to protect some of our application views, routes, and APIs from unauthorized access. Eventually, we imported those APIs into our `WorldCities` Angular app, changing our existing *front-end* and *back-end* code accordingly.

We're ready to switch to the next topic, **progressive web apps**, which will keep us busy throughout the next chapter.

Suggested topics

Authentication, Authorization, HTTP protocol, Secure Socket Layer, Session State Management, Indirection, Single Sign-On, Azure AD Authentication Library (ADAL), ASP.NET Core Identity, IdentityServer, OpenID, Open ID Connect (OIDC), OAuth, OAuth2, Two-Factor Authentication (2FA), SMS 2FA, Time-based One-time Password Algorithm (TOTP), TOTP 2FA, IdentityUser, Stateless, Cross-Site Scripting (XSS), Cross-Site Request Forgery (CSRF), Angular HttpClient, Route Guard, Http Interceptor, LocalStorage, Web Storage API, Server-side prerendering, Angular Universal, Browser Types, Generic Types, JWT Tokens, Claims, AuthorizeAttribute.

References

- *Introduction to Identity on ASP.NET Core*: <https://docs.microsoft.com/en-us/aspnet/core/security/authentication/identity>
- *Authentication and authorization for SPAs*: <https://docs.microsoft.com/en-us/aspnet/core/security/authentication/identity-api-authorization>
- *IdentityServer official documentation*: <http://docs.identityserver.io/en/latest/>
RoleManager<TRole> Class: <https://docs.microsoft.com/en-us/dotnet/api/microsoft.aspnetcore.identity.rolemanager-1>
- *Identity model customization in ASP.NET Core*: <https://docs.microsoft.com/en-US/aspnet/core/security/authentication/customize-identity-model>

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- *Async and Await:* <https://blog.stephencleary.com/2012/02/async-and-await.html>
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- *Don't Block on Async Code:* <http://blog.stephencleary.com/2012/07/dont-block-on-async-code.html>
- *Async/Await – Best Practices in Asynchronous Programming:* <https://msdn.microsoft.com/en-us/magazine/jj991977.aspx>
- *ASP.NET Core SynchronizationContext:* <https://blog.stephencleary.com/2017/03/aspnetcore-synchronization-context.html>
- *Asynchronous programming with async and await:* <https://docs.microsoft.com/en-us/dotnet/csharp/programming-guide/concepts/async/index>
- *EF Core Migrations:* <https://docs.microsoft.com/en-us/ef/core/managing-schemas/migrations/>
- *SQL Server: Create a Full Database Backup:* <https://docs.microsoft.com/en-us/sql/relational-databases/backup-restore/create-a-full-database-backup-sql-server>
- *Two-factor authentication with SMS in ASP.NET Core:* <https://docs.microsoft.com/en-us/aspnet/core/security/authentication/2fa>
- *Enable QR Code generation for TOTP authenticator apps in ASP.NET Core:* <https://docs.microsoft.com/en-us/aspnet/core/security/authentication/identity-enable-qrcodes>
- *Angular: Router Guards:* <https://angular.io/guide/router#guards>
- *Routing in ASP.NET Core:* <https://docs.microsoft.com/en-us/aspnet/core/fundamentals/routing>
- *Introduction to authorization in ASP.NET Core:* <https://docs.microsoft.com/en-us/aspnet/core/security/authorization/introduction>
- *Simple authorization in ASP.NET Core:* <https://docs.microsoft.com/en-us/aspnet/core/security/authorization/simple>
- *Authorize with a specific scheme in ASP.NET Core:* <https://docs.microsoft.com/en-us/aspnet/core/security/authorization/limitingidentitybyscheme>
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- *ASP.NET Core Identity: Create full identity UI source:* <https://docs.microsoft.com/en-us/aspnet/core/security/authentication/scaffold-identity#full>

- *Create reusable UI using the Razor class library project in ASP.NET Core:* <https://docs.microsoft.com/en-us/aspnet/core/razor-pages/ui-class>
- *Angular: HttpInterceptor:* <https://angular.io/api/common/http/HttpInterceptor>
- *Role-based Authorization in ASP.NET Core:* <https://docs.microsoft.com/en-us/aspnet/core/security/authorization/roles>
- *Account confirmation and password recovery in ASP.NET Core:* <https://docs.microsoft.com/en-us/aspnet/core/security/authentication/accountconfirm>

11

Progressive Web Apps

In this chapter, we'll focus on a topic that we just loosely mentioned back in [Chapter 1, Getting Ready](#), when we first talked about the different development patterns for web applications available nowadays: **Progressive Web Apps (PWAs)**.

As a matter of fact, both our `HealthCheck` and `WorldCities` apps currently stick to the **Single-Page Application (SPA)** model, at least for the most part: in the following sections, we'll see how we can turn them into PWAs by implementing several well-established capabilities required by such a development approach.

As we learned in [Chapter 1, Getting Ready](#), a PWA is a web application that uses a modern web browser's capabilities to deliver an app-like experience to users. To achieve this, the PWA needs to meet some technical requirements, including (yet not limited to) a *Web App Manifest file* and a service worker to allow them to work in *offline mode* and behave just like mobile apps.

More precisely, here's what we're going to do:

- **Identify the technical requirements** required by a PWA by following their known specifications.
- **Implement those requirements** on our existing `HealthCheck` and `WorldCities` apps to turn them into PWAs. More precisely, we'll do that using two different approaches: manually performing all of the required steps for the `HealthCheck` app, and then using the *PWA automatic setup* offered by the Angular CLI for the `WorldCities` app.
- **Test the new PWA capabilities** of both of these apps.

By the end of this chapter, we'll have learned how to successfully convert an existing SPA into a PWA.

Technical requirements

In this chapter, we're going to need all previous technical requirements listed in Chapters 1-10, with the following additional packages:

- `@angular/service-worker` (npm package)
- `ng-connection-service` (npm package)
- `Microsoft.AspNetCore.Cors` (NuGet package)
- `WebEssentials.AspNetCore.ServiceWorker` (NuGet package, *optional*)
- `http-server` (npm package, *optional*)

As always, it's advisable to avoid installing them straight away: we're going to bring them in during this chapter to better contextualize their purpose within our project.

The code files for this chapter can be found at: https://github.com/PacktPublishing/ASP.NET-Core-3-and-Angular-9-Third-Edition/tree/master/Chapter_11/

PWA – distinctive features

Let's start by summarizing the main distinctive characteristics of a PWA:

- **Progressive:** A PWA should work for every user, regardless of the platform and/or browser used.
- **Responsive:** They must adapt well to any form factor: desktop, mobile, tablet, and so on.
- **Connectivity independent:** They must be able to work offline—at least to some extent, such as informing the user that some features might not work in *offline mode*—or on low-quality networks.
- **App-like:** They need to provide the same navigation and interaction mechanics of mobile apps. This includes tap support, gesture-based scrolling, and so on.
- **Safe:** They must provide HTTPS support for better security, such as preventing snooping and ensuring that their content has not been tampered with.
- **Discoverable:** They have to be identifiable as *web applications* thanks to a W3C manifest file and a service worker registration scope so that the search engines will be able to find, identify, and categorize them.

- **Re-engageable:** They should make re-engagement easy through features such as *push notifications*.
- **Installable:** They should allow users to install and keep them on their desktop and/or mobile home screen, just like any standard mobile app, yet without the hassle of having to download and install them from an app store.
- **Linkable:** They should be easily shared through a URL, without requiring complex installation.

The preceding characteristics can be inferred from the following articles written by the Google developers and engineers who spent their efforts to introduce the PWA concept and define its core specs:



<https://developers.google.com/web/progressive-web-apps>
<https://developers.google.com/web/fundamentals>
<https://infrequently.org/2015/06/progressive-apps-escaping-tabs-without-losing-our-soul/>

These high-level requirements can be translated into a specific technical task that we have to implement. The best way to do that is starting with the technical baseline criteria described by Alex Russell, the Google Chrome engineer that coined the term PWA together with the designer Frances Berriman back in 2015:

- **Originate from a secure origin:** In other words, there's full HTTPS support with no mixed content (*green padlock* display).
- **Load while offline**, even if it's just an *offline* information page: This clearly implies that we need to implement a service worker.
- **Reference a Web App Manifest** with at least the four key properties: `name`, `short_name`, `start_url`, and `display` (with either a `standalone` or `fullscreen` value).
- **A 144 × 144 icon** in PNG format: Other sizes are supported, but the 144 × 144 one is the minimum requirement.
- **Use vector graphics**, as they can scale indefinitely and require smaller file sizes.

These technical requirements can be translated into a specific technical task that we have to implement. In the following sections, we're going to implement them all.

Secure origin

Implementing the **secure origin** feature basically means serving our app through an HTTPS certificate. Such a requirement is rather easy to fulfill nowadays: TLS certificates are quite cheap thanks to the many resellers available. A Positive SSL issued by Comodo Inc can be purchased online for \$10/year or so and is immediately available for download.

If we don't want to spend money, there's also a free available alternative provided by **Let's Encrypt**: a free, automated, and Open Certificate Authority that can be used to obtain a TLS certificate without costs. However, the method they use to release the certificate requires shell access (also known as SSH access) to the deployment web host.



For additional information about **Let's Encrypt** and how to obtain an HTTPS certificate for free, check out the official site:

<https://letsencrypt.org/>

For the sake of simplicity, we'll not cover the part of the HTTPS certificate release and installation: we'll take for granted that the reader will be able to properly install it, thanks to the many how-to guides available from the various resellers' website (including **Let's Encrypt**).

Offline loading and Web App Manifest

Connection independency is one of the most important capabilities of PWAs: to properly implement it, we need to introduce—and implement—a concept that we've just barely mentioned until now: service workers. What are they, and how can they help our app to work while offline?

The best way to figure out what a service worker is would be to think of it as a *script that runs inside the web browser* and handles a specific task for the application that registered it: such tasks can include *caching support* and *push notifications*.

When properly implemented and registered, service workers will enhance the UX provided by standard websites by delivering a user experience similar to what can be achieved by native mobile apps; technically, their role is to intercept any ongoing HTTP request made by the user and—whenever it's directed to the web application they are registered for—check for the web application's availability and act accordingly. To put it in other words, we could say that they act as an HTTP proxy with fallback capabilities when the application is unable to handle the request.

Such a *fallback* can be configured by the developer to behave in many ways, such as the following:

- **Caching service** (also known as *offline mode*): The service worker will deliver a cached response by querying an internal (local) cache previously built from the app (when it was online).
- **Offline warning:** Whenever no cached content is available (or if we didn't implement a caching mechanism), the service worker can serve an *offline status* informative text, warning the user that the app is unable to work.



Those who are familiar with forward cache services might prefer to imagine service workers as reverse proxies (or CDN edges) installed in the end user's web browser instead.

The *caching service* feature is great for web applications that provide static content, such as HTML5-based gaming apps and Angular apps that don't require any *back-end* interaction. Unfortunately, it's not ideal for our two apps: both `HealthCheck` and `WorldCities` strongly rely upon the *back-end* web API provided by ASP.NET Core. Conversely, these apps can definitely benefit from an *offline mode*, so that their users will be informed that an internet connection is required—instead of getting a *Connection Error*, a *404 - Not Found* message, or any other message.

Service workers versus `HttpInterceptors`

If we remember the various Angular features that we introduced in Chapter 10, *Authentication and Authorization*, we can see how the aforementioned behavior reminds us of the role performed by `HttpInterceptors`.

However, since *interceptors* are part of the Angular app script bundle, they always cease to work whenever the user closes the browser's tab that contains the web app. Conversely, service workers need to be preserved after the user closes the tab so that they can intercept the browser requests *before* connecting to the app.

Enough with the theory: let's now see how we can implement an *offline mode*, *Web App Manifest*, and *PNG icons* to our existing apps.

Introducing @angular/service-worker

Starting with version 5.0.0, Angular provides a fully-featured service worker implementation that can be easily integrated into any app without needing to code against low-level APIs; such an implementation is handled by the `@angular/service-worker` npm package and relies upon a manifest file that is loaded from the server that describes the resources to cache and will be used as an index by the service worker, which behaves in the following way:

- **When the app is online**, each indexed resource will be checked to detect changes; if the source has changed, the service worker will update or rebuild the cache.
- **When the app is offline**, the cached version will be served instead.

The aforementioned manifest file is generated from a CLI-generated configuration file called `ngsw-config.json`, which we'll have to create and set up accordingly.



It's worth mentioning that web browsers will always ignore service workers if the website that tries to register them is served over an unsecured (non-HTTPS) connection. The reason for that is quite simple to understand: since service workers' defining role is to proxy their source web application and potentially serve alternative content, malicious parties could be interested in tampering them; therefore, allowing their registration to secure websites only will provide an additional security layer to the whole mechanism.

The .NET Core PWA middleware alternative

It's worth noting that `@angular/service-worker` isn't the only available approach we could adopt to implement the service worker and *Web App Manifest* file's PWA capabilities. As a matter of fact, .NET Core provides its own way to deal with these requirements with a set of middleware that can be easily installed and integrated into our project's HTTP stack.

Among the various solutions provided, the most interesting one—at least in our opinion—is the `WebEssentials.AspNetCore.ServiceWorker` NuGet package developed by Mads Kristensen, a prolific author of Visual Studio extensions and .NET Core libraries; the package provides fully-featured ASP.NET Core PWA middleware that comes with full *Web App Manifest* support and pre-built service workers and is a valid back-end and *front-end* alternative to the pure *front-end* solution provided by the `@angular/service-worker` NPM package.

To get additional information about the `WebEssentials.AspNetCore.ServiceWorker` NuGet package, check out the following URLs:



<https://github.com/madskristensen/WebEssentials.AspNetCore.ServiceWorker>

<https://www.nuget.org/packages/WebEssentials.AspNetCore.ServiceWorker/>

All in all, it seems that we do have two convenient ways to fulfill our PWA-related tasks: which one should we choose?

Ideally, we would've loved to implement both of them: however, for reasons of space, we'll just use the `@angular/service-worker` npm package, leaving the .NET Core PWA middleware alternative for another time.

In the following section, we'll learn how to implement the `@angular/service-worker` package in our existing Angular apps following two very different—yet equally rewarding—approaches.

Implementing the PWA requirements

To perform the required implementation steps that we've focused on in the previous section, we have two choices:

- **Perform a manual update** of our app's source code.
- **Use the automatic installation feature** provided by the Angular CLI.

To learn the most from that experience, both of these paths should be taken at least once. Luckily enough, we have two existing Angular apps to experiment with. Therefore, we'll take the manual route for our `HealthCheck` app first, then we'll experience the automatic CLI setup for the `WorldCities` app.

Manual installation

In this section, we'll see how to manually implement the required technical steps we're still missing to make our `HealthCheck` app fully compliant with the PWA requirements.

Let's briefly recap them:

- Add the `@angular/service-worker` npm package (`package.json`)
- Enable the service worker support in the Angular CLI configuration file (`angular.json`)
- Import and register `ServiceWorkerModule` in the `AppModule` class (`app.module.ts`)
- Update the main app's HTML template file (`index.html`)
- Add a suitable icon file (`icon.ico`)
- Add the manifest file (`manifest.webmanifest`)
- Add the service worker configuration file (`ngsw-config.json`)

For each step, we've mentioned the relevant file that we'll have to update between parentheses.

Adding the `@angular/service-worker` npm package

The first thing to do is to add the `@angular/service-worker` npm package to our `package.json` file. As we can easily guess, such a package contains Angular's service worker implementation that we were talking about a moment ago.

Open the `/ClientApp/package.json` file and add the following package reference to the "dependencies" section, right below the `@angular/router` package:

```
// ...  
  
"@angular/router": "9.0.0",  
"@angular/service-worker": "9.0.0",  
"@nguniversal/module-map-ngfactory-loader": "9.0.0-next.9",  
  
// ...
```

As soon as we save the file, the npm package should be downloaded and installed automatically by Visual Studio.

Updating the angular.json file

Open the `/ClientApp/angular.json` configuration file and add the `"serviceWorker"` and `"ngswConfigPath"` keys to the end of the `projects | health_check | architect | build | options | configurations | production` section:

```
// ...  
  
  "vendorChunk": false,  
  "buildOptimizer": true,  
  "serviceWorker  "ngswConfigPath": "ngsw-config.json"  
  
// ...
```



As always, whenever we have issues while applying these changes, we can check out the source code available from this book's GitHub repository.

The `"serviceWorker"` flag that we've just set up will cause the production build to include a couple of extra files in the output folder:

- `ngsw-worker.js`: The main service worker file
- `ngsw.json`: The Angular service worker's runtime configuration

Both of these files are required for our service worker to perform its job.

Importing ServiceWorkerModule

`ServiceWorkerModule` provided by the `@angular/service-worker` npm package library will take care of registering the service worker as well as providing a few services we can use to interact with it.

To install it on our `HealthCheck` app, open the `/ClientApp/src/app/app.module.ts` file and add the following lines (the new lines are highlighted):

```
import { BrowserModule } from '@angular/platform-browser';  
import { NgModule } from '@angular/core';  
import { FormsModule } from '@angular/forms';  
import { HttpClientModule, HTTP_INTERCEPTORS } from  
  '@angular/common/http';  
import { RouterModule } from '@angular/router';
```

```
import { ServiceWorkerModule } from '@angular/service-worker';
import { environment } from '../environments/environment';

// ...

imports: [
  BrowserModule.withServerTransition({ appId: 'ng-cli-universal' }),
  HttpClientModule,
  FormsModule,
  RouterModule.forRoot([
    { path: '', component: HomeComponent, pathMatch: 'full' },
    { path: 'health-check', component: HealthCheckComponent }
  ]),
  ServiceWorkerModule.register(
    'ngsw-worker.js',
    { registrationStrategy: 'registerImmediately' })
],
// ...
```

As we've said early on, the `ngsw-worker.js` file referenced in the preceding code is the main service worker file, which will be auto-generated by the Angular CLI when building the app: the `registrationStrategy` property will ensure that it will be registered as soon as the application starts.



For additional information regarding the service worker registration options and the various `registrationStrategy` available settings, read the following URL:

<https://angular.io/api/service-worker/SwRegistrationOptions>

Updating the index.html file

The `/ClientApp/index.html` file is the main entry point for our Angular app(s). It contains the `<app-root>` element, which will be replaced by our app's GUI at the end of the bootstrap phase, as well as some resource references and meta tags that describe our application's behavior and configuration settings.

Open that file and add the following code at the end of the `<head>` element (the updated lines are highlighted):

```
<!DOCTYPE html>
<html lang="en">
<head>
  <meta charset="utf-8" />
```

```
<title>HealthCheck</title>
<base href="/" />

<meta name="viewport" content="width=device-width,
  initial-scale=1" />
<link rel="icon" type="image/x-icon" href="favicon.ico" />

<!-- PWA required files -->
<link
  href="https://fonts.googleapis.com/css?family=Roboto:300,400,
  500&display=swap" rel="stylesheet">
<link
  href="https://fonts.googleapis.com/icon?family=Material+Icons"
  rel="stylesheet">
<link rel="manifest" href="manifest.webmanifest">
<meta name="theme-color" content="#1976d2">

</head>
<body>
  <app-root>Loading...</app-root>
</body>
</html>
```

The highlighted lines configure the app's font, theme-color and—most importantly—the link to the manifest.webmanifest file, which—as its name clearly implies—is the app's *manifest* file, one of the key requirements for any PWA.

That's great to hear, except it's doesn't exist in our app yet: let's fix this gap now.

Adding the Web App Manifest file

Instead of manually creating a *Web App Manifest* file from scratch, we can generate it automatically using the **Firebase Web App Manifest Generator** at <https://app-manifest.firebaseio.com>.

This handy tool will also generate all of the required PNG icon files for us, hence saving us a lot of time. However, we'll require a 512 x 512 image source. If we don't have one, we can easily create one using the *DummyImage* website, another useful free tool that can be used to generate placeholder images of any size, which is available at <https://dummyimage.com/>.

Here's a generated PNG file that we can use to feed the preceding Firebase *Web App Manifest Generator* tool:



As we can easily guess, **HC** stands for **HealthCheck**; we won't likely win a graphic contest with this image, but it will work just fine for our current task.



The preceding PNG file can be downloaded from <https://dummyimage.com/512x512/361f47/fff.png&text=HC>.

The reader is free to either use it, create another file using that same tool, or provide another image.

Once done, go back to the Web App Manifest Generator online tool and configure it using the following parameters:

- **App Name:** HealthCheck
- **Short Name:** HealthCheck
- **Theme Color:** #2196f3
- **Background Color:** #2196f3
- **Display Mode:** Standalone
- **Orientation:** Any
- **Application Scope:** /
- **Start URL:** /

Then, click the **ICON** button and select the HC image that we generated a moment ago, as shown in the following screenshot:

The screenshot shows the 'Web App Manifest Generator' tool interface. On the left, there are input fields for app metadata: App Name ('HealthCheck'), Short Name ('HealthCheck'), Theme Color ('#2196f3'), Background Color ('#2196f3'), Display Mode ('Standalone'), Orientation ('Any'), Application Scope ('/'), and Start URL ('/'). On the right, the generated manifest.json code is displayed:

```
{  
  "name": "HealthCheck",  
  "short_name": "HealthCheck",  
  "theme_color": "#2196f3",  
  "background_color": "#2196f3",  
  "display": "standalone",  
  "scope": "/",  
  "start_url": "/"  
}
```

A 'COPY' button is available above the JSON code. Below it, there's a section for generating icons, with a file named 'fff.png' listed under 'ICON'. A 'GENERATE ZIP' button is at the bottom.

Generate the archive file by clicking to the **GENERATE .ZIP** button, unpack it, and copy the included files in the following way:

- The `manifest.json` file in the `/ClientApp/src/` folder
- The `/icons/` folder, with all of its contents, in the `/ClientApp/src/assets/` folder, so that the actual PNG files will be placed in the `/ClientApp/src/assets/icons/` folder

Once done, we need to perform the following changes to the `manifest.json` file:

- Change all of the icon starting paths from `images/icons/` to `assets/icons/`.
- Rename it from `manifest.json` to `manifest.webmanifest`, since that's the name defined by the Web App Manifest W3C specs.

Those who want to take a look at the *Web App Manifest W3C Working Draft 09 December 2019* can visit the following URL:

<https://www.w3.org/TR/appmanifest/>



As a matter of fact, the `.json` and `.webmanifest` extensions will both work, as long as we remember to set the `application/manifest+json` MIME type; however, since most web servers set the MIME type based upon the file extension, opting for the `.webmanifest` choice will arguably make things easier.

Those who want to know more about this `.json` versus `.webmanifest` extension debate should take a look at this interesting discussion in the Web App Manifest GitHub repository:

<https://github.com/w3c/manifest/issues/689>

Updating the Startup.cs file

If we choose to follow the Web App Manifest W3C specs and use the `.webmanifest` extension, we need to apply a small modification to the .NET Core Startup class to make the Kestrel web server able to serve these files.

In both the `HealthCheck` and `WorldCities` projects, open the `Startup.cs` file and update its `Configure()` method's content as follows (the new/updated lines are highlighted):

```
using Microsoft.AspNetCore.StaticFiles;

// ...

app.UseHttpsRedirection();

// add .webmanifest MIME-type support
FileExtensionContentTypeProvider provider = new
FileExtensionContentTypeProvider();
provider.Mappings[".webmanifest"] = "application/manifest+json";

app.UseStaticFiles(new StaticFileOptions()
{
    ContentTypeProvider = provider,
}

// ...
```

```
if (!env.IsDevelopment())
{
    app.UseSpaStaticFiles(new StaticFileOptions()
    {
        ContentTypeProvider = provider
    });
}

// ...
```

That's it: now all of the files with the `.webmanifest` extension will be properly served as static files with the `application/manifest+json` MIME type.



It's worth noting that we configured either the `app.UseStaticFiles()` or `app.useSpaStaticFiles()` middleware; the first one controls the static files in the `/www/` folder, while the latter handles those located within the `/ClientApp/dist/` app.

Publishing the Web App Manifest file

To have our `/ClientApp/src/manifest.webmanifest` file published together with the rest of our `HealthCheck`'s Angular app files, we need to add it to the `/ClientApp/angular.json` CLI configuration file.

Open that file and replace all of the following entries:

```
"assets": ["src/assets"]
```

Replace them with the following updated value:

```
"assets": [
    "src/assets",
    "src/manifest.webmanifest"
],
```

There should be two "asset" key entries in the `angular.json` file:

- `projects > health_check > architect > build > options`
- `projects > health_check > architect > test > options`

Both of them need to be modified as explained in the preceding.

With this update, the `manifest.webmanifest` file will be published to the output folder whenever we build the Angular app.

Adding the favicon

A *favicon* (also known as favorite icon, shortcut icon, website icon, tab icon, URL icon, or bookmark icon) is a file containing one or more small icons that can be used to identify a specific website; whenever we see a small icon in a browser's address bar, history, and/or tab containing a given website, we're looking at that website's *favicon*.

Favicons can be generated manually, but if we're not graphic designers, we might want to use one of the various *favicon online generators* available online especially considering that most of them are entirely free to use; the only thing that we need is a suitable image, which needs to be provided manually (and uploaded to the service).

Here's a couple of recommended *favicon online generator* available nowadays:



favicon.io (<https://favicon.io/>)

Real Favicon Generator (<https://realfavicongenerator.net/>)

Alternatively, we can download one of the many *loyalty-free* favicon sets available online:

Here are some free websites that offer free favicons to download:



Icons8 (<https://icons8.com/icons/set/favicon>)

FreeFavicon (<https://www.freelfavicon.com/freefavicons/icons/>)

As a matter of fact, the .NET Core and Angular Visual Studio template that we used to create our `HealthCheck` project already provided us with a *favicon*: we can find it in our project's `/www/` root folder.

Honestly speaking, such a *favicon* is quite ugly, as we can see from the following screenshot:



Although not being that great, such a favicon won't prevent our app from becoming a PWA: we can either keep it or change it using one of the aforementioned websites.

Adding the ngsw-config.json file

From **Solution Explorer**, create a new `ngsw-config.json` file in the `HealthCheck` project's `/ClientApp/` folder, and fill its content with the following source code:

```
{
  "$schema": "./node_modules/@angular/service-worker/config/
    schema.json",
  "index": "/index.html",
  "assetGroups": [
    {
      "name": "app",
      "installMode": "prefetch",
      "resources": {
        "files": [
          "/favicon.ico",
          "/index.html",
          "/manifest.webmanifest",
          "/*.css",
          "/*.js"
        ]
      }
    },
    {
      "name": "assets",
      "installMode": "lazy",
      "updateMode": "prefetch",
      "resources": {
        "files": [
          "/assets/**",
          "/*.(eot|svg|cur|jpg|png|webp|gif|otf|ttf|woff|woff2|ani)"
        ]
      }
    }
  ]
}
```

As we can see by looking at the `assetGroup > app` section, the preceding file tells Angular to cache the `favicon.ico` file and the `manifest.webmanifest` files, which we created a short while ago, as well as the main `index.html` file and all of the CSS and JS bundles—in other words, our application's static asset files. Right after that, there is an additional `assetGroup > assets` section, which defines the image files.

The main difference between these two sections is the `installMode` parameter value, which determines how these resources are initially cached:

- **prefetch** tells the service worker to fetch those resources while it's caching the current version of the app; in other words, it will put all of those contents in the cache as soon as they become available, that is, the first time the browser visits the online app. We might call this an *up-front caching strategy*.
- **lazy** tells the service worker to only cache those resources when the browsers explicitly request them for the first time. This could be called an *on-demand caching strategy*.

The preceding settings can be good for generic Angular apps that only rely on the *front-end* (no *back-end* required calls) since *these files basically contain the whole app*; more specifically, an Angular app hosting an HTML5 game—which arguably relies upon a lot of image files—might think about moving some of their image files (or even all of them) from the assets section to the app section, so that the whole application—including the icons, the sprites, and all of the image resources—will be cached upfront and entirely available even when the app is offline.

However, such a caching strategy would not be enough for our `HealthCheck` and `WorldCities` apps: even if we tell our service worker to cache the whole app files, all of our apps' HTTP calls would still fail whenever the browser is offline, without letting the user know anything about it. As a matter of fact, our *back-end* availability requirement forces us to do some additional work for both of our apps.

However, before doing that, let's bring our `WorldCities` app up to speed.

Automatic installation

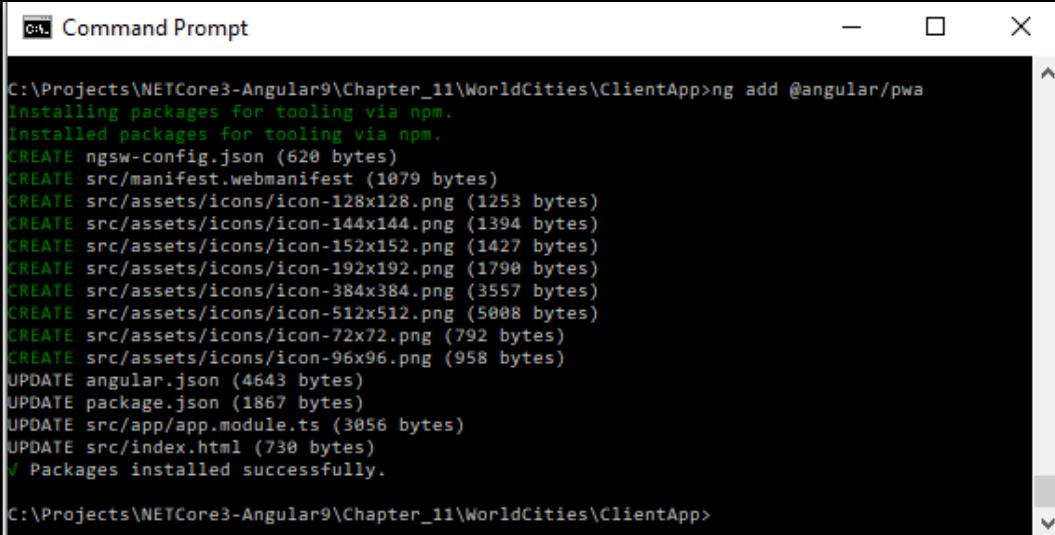
All of the steps that we performed manually in the previous section to enable *Service Worker* support for our `HealthCheck` app can be done automatically by using the following CLI command:

```
> ng add @angular/pwa
```

Let's adopt this alternative technique for our `WorldCities` app.

Open Command Prompt and navigate to the `WorldCities` app's `/ClientApp/` folder, then execute the preceding command: the Angular CLI will automatically configure our app by adding the `@angular/service-worker` package and performing the other required steps.

The most relevant information for the whole operation will be written in the console output, as shown in the following screenshot:



The screenshot shows a Windows Command Prompt window titled "Command Prompt". The command entered was `ng add @angular/pwa`. The output shows the following process:

```
C:\Projects\NETCore3-Angular9\Chapter_11\WorldCities\ClientApp>ng add @angular/pwa
Installing packages for tooling via npm...
Installed packages for tooling via npm.
CREATE ngrsw-config.json (620 bytes)
CREATE src/manifest.webmanifest (1079 bytes)
CREATE src/assets/icons/icon-128x128.png (1253 bytes)
CREATE src/assets/icons/icon-144x144.png (1394 bytes)
CREATE src/assets/icons/icon-152x152.png (1427 bytes)
CREATE src/assets/icons/icon-192x192.png (1790 bytes)
CREATE src/assets/icons/icon-384x384.png (3557 bytes)
CREATE src/assets/icons/icon-512x512.png (5008 bytes)
CREATE src/assets/icons/icon-72x72.png (792 bytes)
CREATE src/assets/icons/icon-96x96.png (958 bytes)
UPDATE angular.json (4643 bytes)
UPDATE package.json (1867 bytes)
UPDATE src/app/app.module.ts (3056 bytes)
UPDATE src/index.html (730 bytes)
✓ Packages installed successfully.

C:\Projects\NETCore3-Angular9\Chapter_11\WorldCities\ClientApp>
```

As we can see from the logs, the automatic process performs the same identical steps that we just applied to the `HealthCheck` app.



At the time of writing, the latest available version of the `@angular/pwa` package is `0.900.0`; however, the `ng add` command will likely install an older version, such as `^0.803.21`. We can either keep that version or manually upgrade it to the latest available one: both of them will work just fine.

The Angular PNG icon set

The PWA automatic setup feature will also provide some PNG icons of various sizes in the `/ClientApp/src/assets/icons/` folder. If we open them with a graphics application, we can see that they all reproduce the Angular logo, as shown in the following:



Whenever we'll want to make our app available to the public, we would likely want to change these icons. However, they are more than enough, at least for the time being: let's keep these files as they are and move on to the last remaining task to transform our SPAs into PWAs.

Handling the offline status

Now that we configured a service worker in both of our apps, we can think of a way to handle the *offline status* message, so that each one of our Components will be able to behave in a different way when the app is offline—such as limiting their features and showing an *offline status* informative message to our users.

To implement these conditional behaviors, we need to find a way to properly determine the browser connectivity status, that is, whether it's online or not; in the following sections, we'll briefly review several different approaches that we can use to do that to make the (arguably) best possible choice.

Option 1 – the `window's isonline/isoffline event`

If we're willing to accept a pure JavaScript way to handle this, such a task can be easily achieved using the `window.ononline` and `window.onoffline` JavaScript events, which are directly accessible from any Angular class.

Here's how we can use them:

```
window.addEventListener("online", function(e) {
  alert("online");
}, false);

window.addEventListener("offline", function(e) {
  alert("offline");
}, false);
```

However, if we're willing to adopt a pure JavaScript approach, there's an even better way to implement it.

Option 2 – the `navigator.onLine` property

Since we don't want to track the network status changes and are just looking for a simple way to determine whether the browser is online or not, we can make things even simpler by just checking the `window.navigator.onLine` property:

```
if (navigator.onLine) {
  alert("online");
}
else {
  alert("offline");
}
```

As we can easily guess from its name, such property returns the online status of the browser. The property returns a Boolean value, with `true` meaning online and `false` meaning offline, and is updated whenever the browser's ability to connect to the network changes.

Thanks to this property, our Angular implementation could be reduced to this:

```
ngOnInit() {
  this.isOnline = navigator.onLine;
}
```

Then, we can use the `isOnline` local variable within our Component's template file so that we can show different content to our users using the `ngIf` structural directive. That would be pretty easy, right?

Unfortunately, things are never that simple: let's try to understand why.

Downsides of the JavaScript approaches

Both of the JS-based approaches we've mentioned suffer from a serious drawback caused by the fact that modern browsers implement the `navigator.online` property (as well as the `window.ononline` and `window.onoffline` events) in a different way.

More specifically, Chrome and Safari will set that property to `true` whenever the browser can connect to a LAN or a router: this can easily produce a false positive since most home and business connections are connected to the internet through a local LAN, which will arguably stay up even when the actual internet access is down.



For additional information regarding the `navigator.onLine` property and its drawbacks, check out the following URL:

<https://developer.mozilla.org/en-US/docs/Web/API/NavigatorOnLine/onLine>

All considered, this basically means that we cannot use the convenient approaches described earlier to check for our browser's online status; as long as we want to seriously deal with this matter, we need to find a better way to do that.

Option 3 – the ng-connection-service npm package

Luckily enough, there's a neat npm package that does precisely what we need: its name is `ng-connection-service` and it's basically an *Internet Connection Monitoring Service* that can detect whether the browser has an active internet connection or not.

The online detection task is being performed using a (configurable) *heartbeat* system, which will periodically issue `HEAD` requests to a (configurable) URL to determine the internet connection status.

Here are the package default values:

- `enableHeartbeat: true`
- `heartbeatUrl: //internethealthtest.org`
- `heartbeatInterval: 1000 (milliseconds)`
- `heartbeatRetryInterval: 1000`
- `requestMethod: head`



For additional information about the `ng-connection-service` npm package, check out the following URL:

<https://github.com/ultrasonicsoft/ng-connection-service>

Most of them are good, except for the `heartbeatUrl`—for various reasons that we'll explain later on.

Needless to say, it being an Angular service, we'll be able to configure it in a centralized way and then inject it whenever we need to without having to manually configure it every time: that almost seems too good to be true!

Let's see how we can implement it.

Installing `ng-connection-service`

Unfortunately, the `ng-connection-service` latest version—which introduced the heartbeat—is not available on npm as of today: the last updated version is **1.0.4**, which was developed for Angular 6 more than a year ago (at the time of writing) and was still based upon the `window.isonline` and `window.isoffline` events that we talked about early on.

At the time of writing, I don't know why the author (Balram Chavan) hasn't updated the npm package yet: however, since he made the latest version's source code available on GitHub under **MIT** license, we can definitely manually install it to our `HealthCheck` and `WorldCities` apps.

To do this, we need to perform the following steps in both our `HealthCheck` and `WorldCities` projects:

1. Visit the project's GitHub repository at <https://github.com/ultrasonicsoft/ng-connection-service>
2. Clone the project using GIT or download the ZIP file locally and unzip it somewhere
3. Create a new `/ClientApp/src/ng-connection-service/` folder and copy the following files there:
 - `connection-service.module.ts`
 - `connection-service.service.spec.ts`
 - `connection-service.service.ts`

The files can be found in the following subfolder of the ng-connection-service npm package bundle:

- ng-connection-service-master\projects\connection-service\src\lib

That's it! Now we can implement the service within our apps.

Updating the app.component.ts file

The *offline status* informative message should be shown to our users:

- **As soon as possible**, so that they'll know the app's connectivity status before navigating somewhere
- **Everywhere**, so that they will be warned about it even if they're visiting some internal views

Therefore, a good point to implement it would be the AppComponent class, which contains all of our apps, regardless of the *front-end* route picked by the user.

Open the /ClientApp/src/app/app.component.ts file and modify its class file accordingly (the updated lines are highlighted):

```
import { Component } from '@angular/core';
import { ConnectionService } from '../ng-connection-
service/connection-service.service';

@Component({
  selector: 'app-root',
  templateUrl: './app.component.html'
})
export class AppComponent {
  title = 'app';

  hasNetworkConnection: boolean;
  hasInternetAccess: boolean;
  isConnected = true;
  status: string;
  constructor(private connectionService: ConnectionService) {
    this.connectionService.updateOptions({
      heartbeatUrl: "/isOnline.txt"
    });
    this.connectionService.monitor().subscribe(currentState => {
      this.hasNetworkConnection = currentState.hasNetworkConnection;
      this.hasInternetAccess = currentState.hasInternetAccess;
    });
  }
}
```

```
        if (this.hasNetworkConnection && this.hasInternetAccess) {
            this.isConnected = true;
            this.status = 'ONLINE';
        } else {
            this.isConnected = false;
            this.status = 'OFFLINE';
        }
    });
}
}
```

As we can see, we took the chance to modify the `heartbeatUrl` value: instead of querying a third-party website, we're going to check a dedicated `isOnline.txt` file that we'll create and properly configure within our app. We've opted for that choice for several good reasons, the most important of them being the following:

- **To avoid being a nuisance** for those third-party hosts
- **To avoid Cross-Origin Resource Sharing (CORS) issues** against third-party resources

We'll talk more about CORS in a dedicated mini-section in a short while.



Since the aforementioned `isOnline.txt` file doesn't exist yet, we're going to create it now.

From **Solution Explorer**, right-click to the `HealthCheck` project's `/www/` folder, then create a new `isOnline.txt` file there and fill its content with the following line:

.

As a matter of fact, the content is not relevant; since we'll just perform some HEAD requests against it to check for our app's online status, a single dot will suffice.



IMPORTANT: Remember to perform the preceding changes (and to create the `isOnline.txt` file) for both our projects (`HealthCheck` and `WorldCities`).

Removing the `isOnline.txt` static file from the cache

The `isOnline.txt` file is, by all means, a *static* file; therefore, it is subject to the *static file caching rules* that we set up for our `HealthCheck` app back in Chapter 2, *Looking Around*. However, since that file would be used to periodically check for our app's online status, having it cached on the *back-end* would hardly be a good idea.

To remove it from the global static file caching rule that we've set, open the `Startup.cs` file of `HealthCheck` and update its contents in the following way (the new/updated lines are highlighted):

```
// ...  
  
app.UseStaticFiles(new StaticFileOptions()  
{  
    ContentTypeProvider = provider,  
    OnPrepareResponse = (context) =>  
    {  
        if (context.File.Name == "isOnline.txt")  
        {  
            // disable caching for these files  
            context.Context.Response.Headers.Add("Cache-Control",  
                "no-cache, no-store");  
            context.Context.Response.Headers.Add("Expires", "-1");  
        }  
        else  
        {  
            // Retrieve cache configuration from appsettings.json  
            context.Context.Response.Headers["Cache-Control"] =  
                Configuration["StaticFiles:Headers:Cache-Control"];  
            context.Context.Response.Headers["Pragma"] =  
                Configuration["StaticFiles:Headers:Pragma"];  
            context.Context.Response.Headers["Expires"] =  
                Configuration["StaticFiles:Headers:Expires"];  
        }  
    }  
});  
  
// ...
```

Now that we've excluded the `isOnline.txt` file from the *back-end* cache, we can move to the next step.



IMPORTANT: Remember to configure the `isOnline.txt` file no-cache features in the `WorldCities` project as well. Even if no caching rules have been defined there, it's definitely a good idea to explicitly keep it outside the cache by adding the above headers.

Installing the `ng-connection-service` via NPM (alternate route)

If we don't want to install the `ng-connection-service` manually, we can still use the 1.0.4 version by adding the following highlighted line to the `/ClientApp/src/package.json` file for both of the preceding projects, at the end of the "dependencies" section:

```
// ...  
  
"zone.js": "0.10.2",  
"ng-connection-service": "1.0.4"  
  
// ...
```

And implement it in our `AppComponent`'s file in the following way:

```
import { Component } from '@angular/core';  
import { ConnectionService } from 'connection-service';  
  
@Component({  
    selector: 'app-root',  
    templateUrl: './app.component.html'  
)  
export class AppComponent {  
    status = 'ONLINE';  
    isConnected = true;  
  
    constructor(private connectionService: ConnectionService) {  
        this.connectionService.monitor().subscribe(isConnected => {  
            this.isConnected = isConnected;  
            if (this.isConnected) {  
                this.status = "ONLINE";  
            }  
            else {  
                this.status = "OFFLINE";  
            }  
        })  
    }  
}
```

As we can see, the `ConnectionService` interface is slightly different in this version: as a result, we won't be able to rely upon the `hasNetworkConnection` and `hasInternetAccess` variables, as well as the useful info they provide in the new version.



However, if we choose that (simplified and less robust) approach, we won't have to configure the `internethealthtest.org` website to our app's CORS policy: we'll talk about it later on.

Updating the `app.component.html` file

Last but not least, we need to modify the template file of `AppComponent` to show the "offline status" informative message to our users whenever the `isConnected` local variable evaluates to `false`.

Open the `/ClientApp/src/app/app.component.html` file and update its content accordingly:

```
<body>

<div class="alert alert-warning" *ngIf="!isConnected">
  <strong>WARNING</strong>: the app is currently <i>offline</i>:
  some features that rely upon the back-end might not work as
  expected. This message will automatically disappear as soon
  as the internet connection becomes available again.
</div>

<app-nav-menu></app-nav-menu>
<div class="container">
  <router-outlet></router-outlet>
</div>
</body>
```

That's it: since our app's *Home view* doesn't directly require a *back-end* HTTP request, we've chosen to just show a warning message to inform the user that some of our app's features might not work while offline. Conversely, we could've entirely shut down the app by putting an additional `ngIf="isConnected"` structural directive to the other elements, so that the *offline status* message would be the only visible output.

Cross-Request Resource Sharing

As we said early on, the latest version of the `ng-connection-service` allows us to perform a HEAD request over a defined amount of time ("heartbeat") to determine whether we're online or not. However, we have chosen to change the third-party website that was set in the service's default values (`internethealthtest.org`) with a local file (`isOnline.txt`) that we created just for that purpose.

Why we did that? What's wrong with periodically issue a HEAD request against a third-party website?

The first reason is rather simple to understand: we don't want to be a nuisance for those websites since they're definitely not meant for us to check for their online status. If their system administrators see our requests in their log, they could ban us or take some countermeasures that could prevent our heartbeat check from working or—even worse—compromise its reliability status.

However, there's another important reason for avoiding such a practice.

Allowing our app to issue HTTP requests to *external* websites might violate the default CORS policy settings of those websites; while we're here, it could be useful to spend a couple of words to better understand this concept.

As we might already know, modern browsers have built-in security settings that prevent a web page from making JavaScript requests to a different domain than the one that served the web page: such restriction is called *same-origin policy* and has been introduced to prevent a malicious third-party website from reading data from another site.

However, most websites might want (or need) to issue some external requests to other websites: for example, the default `heartbeatUrl` configured in `ng-connection-service` would have told our app to issue a HEAD request to the `internethealthtest.org` external website to check for its online status.

These requirements, which are rather common in most apps, are called CORS: to allow them, the browser expects to receive from the receiving server—the one that hosts the required resources—a suitable **CORS policy** that will allow them to pass: if this policy doesn't come—or doesn't include the requesting origin—the HTTP request will be blocked.



For additional information about CORS and its settings, visit the following URL:

<https://developer.mozilla.org/en-US/docs/Web/HTTP/CORS>

If we were the **remote** server, we could configure such policy by configuring the .NET CORS middleware, which is part of the `Microsoft.AspNetCore.Cors` NuGet package: unfortunately, the heartbeat mechanism used by the `ng-connection-service` npm package makes our app—and its hostname—the **origin** server, meaning that such a method would only work if the remote server features a CORS policy compatible with us, without ever changing it.

Since such *heartbeat-based* mechanism is now a critical part of our app, we can't take the risk of being cut out: therefore, we've replaced that *unsafe* third-party reference with a more secure URL pointing to an *internal* resource under our control—and with no CORS policy requirements, since it's being hosted on the same server that serves the Angular app.



To know more about the `Microsoft.AspNetCore.Cors` NuGet package and how to configure CORS in .NET Core apps, check out the following URL:

<https://docs.microsoft.com/en-us/aspnet/core/security/cors>

With this, we've successfully implemented all of the required PWA features. Let's now find a way to properly test out what we did: it won't be easy to do that from within Visual Studio due to the distinctive features of PWAs, yet there are some workarounds we can use to pull it off.

Testing the PWA capabilities

In this section, we'll try to test the service worker registration for our `HealthCheck` app. Unfortunately, doing it from a Visual Studio development environment is a rather a complex task for several reasons, including the following:

- `ng serve`, the Angular CLI command that pre-installs the packages and start the app whenever we run our app in *debug* mode, doesn't support service workers
- The service worker registration tasks that we've put in the `AppModule` class a while ago only register it when the app is running in a *production* environment

- The required static files generated by the Angular CLI using the `angular.json` configuration file that we modified early on will only be available on *production* environments

Luckily enough, we can work around these limitations with a little tweak that will allow us to properly test both our *Web App Manifest* file and *service worker* from within Visual Studio and IIS Express.

Using Visual Studio and IIS Express

In a nutshell, here's what we need to do:

1. Create a Publish Profile for our `HealthCheck` and `WorldCities` projects and use it to publish our projects on a temporary folder using the *production* environment, which is the default configuration when publishing our app
2. Copy the CLI-generated files from the publishing folder to the `/www/` folder of our projects
3. Run the two apps in *debug* mode and properly check out their PWA capabilities



The tweak is to copy the CLI-generated files to the `/www/` folder so that they will be available to the web browser even if the app is being built and launched from a *development* environment.

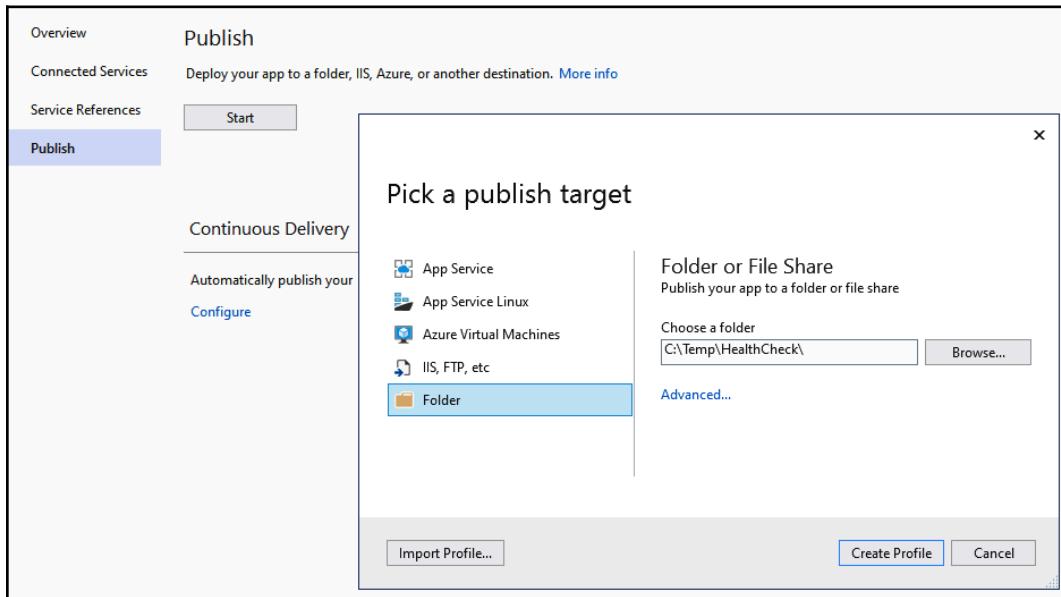
Let's get to work.

Creating a Publish Profile

As we probably already know, **Publish Profiles** are a convenient way offered by Visual Studio to deploy our web application projects for production environments. Such a feature allows us to publish our app on the filesystem, over an FTP/FTPS server, on an Azure App Service on Windows or Linux, and so on.

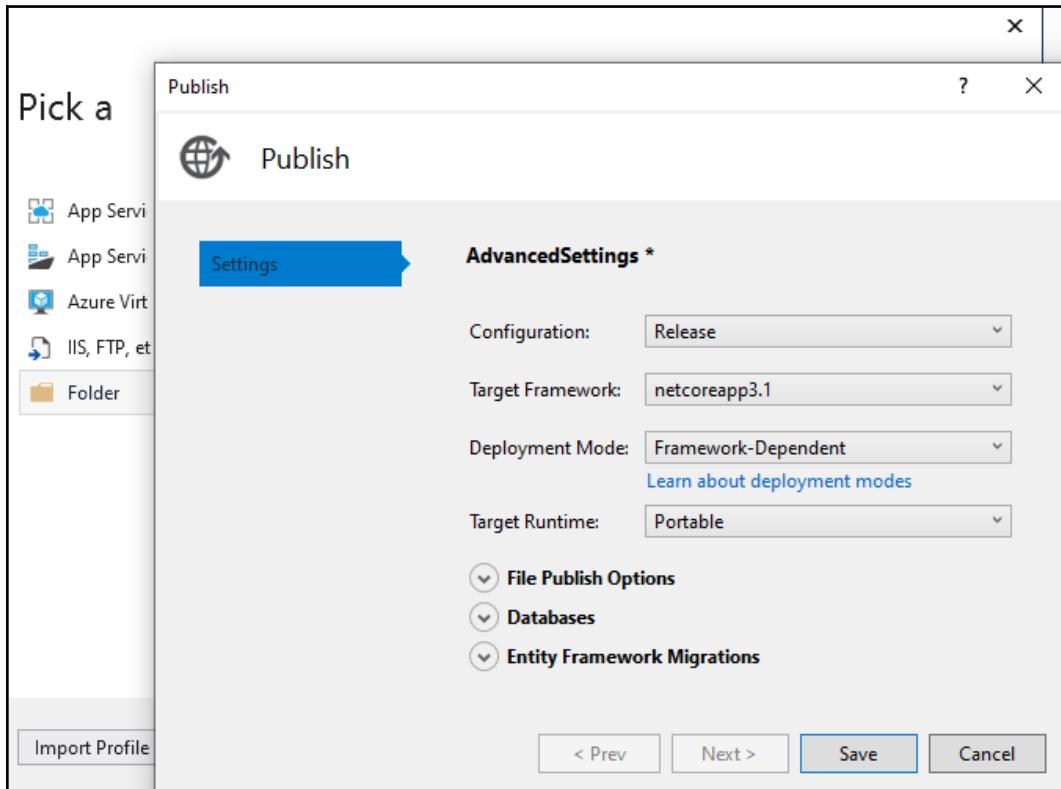
In our specific scenario, we need to publish our .NET Core and Angular web app to a filesystem folder, so that we can serve it with `http-server` from the command line; to do that, we need to perform the following steps:

1. Right-click the project in **Solution Explorer** and select **Publish**.
2. Select **Folder** from the various options available to the right.
3. Choose a suitable folder path—such as `C:\Temp\HealthCheck\`—and click to the **Advanced** link (see the following screenshot):



4. In the advanced settings, choose the following parameters:
 - **Configuration:** Release
 - **Target Framework:** netcoreapp3.1
 - **Deployment Mode:** Framework-Dependent
 - **Target Runtime:** Portable

You can see this in the following screenshot:



- Once done, click **Save** to save the advanced settings and then **Create Profile** to complete the task. As a result, a new `FolderProfile.pubxml` file will be added to the project's `Properties/PublishProfiles` folder.

Now we can press the **Publish** button to publish the `HealthCheck` app files in the selected folder. Once done, we can repeat the same tasks for the `WorldCities` app, changing the target folder accordingly.

Copying the CLI-generated files

Now that we have a production build, we can copy the following CLI-generated files from the filesystem publishing folder—in our example, C:\Temp\HealthCheck\ and C:\Temp\WorldCities\—to the project's /www/ folder.



The /www/ folder, as we already know since *Chapter 2, Looking Around*, can be used to host the web app's static files, that is, those that we want to make available to the public; that's just what we need to make those CLI-generated files available to the browser to fetch the Web Manifest File and register the service worker.

Here are the files that we need to copy:

- manifest.webmanifest
- ngsw.json
- ngsw-worker.js
- safety-worker.js
- worker-basic.min.js

Once done, we can launch the app in debug mode by hitting F5 just like we've always done.

Testing out our PWAs

Finally, we're able to properly test the PWA capabilities of our apps: for the sake of simplicity, the following screenshots will be all related to HealthCheck, but the same checks could be applied to the WorldCities app as well since we configured it using the same implementation patterns.



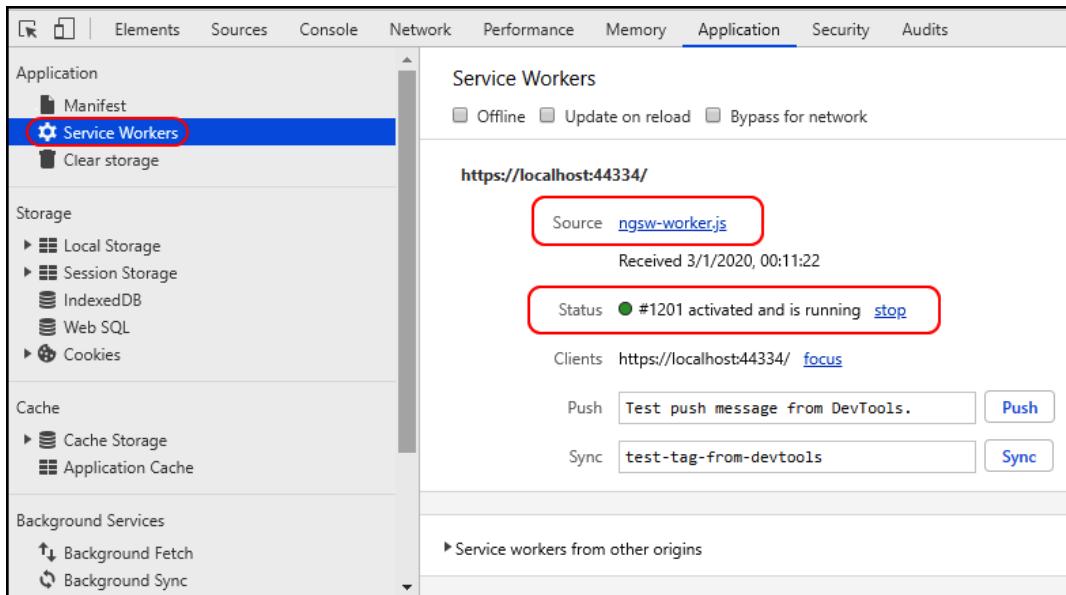
It's strongly advisable to perform the following tests with Google Chrome since it comes with some neat built-in tools to check for *Web App Manifest* and service workers presence. Also, be sure to use the *incognito mode* to ensure that the service worker will always start from scratch, without reading previously built caches or states.

Right after the app's **Home view** is properly loaded, press **Shift + Ctrl + J** to open the Chrome Developer Tools, as shown in the following screenshot:

The screenshot shows the Chrome Developer Tools interface with the "Application" tab selected. On the left, there's a sidebar with sections like "Application" (highlighted with a red box), "Storage", "Cache", and "Background Services". Under "Application", the "Manifest" item is also highlighted with a red box. In the main panel, the "App Manifest" section displays the file path "manifest.webmanifest", which is also highlighted with a red box. Below it, the "Identity" section shows the application name as "HealthCheck". The "Presentation" section includes fields for "Start URL" (set to "/"), "Theme color" (#2196f3), "Background color" (#2196f3), "Orientation", and "Display" (set to "standalone").

As we can see, if we navigate to the developer tool's **Application** tab, we can see that our *Web App Manifest* file has been properly loaded: if we scroll down the **Application | Manifest** panel, we'll be able to see our PNG icons as well.

The next thing we can check is the **Application | Service Workers** panel, which should strongly resemble the one shown in the following screenshot:



The *service worker* JavaScript file should be clearly visible, as well as with its registration date and current *up and running* status.

Let's now try to put our web browser offline. To do that, activate the **Offline** checkbox in the left-top section of the Chrome Developer Tools' **Application** tab and see what happens:

WARNING: the app is currently *offline*: some features that rely upon the back-end might not work as expected. This message will automatically disappear as soon as the internet connection becomes available again.

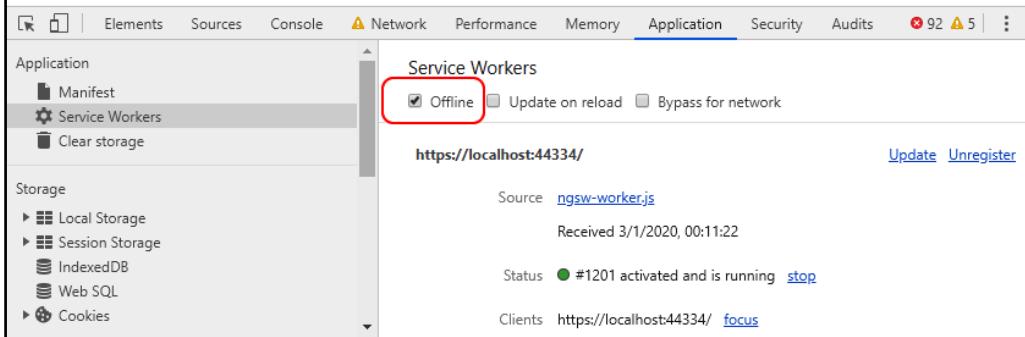
HealthCheck

Home Health Check

Hello, world!

Welcome to your new single-page application, built with:

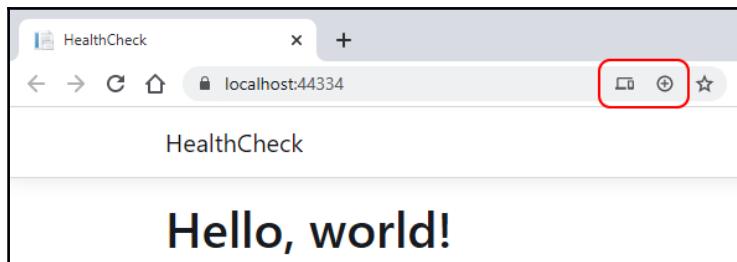
- ASP.NET Core and C# for cross-platform server-side code
- Angular and TypeScript for client-side code
- Bootstrap for layout and styling



The screenshot shows the Chrome DevTools Application tab. In the left sidebar, under 'Application', 'Service Workers' is selected and highlighted with a red box around the 'Offline' checkbox. The main panel displays information about a service worker at `https://localhost:44334/`. The 'Source' is listed as `ngsw-worker.js`, it was 'Received' on 3/1/2020, 00:11:22, and its 'Status' is green with the message '#1201 activated and is running'. A link to 'stop' the worker is also present. Below this, under 'Clients', there is a link to `https://localhost:44334/ focus`.

Our *offline warning* info message should immediately kick in, thanks to our `ng-connected-service` implementation. If we move to the **Network** tab, we can see that the `isOnline.txt` file isn't reachable anymore, meaning that the `isConnected` variable of `AppComponent`s now evaluates to `false`.

Now, we can resume the connectivity (by de-selecting the **Offline** checkbox) and check out two more things: the *linkable* and *installable* PWA capabilities. Both of them are clearly shown on the rightmost part of the browser's address bar, as we can see in the following screenshot:

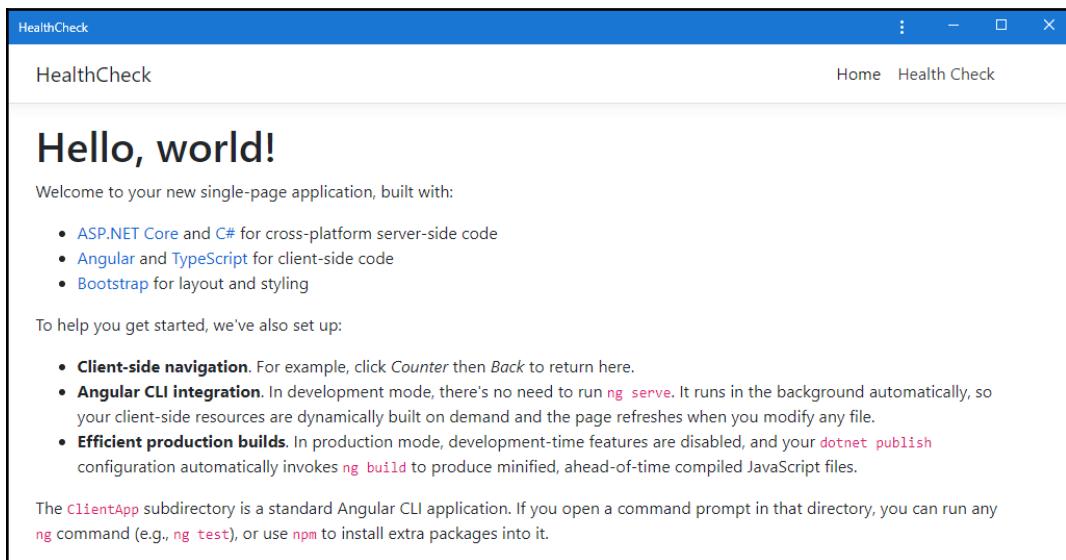


If we go there with the mouse pointer, we should be able to see the contextual messages asking us to respectively send the app's URL to other devices and install it to the desktop.

Installing the PWA

Let's now click the **install** button (the one with the *plus* sign inscribed in a circle) and confirm that we want to locally install the **HealthCheck** PWA.

A new popup should be able with the **Home** view of our newly installed app in a *desktop-app-like* window, as shown in the following screenshot:

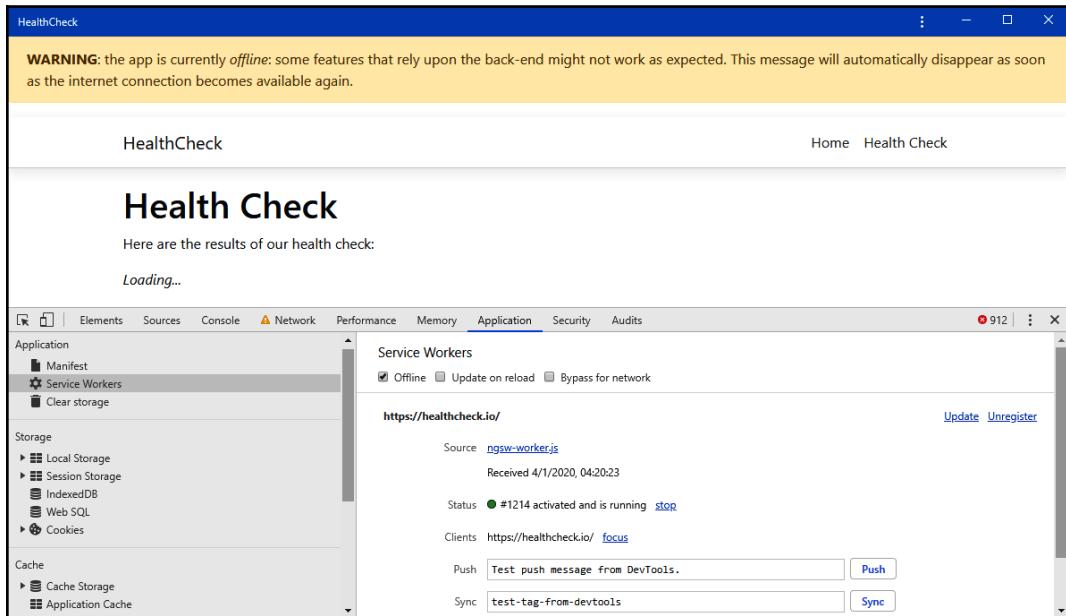


From there, do the following:

1. Click *Shift + Ctrl + J* to open again the *Google Chrome Developer Tools*
2. Navigate to the **Application | Service worker** panel
3. Click to the **Offline** checkbox to check/activate it again

The app should again show the *offline warning* information message; once done, try to navigate to the **Health Check** view by clicking to the rightmost link in the app's navigation menu near the top-right corner.

We should be able to see something like this:



As we can see, our app is working even while offline: the *offline* message is shown to the user.



The "912" attempts shown in the top-right section of the *Google Chrome Developer tools* containing window also shows that our heartbeat is doing its job, periodically trying to find to the `isOnline.txt` file back up.

Needless to say, we won't be able to see our health check results table: however, the *offline warning* information message is enough to make our users aware of the fact that such behavior is perfectly acceptable while the app is offline.

That's it: we have successfully turned our SPAs into PWAs. As a matter of fact, we have just scratched the surface of the many possibilities offered by such a promising deployment approach: however, we've successfully demonstrated that our *front-end* and *back-end* frameworks are fully able to handle its main requirements properly and consistently.

Alternative testing ways

If we don't want to use the preceding tweak, there are various possible options available, such as the following:

- Publishing our app in a production-like environment
- Locally serving the contents of the filesystem folders used to publish our app(s) with an HTTP server that does support service workers

The first option will be extensively covered in [chapter 12, Windows and Linux Deployment](#); to implement the second option, we can use `http-server`, a simple and lightweight command-line HTTP server that can be installed and launched within seconds.

Serving our PWA using `http-server`

`http-server` can be either installed using `npm` or directly launched using `npx`, a tool shipped with Node.js that can be used to execute `npm` package binaries without installing them.

If we want to globally install it before launching it, we can do so with the following commands:

```
> npm install http-server -g  
> http-server -p 8080 -c-1 C:\Temp\HealthCheck\ClientApp\dist\
```

If we just want to test out our service worker, we can use the following command instead:

```
> npx http-server -p 8080 -c-1 C:\Temp\HealthCheck\ClientApp\dist\
```

Both commands will launch `http-server` and serve our `HealthCheck` app to the local 8080 TCP port, as shown in the following screenshot:

```
E:\>npx http-server -p 8080 -c-1 C:\Temp\HealthCheck\ClientApp\dist\  
npx: installed 27 in 3.25s  
Starting up http-server, serving C:\Temp\HealthCheck\ClientApp\dist\  
Available on:  
  http://169.254.251.188:8080  
  http://192.168.1.101:8080  
  http://192.168.112.1:8080  
  http://192.168.159.1:8080  
  http://127.0.0.1:8080  
Hit CTRL-C to stop the server  
> -
```

As soon as we do that, we can connect to it by opening a browser and typing the following URL in the address bar: `http://localhost:8080`.

We can check out the PWA capabilities of our apps just like we did with Visual Studio and IIS Express early on; however, we won't be able to test the *back-end* HTTP requests since `http-server` won't natively support .NET Core. Luckily enough, we don't need the *back-end* to run these tests.

Summary

This chapter was all about PWA: we've spent some valuable time to better understand the high-level distinctive features of this modern web development pattern and how to translate them into technical specifications. Right after that, we started implementing them, taking into account the various available options offered by our *front-end* and *back-end* frameworks.

Since the PWA concept is closely related to the *front-end* aspects of our app, we chose to adopt the Angular way of implementing their required capabilities: with that in mind, we've chosen to take the manual route for our `HealthCheck` app first, then to experience the automatic installation feature powered by the Angular CLI for the `WorldCities` app. In both scenarios, we made good use of the `@angular/service-worker` npm package, a module available since Angular 5 that provides a fully featured service worker implementation that could be easily integrated into our apps.

Once we did that, we manually ran some consistency tests to check the brand-new PWA capabilities of our apps using Google Chrome and its developer tools. To do that, we've taken the chance to learn how to publish our app using the Visual Studio's *Publish Profiles* feature.

By the end of this chapter, we've finally seen our service worker in action, as well as the *Web App Manifest* file being able to serve the PNG icons and provide the installing and linking features to our apps.

The various concepts that we learned throughout this chapter have also helped us to focus on some very important issues regarding the differences between *development* and *production* environments, hence making us ready to properly face the final part of our journey: Windows and Linux deployment, which will be the main topics of the next chapter.

Suggested topics

Progressive Web Apps (PWA), @angular/service worker, secure origin, HTTPS, TLS, Let's Encrypt, service workers, HTTP Interceptors, favicon, Web App Manifest File, Microsoft.AspNetCore.Cors, Cross-Origin Resource Sharing (CORS), Offline Status, window.navigator, ng-connection-service, IIS Express, http-server.

References

- *Progressive Web Apps*: <https://developers.google.com/web/progressive-web-apps>
- *Web Fundamentals*: <https://developers.google.com/web/fundamentals>
- *Progressive Web Apps: Escaping Tabs Without Losing Our Soul*: <https://infrequently.org/2015/06/progressive-apps-escaping-tabs-without-losing-our-soul/>
- *Let's Encrypt*: <https://letsencrypt.org/>
- *The Web App Manifest*: <https://developers.google.com/web/fundamentals/web-app-manifest>
- *Angular Service Workers*: <https://angular.io/guide/service-worker-getting-started>
- *Service worker configuration*: <https://angular.io/guide/service-worker-config>
- *Service Workers - Practical Guided Introduction (several examples)*: <https://blog.angular-university.io/service-workers/>
- *Angular University: Service Worker step-by-step guide*, <https://blog.angular-university.io/angular-service-worker/>
- *favicon.io*: <https://favicon.io/>
- *Real Favicon Generator*: <https://realfavicongenerator.net/>
- *Icons8*: <https://icons8.com/icons/set/favicon>
- *FreeFavicon*: <https://www.freelfavicon.com/freefavicon/icons/>
- *Firebase Web App Manifest Generator*: <https://app-manifest.firebaseio.com>
- *DummyImage - Placeholder Image Generator*: <https://dummyimage.com/>
- *Web App Manifest - W3C Working Draft 09 December 2019*: <https://www.w3.org/TR/appmanifest/>
- *Enable Cross-Origin Requests (CORS) in ASP.NET Core*: <https://docs.microsoft.com/en-us/aspnet/core/security/cors>

- *http-server*: <https://www.npmjs.com/package/http-server>
- *npx - execute npm package binaries*: <https://www.npmjs.com/package/npx>
- *ng-serve*: <https://angular.io/cli/serve>
- *Visual Studio publish profiles (.pubxml) for ASP.NET Core app deployment*:
<https://docs.microsoft.com/en-us/aspnet/core/host-and-deploy/visual-studio-publish-profiles>
- *Angular - Service Worker registration options*: <https://angular.io/api/service-worker/SwRegistrationOptions>

12

Windows and Linux Deployment

Our valuable journey through ASP.NET Core and Angular development is coming to an end. The web applications we've been working on since [Chapter 1, Getting Ready – HealthCheck and WorldCities](#) – are now potentially shippable products and mostly ready to be published in a suitable environment for evaluation purposes.

In this chapter, we'll deal with the following topics:

- **Preparing our app for production**, where we'll learn some useful optimization strategies to move our app into a production folder
- **Windows deployment**, where we'll see how we can deploy our `HealthCheck` web application to a Windows Server 2019 environment and publish it over the web using IIS with the new in-process hosting model
- **Linux deployment**, where we'll deploy our `WorldCities` web application to a Linux CentOS server and publish it over the web using the Kestrel web server over an Nginx-based proxy

The ultimate goal of this long and ambitious chapter is to learn the requisite tools and techniques to deploy a .NET Core and Angular app on a production Windows and/or Linux hosting server, so let's embark upon this final effort.

Technical requirements

In this chapter, we're going to need all the previous technical requirements listed in *Chapters 1-11*, together with the following additional packages:

For Windows deployment:

- **Internet Information Services (IIS)** (Windows Server)
- **ASP.NET Core 3.1 Runtime and Windows Hosting Bundle Installer for Win64** (ASP.NET Core official website)

For Linux deployment:

- **ASP.NET Core 3.1 Runtime for Linux** (YUM package manager)
- **.NET Core 3.1 CLR for Linux** (YUM package manager)
- **Nginx HTTP Server** (YUM package manager)

As always, it's advisable to avoid installing them straight away: we're going to bring them in over the course of the chapter to better contextualize their purpose within our project.

The code files for this chapter can be found here: https://github.com/PacktPublishing/ASP.NET-Core-3-and-Angular-9-Third-Edition/tree/master/Chapter_12/.

Getting ready for production

In this section, we'll see how we can further refine our apps' source code in order to get them ready for production usage. We'll mostly deal with server-side and client-side caching, environment configuration, and so on. While we're there, we'll take the chance to learn some useful production optimization tips offered by our *front-end* and *back-end* frameworks.

More specifically, we're going to cover the following:

- **.NET Core deployment tips**, where we'll learn how our *back-end* has been optimized for production usage
- **Angular deployment tips**, where we'll review some strategies used by the Visual Studio template to optimize the *front-end* production building phase

Let's get to work!

.NET Core deployment tips

As we most likely already know, ASP.NET Core allows developers to adjust an application's behavior across many environments: the most common of these are development, staging, and production environments. The currently active environment is identified at runtime by checking an environment variable that can be configured and modified from the project's configuration files.

This variable is called `ASPNETCORE_ENVIRONMENT` and, while we're running our project on Visual Studio, it can be set by using the `/Properties/launchSettings.json` file, which controls various settings that will be applied to our local development machine upon our web application's launch.

The `launchSettings.json` file

If we take a look at the `launchSettings.json` file, we can see that it contains some specific settings for each execution profile of our app. To look at a quick example of this, here are the contents of the `HealthCheck` project's `/Properties/launchSettings.json` file:

```
{
  "iisSettings": {
    "windowsAuthentication": false,
    "anonymousAuthentication": true,
    "iisExpress": {
      "applicationUrl": "http://localhost:40082",
      "sslPort": 44334
    }
  },
  "profiles": {
    "IIS Express": {
      "commandName": "IISExpress",
      "launchBrowser": true,
      "environmentVariables": {
        "ASPNETCORE_ENVIRONMENT": "Development"
      }
    },
    "HealthCheck": {
      "commandName": "Project",
      "launchBrowser": true,
      "applicationUrl": "https://localhost:5001;http://localhost:5000",
      "environmentVariables": {
        "ASPNETCORE_ENVIRONMENT": "Development"
      }
    }
  }
}
```

```
        }
    }
}
```

As we can see, there are two execution profiles currently set:

- **The IIS Express profile**, which is related to the IIS Express HTTP Server. This profile will be used whenever we launch our project in debug mode, which we can do by pressing *F5* (unless we changed the default debugging behavior).
- **The HealthCheck profile**, which is related to the application itself. This profile will be used whenever we launch our app using the .NET Core CLI (in other words, the `dotnet run` console command).

For both of them, the `ASPNETCORE_ENVIRONMENT` variable is currently set to the *Development* value, meaning that we're always going to run our apps in *development* mode from Visual Studio, unless we change these values.

Development, staging, and production environments

How do the different environments affect our web application's behavior?

Right after our web application starts, ASP.NET Core reads the `ASPNETCORE_ENVIRONMENT` environment variable and stores its value in the `EnvironmentName` property of our app's `IWebHostEnvironment` instance, which, as its name suggests, provides information about the web hosting environment our application is running in. Once set, this variable can be used programmatically – either directly or with some helper methods – to determine our app's behavior at any moment of our *back-end* life cycle.

We've already seen these methods in action in the `Startup` class of our .NET Core applications—for example, here's what we can find in the `HealthCheck` `Startup.cs` source code:

```
// ...

if (env.IsDevelopment())
{
    app.UseDeveloperExceptionPage();
}
else
```

```
{  
    app.UseExceptionHandler("/Error");  
    // The default HSTS value is 30 days. You may want to change this  
    // for production scenarios, see https://aka.ms/aspnetcore-hsts.  
    app.UseHsts();  
}  
  
// ...
```

In the preceding lines, part of the `Startup` class's `Configure()` method, we're telling our app to conditionally use the following:

- The developer exception pages when running in a development environment
- A custom `ExceptionHandler` middleware on stage and production environments

This basically means that, whenever our .NET Core app crashes, it will conditionally show the following:

- Low-level/detailed error messages (such as the exception info and the stack trace) to developers
- High-level/generic unavailability messages to end users

The developer exception page includes a detailed series of useful information about the exception and the request, such as exception and inner exception(s), stack trace, query string parameters, cookies, and HTTP headers.



For additional information about this, and error handling in ASP.NET Core in general, visit the following URL:

<https://docs.microsoft.com/en-us/aspnet/core/fundamentals/error-handling>

From this, we can also see how our app, when executed in a production environment, will set up a 30-day **HTTP Strict Transport Security (HSTS)** max-age header value. Such behavior, which complies with some good HTTP security practices and is therefore highly desirable when the app is publicly facing the web, is often useless (and can be a hindrance) during debugging, which is the reason why it's not being set.

Also, a few lines beneath this, we can find the following code:

```
// ...  
  
if (!env.IsDevelopment())  
{  
    app.UseSpaStaticFiles(new StaticFileOptions()  
    {  
        ContentTypeProvider = provider  
    });  
}  
  
// ...
```

This is another key structural point of our app, which we briefly mentioned back in Chapter 2, *Looking Around*, when we were given our first look at .NET Core's Startup class.

The `UseAngularCliServer()` method will pass through all the requests addressed to the Angular app to an in-memory instance of the Angular CLI server (`ng serve`). Such an approach is definitely the way to go for most development scenarios since it will ensure that our app will serve up-to-date CLI-built resources; however, it's not that great for production scenarios, where those files are not subject to changes and could be served using the static files generated by the Angular CLI (`ng build`) without wasting our server's CPU and memory resources.

Rule(s) of thumb

Now that we've seen how to programmatically determine our web app's execution environment and make our HTTP pipeline act accordingly, we should learn how to properly adopt, and adapt, these conditional practices to best suit those environments.

Since the development environment is only available to developers, it should always favor debugging capabilities over performance. Therefore, it should avoid caching, use in-memory loading strategies to quickly respond to changes, and emit as much diagnostic information as possible (logs, exceptions, and so on) to help the developers promptly understand what's happening.



If we remember what we said in Chapter 9, *ASP.NET Core and Angular Unit Testing*, regarding **Test-Driven Development (TDD)**, we should easily understand how the development environment is where the TDD practice mostly shines.

Conversely, while addressing a production environment, a good way to make these decisions is by applying the following rules of thumb:

- **Turn on caching whenever possible** in order to save resources and increase performance
- **Ensure that all the client-side resources** (JavaScript, CSS files, and so on) are bundled, minified, and potentially served from a **Content Delivery Network (CDN)**
- **Turn off diagnostic error pages** and/or replace them with friendly, human-readable error pages instead
- **Enable production logging and monitoring** using application performance management tools or other real-time monitoring, auditing, and watchdog strategies
- **Implement the best security practices** made available by the frameworks, such as adopting the **Open Web**
- **Implement Open Web Application Security Project (OWASP)** methodologies for software development, as well as network, firewall, and server configurations

These are the general guidelines (or good practices) that we should always take into serious consideration while refining the *back-end* part of our web applications for production usage.

What about the staging environment? As a matter of fact, it's mostly used as a preproduction environment where we can perform (or make some testers perform) our *front-end* testing before giving the OK for production deployment. Ideally, its physical characteristics should mirror that of production, so that any issues that may arise in production occur first in the staging environment, where they can be addressed without impacting on users.



Again, if we think back to our behavior-driven development analysis back in *Chapter 9, ASP.NET Core and Angular Unit Testing*, we can definitely acknowledge that the staging environment would be the perfect place to test for the expected behavior of any newly added feature of our apps before releasing them into production.

Setting the environment in production

What happens to the `ASPNETCORE_ENVIRONMENT` variable when we publish our web application for production deployment, just like we did during [Chapter 11, Progressive Web Apps](#), when we configured a folder-based publish profile for our `HealthCheck` and `WorldCities` apps?

As we can see by looking inside those folders, the `launchSettings.json` file cannot be found there, since it is not being published. That is certainly to be expected, since it's only meant to be used by Visual Studio and other local development tools.

Whenever we host the app on a production server, we'll have to manually set that value using one of the following approaches:

- A dedicated **environment variable** with the same name
- Specific **platform settings**
- A **command-line** switch

These methods strongly depend on the server's operating system. In the upcoming sections, we'll see how we can perform them on Windows and Linux servers.



It's important to remember that the environment, once set, can't be changed while the web app is running.

If no environment-related setting is found, the web app will always use the production value as the default, this being the most conservative choice for performance and security, since most debugging features and diagnostic messages will be disabled.

Conversely, if the environment is set multiple times (such as by the environment variable and then a command-line switch), the app will use the last environment setting read, thereby following a cascading rule.

ASP.NET Core deployment modes

In Chapter 11, *Progressive Web Apps*, when we created our first publish profile to deploy our app to a local folder, we didn't change the **deployment mode** settings, leaving them as they were. Truth be told, we did that because it wouldn't have made any difference, since we used that build just to *steal* some PWA-related generated files and used them to register our service worker from a standard Visual Studio debug run.

However, the .NET Core deployment mode is a very important configuration feature that we definitely need to understand in order to make the right choice whenever we have to deploy our application for production usage.

Let's now try to shed some light on the three different types of deployments available from Visual Studio for .NET Core applications:

- **Framework-dependent deployment (FDD):** As the name implies, such a deployment mode requires the presence of the .NET Core framework, which must be installed and available on the target system; in other words, we'll build a portable .NET application as long as the hosting server supports .NET Core.
- **Self-contained deployment (SCD):** This deployment mode doesn't rely on the presence of .NET Components on the target system. All Components, including the .NET Core libraries and runtime, will be included in the production build. If the hosting server supports .NET Core, the app will run in isolated mode, separating itself from other .NET Core applications. SCD deployment builds will include an executable file (a .exe file on Windows platforms) as well as a .dll file containing the application's runtime.
- **Framework-dependent executable (FDE):** This deployment mode will produce an executable file that will run on the hosting server, which must have the .NET Core runtime installed. Therefore, such a mode is rather similar to FDD, since both of them are framework dependent.

Let's now try to understand the pros and cons of each deployment mode.

Framework-dependent deployment pros and cons

Using the FDD mode grants the developer a number of advantages, including the following:

- **Platform independence:** There's no need to define the target operating system since the .NET Core runtime installed on the hosting server will seamlessly handle the app's execution, regardless of its platform.
- **Small package size:** The deployment bundle will be small since it will only contain the app's runtime and the third-party dependencies. .NET Core itself won't be there since we expect it to be already present on the target machine by design.
- **Latest version:** As per its default settings, FDD will always use the latest serviced runtime installed on the target system, with all the latest security patches.
- **Better performance in multihosting scenarios:** If the hosting server has multiple .NET Core apps installed, the shared resources will enable us to save some storage space and, most importantly, obtain reduced memory usage.

However, such a deployment mode also has a number of weaknesses, including the following:

- **Reduced compatibility:** Our app will require a .NET Core runtime with a version compatible with the one used by our app (or later). If the hosting server is stuck to a previous version, our app won't be able to run.
- **Stability issues:** If the .NET Core runtime and/or libraries were to change their behavior (in other words, if they had breaking changes or reduced compatibility for security or licensing reasons), our app will arguably be impacted by these changes as well.

Self-contained deployment pros and cons

Using the SCD mode has two big advantages that could easily outvalue the disadvantages regarding some specific scenarios:

- **Full control over the published .NET Core version,** regardless of what is installed on the hosting server (or what will happen to it in the future)
- **No compatibility issues,** since all the requisite libraries are provided within the bundle

Unfortunately, there are also some relevant disadvantages:

- **Platform dependency:** Being able to provide the .NET Core runtime with the production package requires the developer to select the target building platforms in advance.
- **Increased bundle size:** The additional presence of .NET Core will definitely take its toll in terms of disk space requirements. This can be a heavy hit if we plan to deploy multiple SCD .NET Core apps to a single hosting server, as each one of them will require a significant amount of disk space.

Framework-dependent executable pros and cons

The FDE deployment mode has been introduced in .NET Core 2.2 and, starting from version 3.0, is the default mode for the basic `dotnet publish` command (if no options are specified). This new approach has the following advantages:

- **Small package size, latest version, and better performance in multihosting scenarios,** just like FDD mode.
- **Easy to run:** the deployed executable can be directly launched and executed, without having to invoke the `dotnet` CLI.

This approach also has some disadvantages:

- **Reduced compatibility:** Just like FDD, the app requires a .NET Core runtime with a version compatible with the one used by our app (or later).
- **Stability issues:** Again, if the .NET Core runtime and/or libraries were to change their behavior, those changes could break the app or alter its behavior.
- **Platform dependency:** As the app is an executable file, it must be published for each different target platform.

As we can easily guess, all of these three deployment modes can either be good or bad, depending on a number of factors, such as how much control we have over the deployment server, how many .NET Core apps we plan to publish, and the target system's hardware and software capabilities.

As a general rule, as long as we have the rights to install and update system packages on the deployment server, the FDD modes should work well; conversely, if we host our apps on a cloud-hosting provider that doesn't have our desired .NET Core runtime, SCD would arguably be the most logical choice. The available disk space and memory size will also play a major role, especially if we plan to publish multiple apps.

That said, we're going to use the FDD (default) deployment mode, since our current scenario requires the publication of two different apps that share the same .NET Core version on the same server.

Angular deployment tips

Let's now turn our gaze to the *front-end* to properly understand how the Visual Studio template that we've used to build our two apps handles Angular's production deployment tasks.

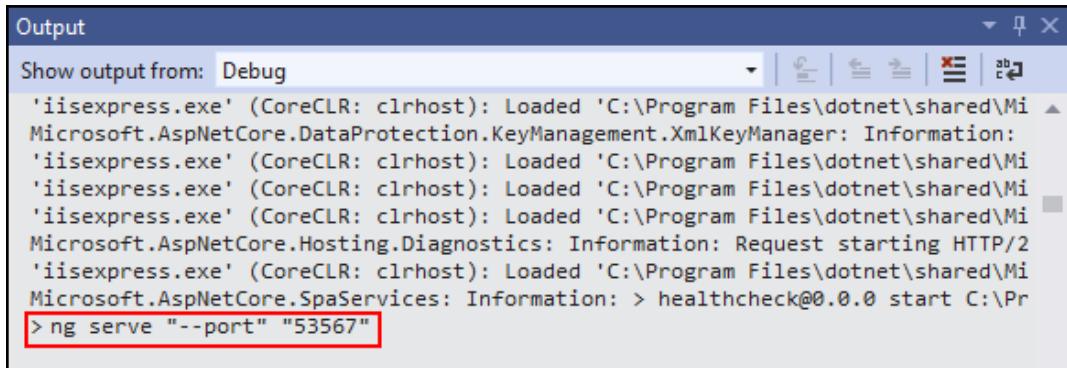
It goes without saying that the same good practices we've determined for the *back-end* retain their value at the *front-end* as well, as we'll see in a short while. In other words, performance and security will still be the principal goals in this regard.

Let's now try to understand how the Angular CLI, powered by Ivy, the new compilation and rendering pipeline, handles our applications' publishing and deployment tasks.

ng serve, ng build, and the package.json file

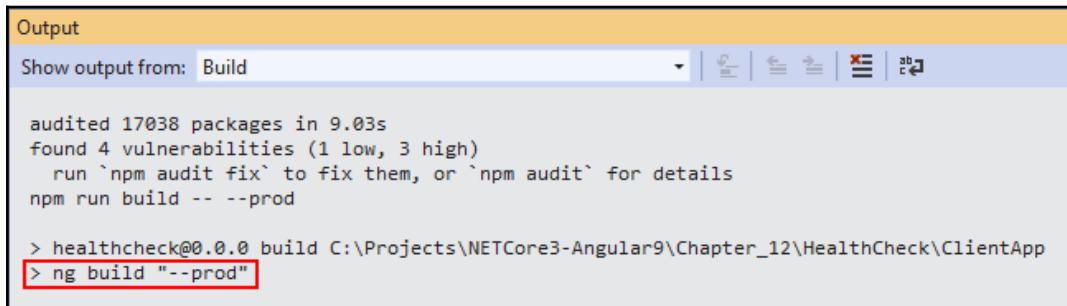
As we should already know, whenever we hit *F5* in Visual Studio, our Angular app is being served using an in-memory instance of the Angular CLI server. Such a server is launched by Visual Studio using the `ng serve` command.

If we take a look at the Visual Studio output window during the initial debug phase, right before the web browser kicks in, we can see it clearly in the following screenshot:



The screenshot shows the Visual Studio Output window with the title 'Output' at the top. The dropdown menu 'Show output from:' is set to 'Debug'. The window displays several lines of log output from the 'iisexpress.exe' process, including messages from 'Microsoft.AspNetCore.DataProtection.KeyManagement.XmlKeyManager' and 'Microsoft.AspNetCore.Hosting.Diagnostics'. At the bottom of the list, there is a command: '> ng serve "--port" "53567"'. This command is highlighted with a red rectangular box.

Conversely, when we deploy our app for production using a publish profile, Visual Studio uses the `ng build` command with the `--prod` flag instead:



The screenshot shows the Visual Studio Output window with the title 'Output' at the top. The dropdown menu 'Show output from:' is set to 'Build'. The window displays log output from an npm audit and then the command 'npm run build -- --prod'. Below this, there is a sequence of commands: '> healthcheck@0.0.0 build C:\Projects\NETCore3-Angular9\Chapter_12\HealthCheck\ClientApp' followed by '> ng build "--prod"'. The last command, '`> ng build "--prod"`', is highlighted with a red rectangular box.

Both commands can be found in the `/ClientApp/package.json` file, where we can modify or configure them to suit our needs, even if the default settings are already good for both development and production to deploy.

The `--prod` flag that Visual Studio adds to the `ng build` command activates a number of useful optimization features, including the following:

- **Ahead-of-Time (AOT) compilation:** This converts the HTML and TypeScript code into efficient JavaScript code in order to provide a faster rendering in the browser; the default mode (used for `ng serve` and when the `--prod` flag is not enabled), called **Just-in-Time (JIT)** compilation, compiles the app in the browser at runtime and is, therefore, a much slower and less optimized alternative
- **Production mode:** This makes the app run faster by disabling some development-specific checks, such as the dual change detection cycles

- **Bundling:** This concatenates the various app and third-party files (NPM packages) into a few bundles
- **Minification:** This removes whitespaces, comments, optional tokens, and any unnecessary characters and artifacts to HTML, JS, and CSS files
- **Uglification:** This internally rewrites the JavaScript code to shorten the variable and function names and make them unreadable, and also makes malicious reverse-engineering attempts much harder
- **Dead code purging:** This removes any unreferenced module and/or unused code file, snippet, or section

As we can see, all of the preceding features aim to increase the performance and security capabilities of our production build.

Differential loading

Another nice feature worth mentioning is differential loading, which was introduced in Angular 8. We haven't added it to the preceding `--prod` switch optimization benefits list because it's there by default, and is therefore not limited to that switch's usage.

Differential loading is Angular's way of overcoming the compatibility issues between the various browsers, especially the older ones; in other words, those that are still based on older versions of JavaScript.

As we can see by looking at the `/ClientApp/tsconfig.json` file, our TypeScript code will be transpiled and bundled into *ES2015*, also known as *ECMAScript 2015*, *ECMAScript version 6*, or *ES6*, a JavaScript syntax that is compatible with the vast majority of modern browsers. However, there are still a number of users with older clients, such as old desktop, laptop and/or mobile devices, that are still bound to *ES5* and earlier versions.

To work around this, previous versions of Angular, as well as most other *front-end* frameworks, provided a number of support libraries (known as polyfills) that would have conditionally implemented the missing features for those browsers that didn't natively support them. Unfortunately, such a workaround massively increased the production bundle, thereby resulting in a performance hit for all users, including those using modern browsers that didn't need those polyfills to begin with.

Differential loading solves this issue by generating two separate bundle sets during the build phase:

- The first bundle contains the app's code, which has been transpiled, minified, and uglyfied using a modern ES2015 syntax. Such a bundle ships fewer polyfills and therefore results in a much smaller size.
- The second bundle contains the same code transpiled in the old ES5 syntax, along with all the necessary polyfills. Needless to say, this bundle features a much larger bundle size, but properly supports older browsers.

The differential loading feature can be configured by altering two files:

- The `/ClientApp/browserlist` file, which lists the minimum browsers supported by our application
- The `/ClientApp/tsconfig.json` file, which determines the ECMAScript target version that the code is compiled to

By taking both of these settings into consideration, the Angular CLI will automatically determine whether or not to enable the differential loading functionality.

In our specific scenario, such a feature is enabled, as we can see by looking at the generated `index.html` file's `<body>` section within our app's production deploy folder (the relevant parts are highlighted):

```
<!-- ... -->

<body>
  <app-root>Loading...</app-root>
  <script src="runtime-es2015.e59a6cd8f1b6ab0c3f29.js"
    type="module"></script>
  <script src="runtime-es5.e59a6cd8f1b6ab0c3f29.js" nomodule
    defer></script>
  <script src="polyfills-es5.079443d8bcab7d711023.js" nomodule
    defer></script>
  <script src="polyfills-es2015.58725a5910daef768ca8.js"
    type="module"></script>
  <script src="main-es2015.fc7dc31b264662448f17.js"
    type="module"></script>
  <script src="main-es5.fc7dc31b264662448f17.js" nomodule
    defer></script>
</body>

<!-- ... -->
```

Such a strategy is very effective since it will allow our Angular apps to support multiple browsers without forcing our *modern* users to retrieve all the unnecessary bundles.

The angular.json configuration file

The most important difference between `npm serve` and `npm build` is that the latter is the only command that actually writes the generated build artifacts to the output folder: those files are built using the webpack build tool, which can be configured using the `/ClientApp/src/angular.json` configuration file.

The output folder is also set within that file, more precisely, in the `projects | [projectName] | architect | build | options | outputPath` section. In our sample apps, it's the `dist` folder, meaning that they will be deployed in the `/ClientApp/dist/` folder.

Automatic deployment

Angular 8.3.0 introduced the new `ng deploy` command, which can be used to deploy the Angular app to one of the available production platforms thanks to some third-party builders that can be installed using `ng add`.

Here's a list of the supported builders at the time of writing:

- `@angular/fire` (Firebase)
- `@azure/ng-deploy` (MS Azure)
- `@zeit/ng-deploy` (ZEIT Now)
- `@netlify-builder/deploy` (Netlify)
- `angular-cli-ghpages` (GitHub pages)
- `ngx-deploy-npm` (NPM)

Although the `ng deploy` CLI option is not yet supported by Visual Studio, it can be very useful to instantly deploy our app using some presets that can be configured in the `deploy` section of the `angular.json` file. Such a section isn't available in the `angular.json` file of our projects, but it will be automatically added as soon as one of the preceding projects is installed using the `ng add` CLI command (with its corresponding default settings).

CORS policy

We've already talked about **Cross-Request Resource Sharing (CORS)** in Chapter 11, *Progressive Web Apps*, when we changed the `ng-connection-service heartbeatUrl` default settings by pinging a local `.txt` file hosted by us instead of a third-party URL. Thanks to that modification, neither of our apps will face CORS errors because they will only make HTTP requests to our .NET Core *back-end*, which is likely hosted within the same server and so will have the same IP address/hostname.

However, we might want to either move the *back-end* in the future or add some additional HTTP calls to other remote services (multiple *back-end* systems and/or stores). If we plan to do that, then there's nothing we can do at the client-side level. We would need to implement a suitable CORS policy to the destination server instead.



For additional information regarding CORS and instructions on how to enable it for specific servers, go to:
<https://enable-cors.org>.

Luckily enough, we won't need to implement any CORS-specific policy for the Windows and Linux deployment scenarios that we're about to introduce.

Windows deployment

In this section, we'll learn how to deploy our `HealthCheck` web application on a Windows 2019 DataCenter Edition server hosted on MS Azure.

Here's what we're going to do:

- **Create a new VM on MS Azure** using the Windows 2019 Datacenter Edition template and configure it to accept inbound calls to TCP ports 3389 (for Remote Desktop) and 443 (for HTTPS)
- **Configure the VM** by downloading and/or installing all the necessary services and runtimes to host the `HealthCheck` app
- **Publish the HealthCheck app** to the web server we've just set up
- **Test the HealthCheck app** from a remote client

Let's get to work!



In this deployment example, we're going to set up a brand new VM on the MS Azure platform, which requires some additional work; those users who already have a production-ready Windows server should likely skip the paragraphs related to the VM setup and go directly to the publishing topics.

Creating a Windows Server VM on MS Azure

If we remember our journey through MS Azure in Chapter 4, *Data Model with Entity Framework Core*, when we deploy an SQL Database there, we should already be prepared for what we're going to do:

- Access the MS Azure portal
- Add and configure a new VM
- Set the inbound security rules to access the VM from the internet.

Let's do this.

Accessing the MS Azure portal

As usual, let's start by visiting the following URL, which will bring us to the MS Azure website: <https://azure.microsoft.com/>

Again, we can either log in using an already-existing MS Azure account or create a new one (possibly taking the chance to use the free 30-day trial, if we haven't used it already).

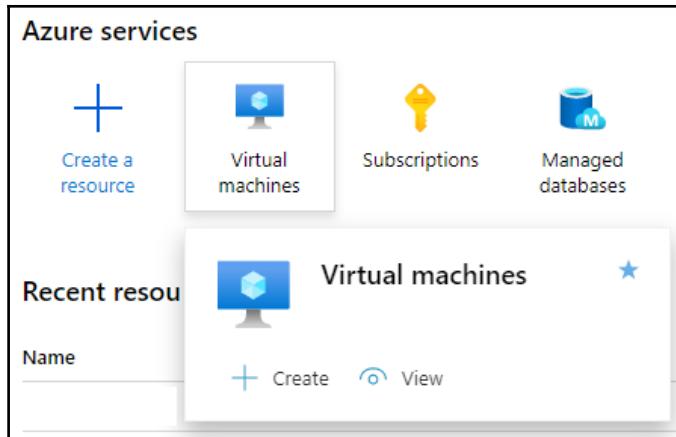


Refer to Chapter 4, *Data Model with Entity Framework Core*, for additional information on creating a free MS Azure account.

As soon as we have created the account, we can go to <https://portal.azure.com/> to access the MS Azure administration portal, where we can create our new VM.

Adding and configuring a new VM

Once logged in, click on the **Virtual machines** icon (refer to the following screenshot):



From the next page, click **Add** (near the top-left corner of the page) to access the **Create a virtual machine** panel.

The **Create a virtual machine** panel is basically a detailed wizard that allows us to configure a new VM from scratch. The various configuration settings are split into a number of panels, each one dedicated to a specific set of capabilities, as shown in the following screenshot:

The screenshot shows the Microsoft Azure 'Create a virtual machine' wizard. The title bar says 'Microsoft Azure'. The breadcrumb navigation shows 'All services > Virtual machines > Create a virtual machine'. The main title is 'Create a virtual machine'. Below it, a navigation bar has 'Basics' selected, along with 'Disks', 'Networking', 'Management', 'Advanced', 'Tags', and 'Review + create'. A descriptive text block says: 'Create a virtual machine that runs Linux or Windows. Select an image from Azure marketplace or use your own customized image. Complete the Basics tab then Review + create to provision a virtual machine with default parameters or review each tab for full customization.' It also links to 'Create VM from Azure Marketplace'. The 'Project details' section asks to select a subscription and resource group. The 'Subscription' dropdown is set to 'Pay-As-You-Go'. The 'Resource group' dropdown is set to 'PacktPub' with a 'Create new' link. The 'Instance details' section includes fields for 'Virtual machine name' (set to 'HealthCheck'), 'Region' (set to '(Europe) West Europe'), 'Availability options' (set to 'No infrastructure redundancy required'), and 'Image' (set to 'Windows Server 2019 Datacenter'). There is also a link to 'Browse all public and private images'. Under 'Azure Spot instance', there is a radio button for 'Yes' (unchecked) and 'No' (checked). The 'Size' section shows 'Standard B1ms' with a note: '1 vcpu, 2 GiB memory (17,38 €/month)' and a 'Change size' link.

Here's a brief summary of the various settings panels:

- **Basics:** Subscription type, VM name, deployment region, image, login credentials, and so on
- **Disks:** The number and capacity of HDD/SDD to provide the VM with
- **Networking:** Network-related configuration settings
- **Management:** Monitoring features, auto-shutdown capabilities, backup, and more
- **Advanced:** Additional configuration, agents, scripts, extensions, and the like
- **Tags:** These allow some name-value pairs that can be useful in categorizing the various MS Azure resources to be set

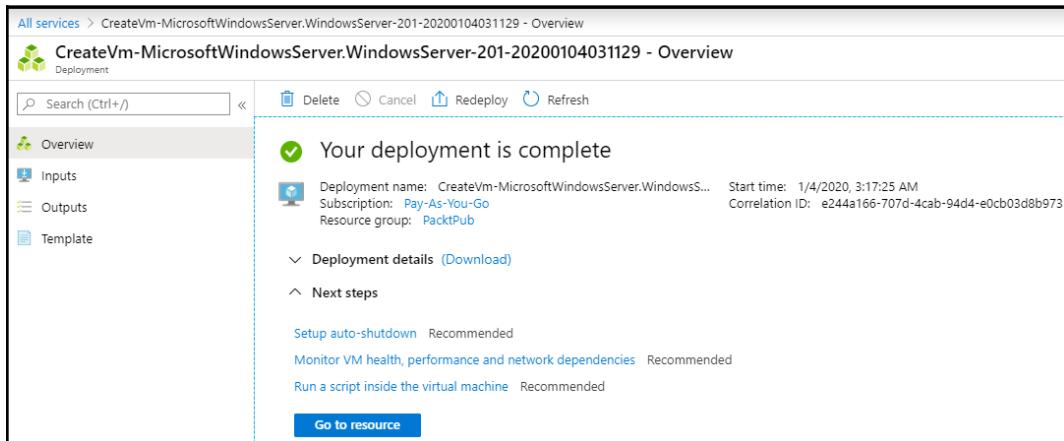
In our current scenario, we just have to slightly modify the first four tabs, leaving the remaining ones as their default settings.

- In the **Basics** tab:
 - **Resource group:** Use the same resource group used for the SQL Database (or create a new one).
 - **Virtual machine name:** Use `HealthCheck` (or any other suitable name).
 - **Region:** Choose the region closest to our geographical position.
 - **Availability options:** No infrastructure redundancy required.
 - **Image:** In our example, we're going to use the Windows Server 2019 Datacenter default image; feel free to use it as well or pick another one.
 - **Azure Spot instance:** No.
 - **Size:** Standard B1ms (1 vcpus, 2 GiB memory). Feel free to choose a different size if we're willing to spend more: the B1ms is an entry-level machine featuring a very limited set of resources that will suffice for this deployment sample, but won't perform well in production.
 - **Administrator account:** Select the Password authentication type, and then create a suitable username and password set. Remember to write these down in a secure place, since we'll definitely need these credentials to access our machine in a while.

- **Public inbound ports:** None (for the time being; we're going to set them up later on in a more secure way).
- In the **Disk** tab:
 - **OS disk type:** Select *Standard HDD*; this is the cheapest available choice.
 - **Data disks:** Create a new *Standard HDD* (or Premium SSD, if we're willing to pay some extra bucks) disk for the OS, with no additional data disks.
- In the **Network** tab:
 - **Virtual Network:** Select the same VNET used for the SQL Database (or create a new one).
- In the **Management** tab:
 - **Monitoring | Boot diagnostics:** Off.

Once done, click the **Review + create** button to review our configuration settings and initiate the VM deployment process.

At the end of the process, we should see a screenshot along the lines of the following:



From there, we can click the **Go to resource** button to access the *Virtual Machine* overview panel.

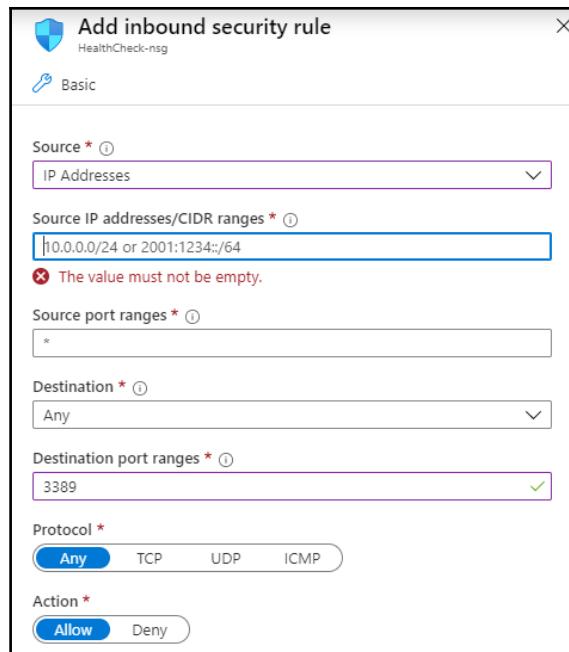
Setting the inbound security rules

Go to the **Settings | Networking** tab and take note of the machine's public IP address; we will need this in a short while. Once done, add the following inbound security rules:

- **TCP and UDP port 3389**, so that we'll be able to access the machine using Remote Desktop
- **TCP port 443**, to access the HTTP Server (and our `HealthCheck` web app) from the internet

For this deployment test, it's strongly advisable to restrict access to these inbound rules to a secure **source IP address** (or address range), which can be set to either our static IP address or our ISP's IP mask. Such a setting will ensure that no third parties will be able to attempt Remote Desktop access or visit our web application.

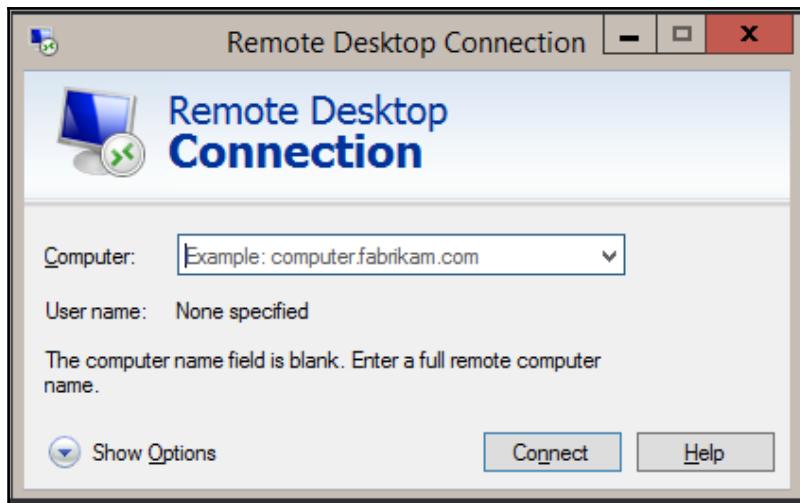
The following screenshot depicts the **Add inbound security rule** panel on the Azure VM portal, which will open when clicking on the corresponding button:



Now, we should be able to access our new VM with a standard Remote Desktop connection from our development system.

Configuring the VM

With TCP port 3389 open, we can launch the **Remote Desktop Connection** built-in tool from our local Windows-based development machine. Type in the public IP address of the Azure VM and click **Connect** to initiate an RDC session with our remote host:



If the inbound security rule has been properly configured, we should be able to connect to our new VM's desktop and set up our VM for serving our ASP.NET Core and Angular `HealthCheck` web application. Doing this requires a series of configuration tasks that will be described in the next sections.

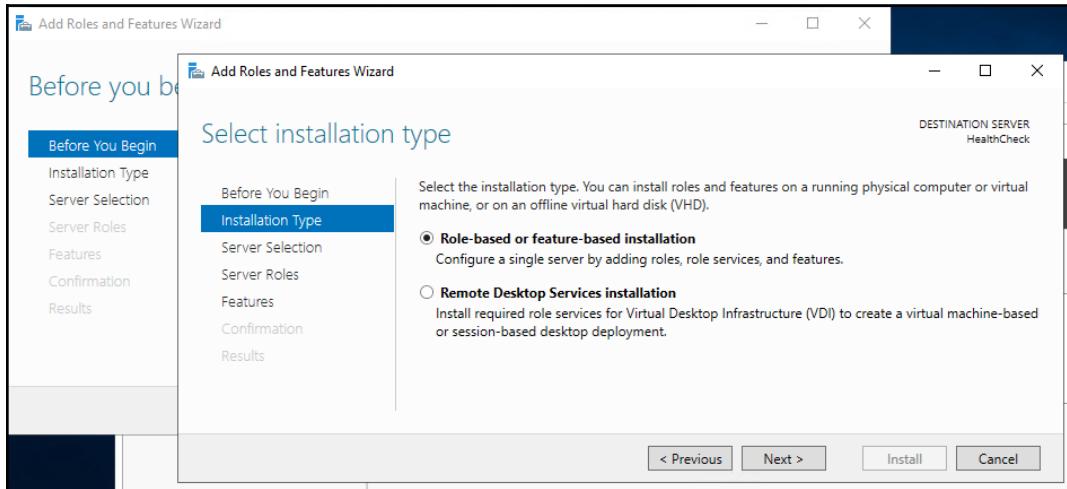
The first step, which we'll be dealing with in the following section, will be installing **Internet Information Services (IIS)**, a flexible, secure, and manageable HTTP Server that we'll use to host our ASP.NET Core and Angular application over the web.



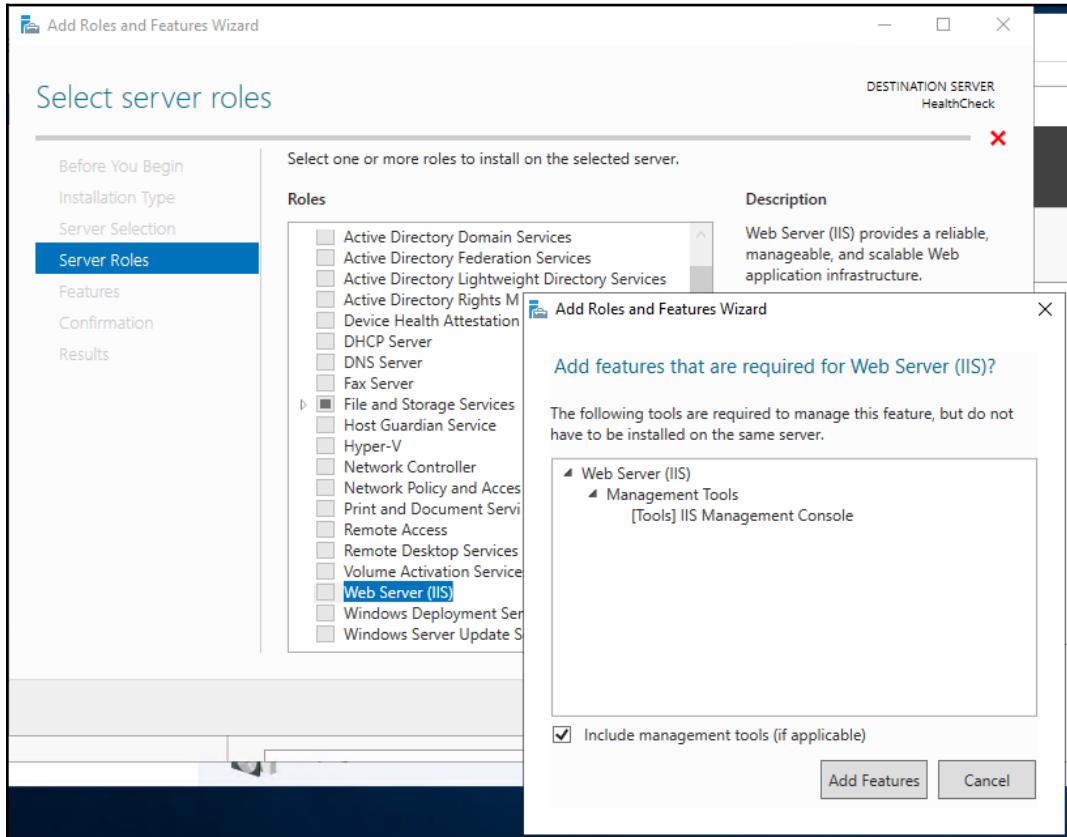
For obvious reasons of space, we're not going to talk about IIS or explore its functionalities. For additional information regarding this, check out the following URL:
<https://www.iis.net/overview>.

Adding the IIS web server

Once connected via Remote Desktop, we can access **Control Panel | Program and Features | Turn Windows features on and off** (or the **Add Roles and Features Wizard** from the **Server Manager dashboard**) to install IIS to the VM, as shown in the following screenshot:



From the various roles available, select **Web Server (IIS)**, as shown in the following screenshot. Be sure that the **Include management tools** checkbox is checked, and then click **Add Features** to start installing it:



There's no need to change anything until the end of the installation phase, the default settings will work just fine for our deployment scenario.

Installing the ASP.NET Core Windows hosting bundle

Once IIS has been installed, we can proceed with downloading and installing the **ASP.NET Core Runtime**.



It's strongly advisable to install the ASP.NET Core runtime after installing IIS because the package bundle will perform some modifications to the IIS default configuration settings.

To download the ASP.NET Core Runtime, visit the following URL: <https://dotnet.microsoft.com/download/dotnet-core/3.1>

Be sure to pick the **ASP.NET Core 3.1.1 Runtime – Windows Hosting Bundle Installer** package for **Windows x64**, as shown in the following screenshot:

Run apps - Runtime ⓘ

ASP.NET Core Runtime 3.1.1

The ASP.NET Core Runtime enables you to run existing web/server applications. **On Windows, we recommended installing the Hosting Bundle which includes the .NET Core Runtime and IIS support.**

IIS runtime support (ASP.NET Core Module v2)
13.1.19350.1

OS	Installers	Binaries
Linux	Package manager instructions	ARM64 Alpine ARM32 ARM64 x64 Alpine x64
macOS		x64
Windows	x64 x86 Hosting Bundle	ARM32 x64 x86

A bundle such as this includes the .NET Core runtime, the ASP.NET Core runtime, and the ASP.NET Core IIS module, everything we need to run our .NET Core and Angular app from our VM.

Restarting IIS following ASP.NET Core runtime installation

Once the ASP.NET Core runtime installation process is complete, it's strongly advisable to issue a stop/start command to restart the IIS service.

To do this, open a Command Prompt window with administrative rights and execute the following console commands:

```
> net stop was /y  
> net start w3svc
```

These commands will allow IIS to pick up a change to the system PATH made by the Windows hosting bundle installer.

Publishing and deploying the HealthCities app

Now, we must find a way to publish the HealthCities app and deploy it to our server. There are a number of alternative options to do this, including the following:

- Use our existing **Folder publish profile** and then copy the files to the web server somehow.
- Install an FTP/FTPS server on our web server and then set up an **FTP publish profile**.
- Use Visual Studio's **Azure Virtual Machine publish profile**.

The latter option is arguably the most obvious choice. However, the other alternatives are perfectly fine as well, as long as we can handle them properly.

Folder publish profile

Since we've created a **Folder publish profile** in Chapter 11, *Progressive Web Apps*, we're going to use it here as well.

If we want to create a new one, here's what we need to do:

1. Select the **Folder** option (or select the previous publishing profile).
2. Specify the path of the folder that will contain the published application.
3. Click the **Create Profile** button to create the profile.
4. Click the **Publish** button to deploy our HealthCheck app to the chosen local folder.



Visual Studio will suggest a path located within the application's `/bin/Release/` subfolder; we can either use this or choose another folder of our choice.

Otherwise, we can just click the **Publish** button for our existing profile to get the job done that way.

When the publishing task is complete, we can copy the whole `HealthCheck` folder inside the `C:\inetpub\` folder of the remote VM. A simple way to do this is by using the Remote Desktop resource-sharing feature, which allows our local HDD to be accessed from a remote instance.

FTP publish profile

If our web server can accept FTP (or FTPS) connections, then a suitable alternative way of publishing our project is to create an FTP-based *Publish Profile* that will automatically upload our web project to our web server using the FTP/FTPS protocol.



If we don't want to use the built-in FTP server provided by Windows Server, we can install a third-party FTP server, such as Filezilla FTP Server, a great open source alternative that comes with full FTPS support. You can find Filezilla FTP Server at the following URL:

<https://filezilla-project.org/download.php?type=server>

To make use of the FTP publish profile, we'll also need to open our VM's TCP port 21 (or another nondefault port) by adding another inbound security rule, just like we did with ports 443 and 3389.

All we need to do is link the FTP destination folder to a new website project using IIS, and we'll be able to publish/update our website in real-time fashion, as everything will be put online as soon as the publishing task is complete.



As we said earlier, we're doing all this assuming that we have a web server accessible through FTP or that we're willing to install an FTP server. If that's not the case, we might as well skip this paragraph and use a different publishing profile, such as Azure Virtual Machine or Folder.

To set up the FTP publishing profile, select the IIS, FTP, and the other icons, wait for the wizard-like modal window to appear, and then select the following options:

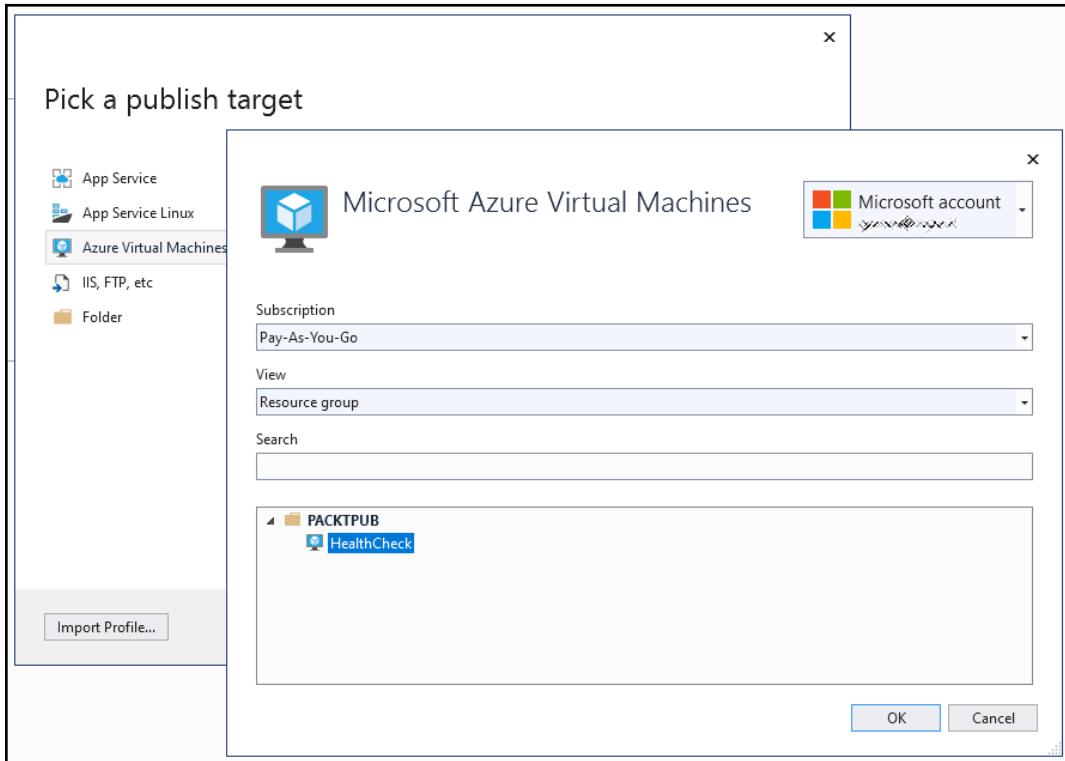
- **Publish method:** Select FTP.
- **Server:** Specify the FTP server URL, such as `ftp.our-ftp-server.com`.
- **Site path:** Insert the target folder from the FTP server root, such as `/TestMakerFree/`. We can also avoid the slashes, as the tool will handle them automatically.
- **Passive Mode, Username, Password:** Set these values according to our FTP server settings and given credentials. Activate **Save Password** if we want to let Visual Studio store it, so we won't have to write it with each publishing attempt.
- **Destination URL:** This URL will be automatically launched as soon as the publishing task successfully ends using the default browser. It's often wise to set it to our web application's base domain, such as `www.our-website-url.com`, or to leave it empty.

Once done, click on the **Validate Connection** button to check the preceding settings and ensure that we're able to reach the server through FTP. In case we aren't, it might be wise to perform a full-scale network check, looking for firewalls, proxies, antivirus, or other software that can prevent the FTP connection from being established.

Azure Virtual Machine publish profile

The **Azure Virtual Machine** publish profile is a great way to enforce the **Continuous Integration** and **Continuous Delivery (CI/CD)** DevOps pattern because it will either act as a build system (for producing packages and other build artifacts) or a release management system to deploy our changes.

To use this, select the **Azure Virtual Machine** option, click **Browse**, and then select the VM that we created a moment ago (see the following screenshot):



However, in order to do this, we need to perform some additional configuration changes to our VM, including the following:

- Install the **WebDeploy** service tool (just like we did with IIS early on)
- Open the 80 and 8172 TCP ports (just like we did with 443 and 3389 a while ago)
- Set up a **globally unique DNS name** for the VM: this can be done from the MS Azure portal's **Overview** page of our VM (DNS name property)

For reasons of space, we won't go through these settings. However, for additional information regarding the preceding tasks, check out the following guide: <https://github.com/aspnet/Tooling/blob/AspNetVMs/docs/create-asp-net-vm-with-webdeploy.md>

Once we're done with these settings, we'll be able to publish our web application to the VM in a seamless and transparent manner.

Configuring IIS

Now that our web application's files have been copied to the server, we need to configure IIS to publish it.

In this section, we're going to configure the IIS service to make it serve our `HealthCheck` web app using the in-process hosting model, which has been made available since ASP.NET Core 2.2 and is a significant improvement over the previous out-of-process model.

To quickly summarize the differences between the two hosting models, we can say the following:

- In the **out-of-process** hosting model, IIS proxies the HTTP requests to the ASP.NET Core Kestrel server, which directly serves the app using a different TCP port (for internal use only): in other words, IIS acts as a reverse proxy.
- In the **in-process** hosting model, the ASP.NET Core application is hosted inside an IIS application pool; therefore, all the HTTP requests are directly handled by IIS, without being proxied to an external `dotnet.exe` instance running the .NET Core native Kestrel web server.

As a matter of fact, the in-process model doesn't use Kestrel at all, replacing it with a new webserver implementation (`IISHttpServer`) that is hosted directly inside the IIS application pool. Therefore, we could say that this new model is somewhat similar to the classic ASP.NET hosting model that we've been used to since ASP.NET version 1.x (and then 2.x, up to 4.x).

The in-process model is the default method for ASP.NET Core 3.1 projects, and it's often a better approach when it comes to serving ASP.NET Core web applications, providing us with the following benefits:

- It provides better performances since, instead of using Kestrel, it relies on a custom `IISHttpServer` implementation that directly interfaces with the IIS request pipeline
- It's less resource intensive, as it avoids the extra network hop between IIS and Kestrel

In the following section, we'll see how to configure it properly.

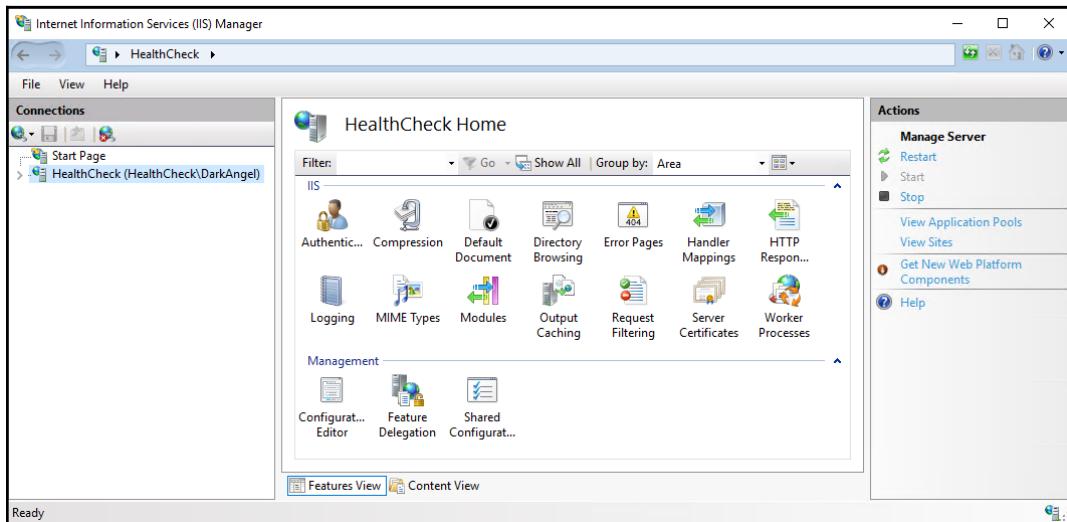
Adding an SSL certificate

Since our app will be served using HTTPS, we have two choices:

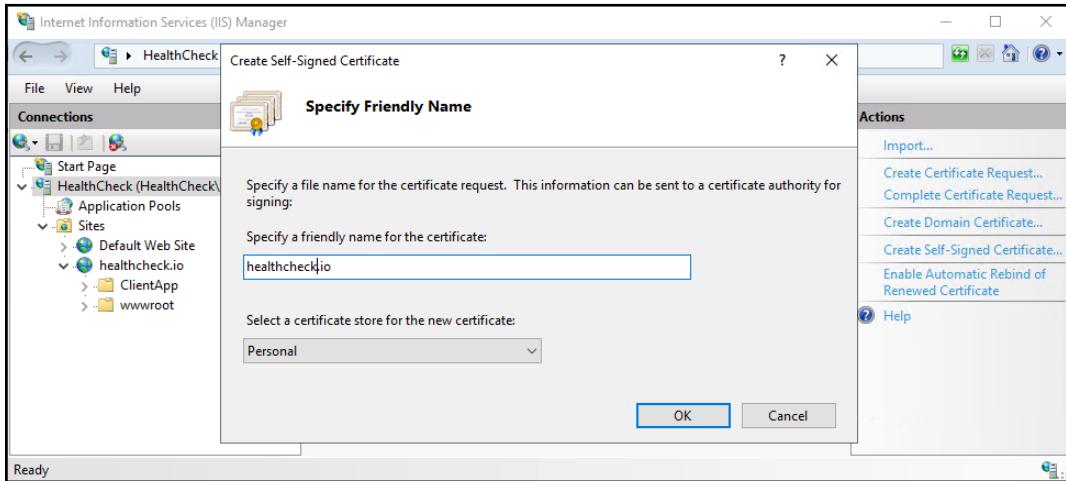
- Purchase and install an SSL certificate from a third-party reseller.
- Create a self-signed one.

For actual production scenarios, we should definitely follow the former path; however, in our deployment sample, we're going to take the self-signed route, which provides a faster (and no-cost) alternative to achieve our goal. Observe the following steps:

1. Open the **Internet Information Services (IIS) Manager** desktop app, select the **HealthCheck** node from the tree view on the left, and then click the **Server Certificates** icon, as shown in the following screenshot:



2. Once in the **Server Certificates** panel, click the **Create Self-Signed Certificate** link in the **Actions** column on the right.
3. A modal window will appear (see the following screenshot), where we'll be asked to specify a friendly name for the certificate. Type `healthcheck.io`, select the **Personal** certificate store, and then click **OK** to create the self-signed certificate:

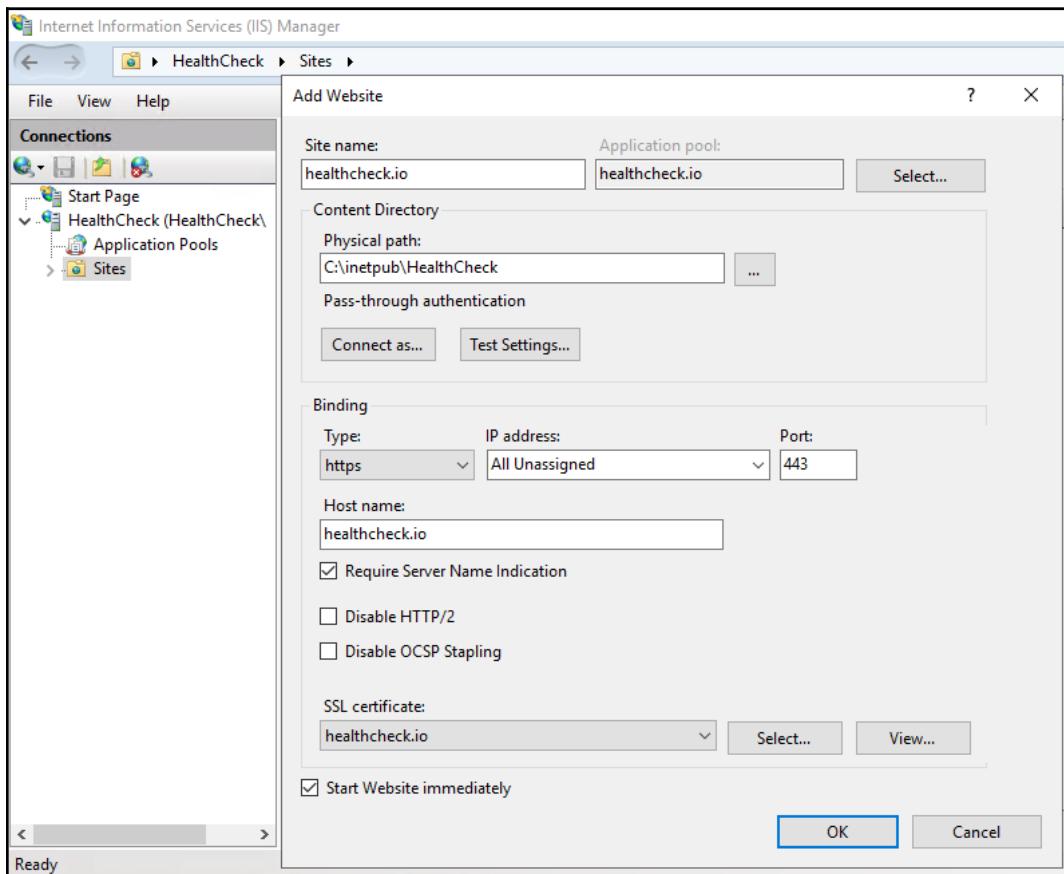


Once done, we can finally add the `HealthCheck` website entry to IIS.

Adding a new IIS website entry

From the **Internet Information Services (IIS) Manager** main page, right-click on the `HealthCheck` root node and select the **Add Website** option to create a new website.

Fill out the **Add Website** modal window, as shown in the following screenshot:



Here's a summary of the most relevant settings:

- **Site name:** healthcheck.io
- **Physical path:** C:\inetpub\HealthCheck (the path where we've copied our development machine's local deployment folder)
- **Binding Type:** https
- **IP Address:** All Unassigned
- **Port:** 443
- **Hostname:** healthcheck.io
- **Require Server Name Indication:** Yes
- **Disable HTTP/2:** No
- **Disable OCSP Stapling:** No
- **SSL certificate:** healthcheck.io (the self-signed certificate we created a moment ago)
- **Start Website immediately:** Yes

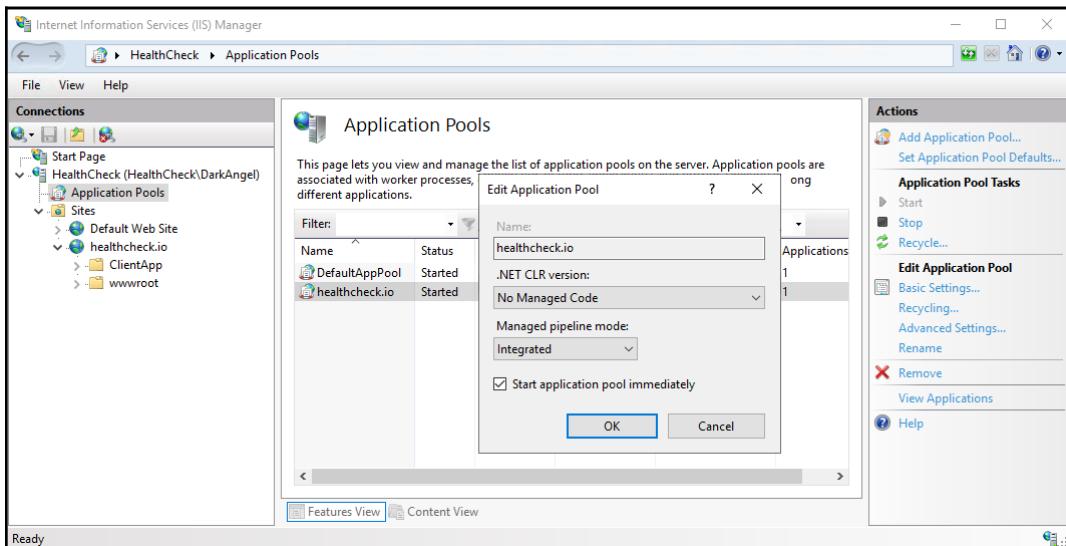
Once done, click **OK** to add the new website: a new healthcheck.io entry will appear in the tree view on the right within the HealthCheck/Sites folder.

Configuring the IIS application pool

As you may already know, the IIS service runs the various configured websites under one or more application pools. Each application pool configured will spawn a dedicated w3wp.exe Windows process that will be used to serve all the websites that have been configured to use it.

Depending on the publishing requirements of the various websites we need to host, we could run all websites in a few application pools (or even a single one) or each one with its own application pool. Needless to say, all the websites that share the same application pool will also share its various settings, such as memory usage, pipeline mode, identity, and idle timeout.

In our specific scenario, when we created our `healthcheck.io` website in the previous section, we chose to create a dedicated application pool with that same name, being it the IIS default behavior. Therefore, in order to configure the website's application pool settings, we need to click on the Application Pools folder from the tree view on the left and then double-click the `healthcheck.io` entry from the Application Pools list panel, as shown in the following screenshot:



In the **Edit Application Pool** modal window, choose the following settings, as shown in the preceding screenshot:

- **.NET CLR version: No Managed Code**
- **Managed pipeline mode: Integrated**

We might be wondering why we're choosing **No Managed Code** since we're clearly using the ASP.NET Core CLR. The answer is simple: since ASP.NET Core runs in a separate process and IIS, there's no need to set any .NET CLR version on IIS.



For additional information regarding the ASP.NET Core hosting model on IIS, including the various differences between the in-process and out-of-process hosting models, check out the following URL:

<https://docs.microsoft.com/en-us/aspnet/core/host-and-deploy/iis/>

Testing the HealthCheck web application

Our web application should now be ready to receive HTTP requests from our remote machine.

However, since we've configured it to accept the HTTP requests addressed to the `healthcheck.io` hostname instead of a numeric IP, we need to find a way to map that hostname to our remote VM's IP address from the Windows-based development machine where we'll perform our tests.

The easiest and most effective way to achieve such a result on any Windows system is by editing the `Windows\System32\drivers\etc\hosts` file, which is used by the operating system to ultimately map hostnames to IP addresses before (and instead of) resolving them through the DNS lookup.



For additional information about the Windows HOSTS file, read the following URL:

[https://en.wikipedia.org/wiki/Hosts_\(file\)](https://en.wikipedia.org/wiki/Hosts_(file))

Updating the testing machine's HOST files

To alter the Windows HOST file, we need to open the following file with a text editor such as `notepad.exe`: `C:\Windows\System32\drivers\etc\hosts`

Then, we need to add the following entry:

VM. IP. ADDRESS healthcheck.io



In order to edit the Windows HOST file, we'll need to acquire administrative privileges for it; otherwise, we won't be able to permanently change it on disk.

Replace the preceding `VM. IP. ADDRESS` placeholder with the VM's external IP file so that Windows will map the `healthcheck.io` hostname to it, ignoring the default DNS resolution: in other words, the preceding line will send all HTTP requests addressing the `healthcheck.io` hostname to our VM, even if we don't own that domain name. As a matter of fact, that's an easy and effective way to test our app using a real hostname (instead of a mere IP address) without having to actually purchase a domain.

Testing the app with Google Chrome

Now, we can finally launch our favorite web browser and call the following URL: <https://healthcheck.io>



For the sake of simplicity, we're going to use Google Chrome so that we'll be able to immediately check out the Web App Manifest file and the service worker, just like we did with the "local" publishing test that we performed in Chapter 11, *Progressive Web Apps*.

If we did everything correctly, we should be able to see our **HealthCheck** web application in all its glory:

The screenshot shows a Google Chrome window with the URL <https://healthcheck.io> in the address bar. The main content area displays the text "Hello, world!" and a welcome message: "Welcome to your new single-page application, built with:

- ASP.NET Core and C# for cross-platform server-side code
- Angular and TypeScript for client-side code
- Bootstrap for layout and styling

To help you get started, we've also set up:

- Client-side navigation.** For example, click Counter then Back to return here.
- Angular CLI integration.** In development mode, there's no need to run `ng serve`. It runs in the background and is dynamically built on demand and the page refreshes when you modify any file.
- Efficient production builds.** In production mode, development-time features are disabled, and your `dotnet publish` invokes `ng build` to produce minified, ahead-of-time compiled JavaScript files.

The `ClientApp` subdirectory is a standard Angular CLI application. If you open a command prompt in that directory, you can run `ng test`, or use `npm` to install extra packages into it."

Below the main content, the DevTools Application tab is selected. The sidebar shows the following sections: Application (selected), Elements, Sources, Console, Network, Performance, Memory, Application, Security, Audits. Under Application, the Service Workers section is expanded, showing a list of workers. One worker, "ngsw-worker.js", is listed with the following details:

- Source: [ngsw-worker.js](#)
- Received: 4/1/2020, 04:20:23
- Status: #1214 activated and is running [stop](#)
- Clients: <https://healthcheck.io/> focus

Other than seeing the home view, we should also be able to see the following:

- The app manifest file (with all the HC icons) in the **Application | Manifest** panel of the Google Chrome Development console
- The service worker properly registered in the **Application | Service Workers** panel of the Google Chrome Development console
- The *send this page* and *install* icons in the rightmost part of the browser's address bar



In order to see those panels, remember to press *Shift + Ctrl + J* to bring the Google Chrome Development console into view.

From there, we can now install the app and check/uncheck its offline status to test the service worker's behavior, just like we did in [Chapter 11, Progressive Web Apps](#), when we tested our published app from a standard Visual Studio debug run: if we did everything properly, everything should work and behave in the same way.

With this, we've completed our Windows deployment journey; our `HealthCheck` web app has achieved its ultimate goal.

In the next section, we'll learn how to deploy our `WorldCities` web app to a completely different Linux machine.

Linux deployment

Throughout this section, we'll learn how to deploy our `WorldCities` web application on a CentOS 7.7 Linux server hosted on MS Azure.

More precisely, here's what we're going to do:

- **Create a new VM on MS Azure** using the CentOS-based 7.7 template
- **Configure the VM to accept inbound calls** to TCP ports 3389 (for Remote Desktop) and 443 (for HTTPS)
- **Adapt the `WorldCities` app** for the Nginx+Kestrel edge-origin hosting model
- **Publish the `WorldCities` app** to the webserver we've just set up
- **Test the `WorldCities` app** from a remote client

Let's get to work!



It's worth noting that the CentOS 7.7 template that we're going to use in this deployment sample can be easily replaced—with minor variations—with any other Linux VM template available on MS Azure.

Needless to say, those who already have a production-ready Linux server could probably skip the paragraphs related to the VM setup and go directly to the following publishing topics.

Creating a Linux CentOS VM on MS Azure

Once again, we need to perform the following steps:

- **Access the MS Azure portal**
- **Add and configure a new VM**
- **Set the inbound security rules** to access the VM from the internet

However, since we've already explained the MS Azure VM creation process with the Windows Server early on in this chapter, we're going to briefly summarize all the common tasks and avoid resubmitting the same screenshots.



Those who require additional explanations regarding the various required steps can check out the *Creating a Windows Server VM on MS Azure* section.

Let's go back to MS Azure once more!

Add and configure the CentOS 7.7 VM

Once again, we need to log in to MS Azure using our (existing or new) account and access the MS Azure portal administration dashboard.

Right after that, we can click on the virtual machine icon and click **Add** to access the **Create a virtual machine** panel and enter the following settings.

- In the **Basics** tab:
 - **Resource group:** Use the same resource group used for the SQL Database (this is mandatory unless our database is not there).
 - **Virtual machine name:** Use WorldCities (or any other suitable name).
 - **Region:** Choose the region closest to our geographical position.
 - **Availability option:** No infrastructure redundancy required.
 - **Image:** In our example, we're going to use the CentOS-based 7.7 default image; alternatively, we can choose any other Linux-based VM template as long as we're willing, and able, to adapt the following instructions to the (arguably minor) differences between different Linux distributions.
 - **Azure Spot instance:** No.
 - **Size:** Standard B1ms (1 vcpus, 2 GiB memory). Feel free to choose a different size if we're willing to spend more: *B1ms* is an entry-level machine featuring a very limited set of resources that will suffice for this deployment sample, but which won't perform well in production.
 - **Administrator account:** Select the Password authentication type, and then create a suitable username and password set. Remember to write these down in a secure place, since we'll definitely need these credentials to access our machine in a while.
 - **Public inbound ports:** None (for the time being, we're going to set them up later on in a more secure way).
- In the **Disk** tab:
 - **OS disk type:** Select *Standard HDD*; this is the cheapest available choice
 - **Data disks:** Create a new *Standard HDD* (or Premium SSD, if we're willing to pay some extra bucks) disk for the OS, with no additional data disks

- In the **Network** tab:
 - **Virtual Network:** Select the same VNET used for the SQL Database (or create a new one)
- In the **Management** tab:
 - **Monitoring | Boot diagnostics:** Off

Once done, click the **Review + create** button to review our configuration settings and initiate the VM deployment process.

Once deployment is complete, we can click the **Go to Resource** button to access the *Virtual Machine* overview panel.

Setting the inbound security rules

Go to the **Settings | Networking** tab and take note of the machine's public IP address. Then, add the following inbound security rules:

- **TCP port 22**, so that we'll be able to access the machine using the Secure Shell protocol (also known as *SSH*)
- **TCP port 443**, to access the HTTP server (and our `WorldCities` web app) from the internet

Again, be sure to restrict access to these inbound rules to a secure **Source IP address** (or address range), which can be set to either our static IP address or our ISP's IP mask.

Configuring the Linux VM

Now, we can use the SSH protocol to access our new Linux VM and perform two different (yet both required) sets of tasks:

- **Set up and configure the VM** by installing the various required packages (the ASP.NET Core runtime, the Nginx HTTP Server, and the like)
- **Publish the `WorldCities` folder** (and the entirety of its contents) generated from the publish profile that we set up in Chapter 11, *Progressive Web Apps*

From the former set of tasks, we're going to use **Putty**, a free SSH client for Windows that can be used to remotely access a Linux machine's console. The latter will be handled with Secure Copy (aka **SCP**), a Windows command-line tool that allows files to be copied from a (local) Windows system to a remote Linux machine.

Putty can be downloaded and installed from the following URL:

<https://www.putty.org/>

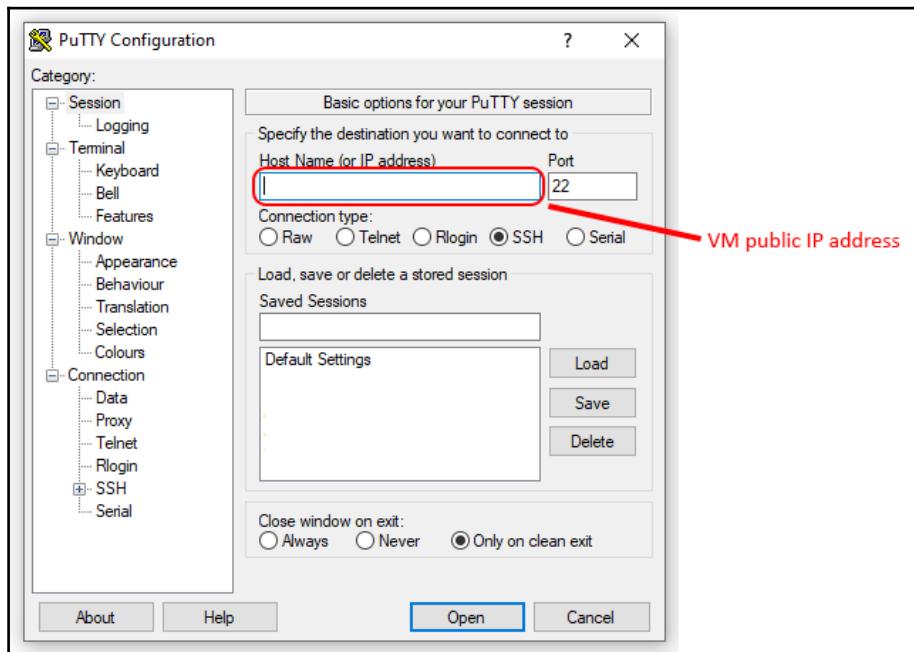


The **SCP** command-line tool is already shipped with most Windows versions, including Windows 10; for additional information on it, visit the following URL:

<https://docs.microsoft.com/en-us/azure/virtual-machines/linux/copy-files-to-linux-vm-using-scp>

Connecting to the VM

- Once installed, launch Putty and insert the VM public IP address, as shown in the following screenshot:



- Once done, click **Open** to launch the remote connection.

We'll be asked to accept the public SSH key. Once accepted, we'll be able to authenticate ourselves with the username and password specified a short time ago in MS Azure Portal's Virtual Machine setup wizard:



Once connected, we'll be able to issue terminal commands on the remote VM to set up and configure it according to our needs.

Installing the ASP.NET runtime

Once we've successfully logged in to the Linux VM terminal, we can start to configure the remote system to enable it to run (and host) ASP.NET Core applications. To achieve this, the first thing to do is to download and install the ASP.NET Core runtime.

However, before we can do that, we need to execute the following required steps:

- Register the Microsoft key
- Register the product repository
- Install the required dependencies

These steps need to be done once per Linux machine. Luckily enough, all of them can be done with the following command:

```
$ sudo rpm -Uvh https://packages.microsoft.com/config/centos/7/  
packages-microsoft-prod.rpm
```

Once this is done, we'll be able to install the ASP.NET Core 3.1 runtime in the following way:

```
$ sudo yum install aspnetcore-runtime-3.1
```



Alternatively, if we don't want to install the .NET Core runtime on the Linux server, we could publish the app as a **Self-Contained Deployment (SCD)**, as explained in the first section of this chapter.

Installing Nginx

The next step involves installing the Nginx server package. Again, before being able to do this, we need to add the CentOS 7 EPEL repository, which is required for yum to find the Nginx package to install:

```
$ sudo yum install epel-release
```

Once this is done, we can install the Nginx HTTP server—which we're going to use to serve our web application by reverse-proxying the Kestrel service in the following way:

```
$ sudo yum install nginx
```

For additional information about installing an ASP.NET Core web application on Linux with Nginx, check out the following URLs:



<https://docs.microsoft.com/en-us/dotnet/core/install/linux-package-manager-centos7>

<https://docs.microsoft.com/en-us/aspnet/core/host-and-deploy/linux-nginx>

Starting up Nginx

When we install IIS on Windows, the service will start automatically and will be configured with an automatic start up type by default. Conversely, Nginx does not start on its own and won't be executed automatically upon startup.

To start Nginx, execute the following command:

```
$ sudo systemctl start nginx
```

To set Nginx to run automatically on system startup, use the following command:

```
$ sudo systemctl enable nginx
```

After applying these settings, it would be wise to reboot the Linux machine to be sure that all the configured settings will be applied upon reboot.

Checking the HTTP connection

The CentOS7-based MS Azure VM template that we've used in this deployment scenario doesn't come with a local firewall rule blocking TCP port 443. Therefore, as soon as Nginx is up and running, we should be able to connect to it properly by typing the VM's public IP address in the browser's address bar from our development machine.

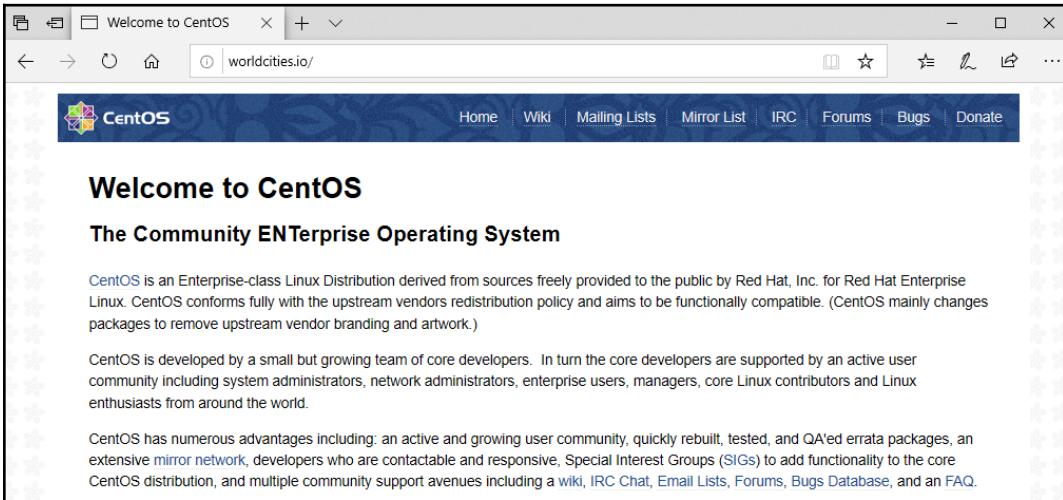
While we're there, instead of using the numeric IP address directly, we can take the chance to add another mapping to the Windows

C:\Windows\System32\drivers\etc\hosts file:

```
VM.IP.ADDRESS      worldcities.io
```

Here, we replace the preceding VM.IP.ADDRESS placeholder with the VM's external IP file so that Windows will map the worldcities.io hostname to it (as already explained in the Windows deployment section).

Once done, we should be able to connect to the VM's Nginx HTTP server using that hostname address, as shown in the following screenshot:



As we can see from the preceding screenshot, we can skip the following paragraph and move on to the next. Conversely, if the connection cannot be established, we might have to perform some additional steps to open the VM's TCP 443 port.



Before altering the VM firewall rules, it might be wise to carefully check for the TCP 443 inbound security rule that we should have set on the MS Azure portal administration site, as explained in the *Setting the inbound security rules* section.

Opening the 443 TCP port

Depending on the Linux template chosen, it could be necessary to change the local firewall settings to allow incoming traffic for the 443 TCP port. The commands required to do this might vary, depending on the built-in firewall abstraction layer shipped with the Linux distributions.

In Linux, the Kernel-based firewall is controlled by `iptables`; however, most modern distributions commonly use either the `firewalld` (CentOS, RHEL) or `ufw` (Ubuntu) abstraction layers to configure `iptables` settings.



In a nutshell, both `firewalld` and `ufw` are firewall-management tools that can be used by the system administrators to configure the firewall features using a *managed* approach. We can think of them as *front-ends* for the Linux kernel's networking internals.

In VM Azure's CentOS7-based Linux template, `firewalld` is present, but it's usually disabled (although it can be started and/or enabled to have it automatically run on each startup); however, if we're using a different template/VM/Linux distribution, it might be useful to spend a couple of minutes learning how we can properly configure these tools.

firewalld

Here's the command to check whether `firewalld` is installed:

```
$ sudo firewall-cmd --state
```

If the command returns something other than *not running*, this means that the tool is installed and active. Therefore, we need to execute the following `firewalld` commands to open TCP port 443:

```
$ sudo firewall-cmd --permanent --add-port=443/tcp  
$ sudo firewall-cmd --reload
```

The `--reload` command is required to immediately apply the `firewalld` settings without having to issue a reboot.

ufw

Here's the command to check whether `ufw` is running:

```
$ sudo ufw status
```

If the preceding command returns something other than *command not found*, this means that the tool is installed and running.

Here's the `ufw` required terminal command to open TCP port 443:

```
$ sudo ufw allow 443/tcp
```

After executing these commands, we should be able to connect the Nginx HTTP server from our developer machine.

Adapting the WorldCities app

Before publishing the `WorldCities` app to the Linux VM, we need to ensure that our web application is properly configured to be served through a reverse proxy.

In order to do this, we need to use the **Forwarded Headers Middleware** from the `Microsoft.AspNetCore.HttpOverrides` package.

When HTTPS requests are proxied over HTTP using an edge-origin technique, such as the one we're pulling off with Kestrel and Nginx, the originating client IP address, as well as the original scheme (HTTPS) are lost between the two actors. Therefore, we must find a way to forward this information. If we don't do this, we could run into various issues while performing routing redirects, authentication, IP-based restrictions or grants, and so on.



The most convenient way to forward this data is to use the HTTP headers: more specifically, using the `X-Forwarded-For` (client IP), `X-Forwarded-Proto` (originating scheme), and `X-Forwarded-Host` (host header field value). The built-in **Forwarded Headers Middleware** provided by ASP.NET Core performs this task by reading these headers and filling in the corresponding fields on the web application's `HttpContext`.

For additional information regarding forwarded headers middleware and its most common usage scenarios, check out the following URL:

<https://docs.microsoft.com/en-us/aspnet/core/host-and-deploy/proxy-load-balancer>

While we're there, we also need to properly check the connection string to the SQL Database that we've set up in Chapter 4, *Data Model with Entity Framework Core*, to ensure that it will still be reachable by the Linux VM (or change it accordingly).

Adding the forwarded headers middleware

To add the forwarded headers middleware, open the `WorldCities Startup.cs` file and add the following highlighted lines to the `Configure()` method:

```
using Microsoft.AspNetCore.HttpOverrides;

// ...

app.UseRouting();

// Invoke the UseForwardedHeaders middleware and configure it
// to forward the X-Forwarded-For and X-Forwarded-Proto headers.
// NOTE: This must be put BEFORE calling UseAuthentication
// and other authentication scheme middlewares.
app.UseForwardedHeaders(new ForwardedHeadersOptions
{
    ForwardedHeaders = ForwardedHeaders.XForwardedFor
        | ForwardedHeaders.XForwardedProto
});

app.UseAuthentication();
app.UseIdentityServer();
app.UseAuthorization();

// ...
```

As we can see, we're telling the middleware to forward the `X-Forwarded-For` and `X-Forwarded-Proto` headers, thereby ensuring that redirected URIs and other security policies will work properly.



IMPORTANT: As written in the comments, this middleware must be put *before* calling `UseAuthentication` or other authentication scheme middlewares.

Now, we can move on to the following step.

Checking the database connection string

From **Solution Explorer**, open the `appsettings.json` file and check out the connection string that we set up in [Chapter 4, Data Model with Entity Framework Core](#), which has arguably worked flawlessly for our development machine since then. We need to be sure that such a connection string will work on our Linux VM as well.

If the SQL Database is hosted on MS Azure or on a publicly accessible server, we won't have to do anything; however, in the case where we've used a local SQL Database instance installed on our development machine, we'll need to choose one of the following available workarounds:

1. Move and/or copy the `WorldCities` SQL Database to MS Azure.
2. Install a local SQL Server Express (or Development) instance on the CentOS VM right after creating it.
3. Configure an inbound rule to the custom local (or remote) SQL Server Express (or Development) instance that we set up in [Chapter 4, Data Model with Entity Framework Core](#), possibly restricting external access to the new VM's public IP address only.

For workaround #1, right-click the local SQL Database instance and select **Tasks > Deploy Database to MS Azure SQL Database**; check out [Chapter 4, Data Model with Entity Framework Core](#), for additional details.



For workaround #2, take a look at the following SQL Server Linux installation guide:

<https://docs.microsoft.com/en-us/sql/linux/sql-server-linux-setup>

For workaround #3, check out the following URL:

<https://docs.microsoft.com/en-us/sql/sql-server/install/configure-the-windows-firewall-to-allow-sql-server-access>

The connection string is not the only value we need to check and/or update in the `appsettings.json` file. We also need to properly configure the key settings of the `IdentityServer`, replacing the *Development* values that we set in [Chapter 10, Authentication and Authorization](#):

```
"IdentityServer": {  
    "Key": {  
        "Type": "Development"  
    }  
}
```

Now that we're going to deploy our web app in production, we can move the entire preceding `IdentityServer` section in the `appsettings.Development.json` file and replace the corresponding `appsettings.json` block in the following way:

```
"IdentityServer": {  
    "Clients": {  
        "WorldCities": {  
            "Profile": "IdentityServerSPA"  
        }  
    },  
    "Key": {  
        "Type": "File",  
        "FilePath": "/var/ssl/worldcities.pfx",  
        "Password": "MyVerySecretCAPassword$"  
    }  
}
```

This will ensure that `IdentityServer` will check for a real SSL certificate while in production. Such a certificate doesn't exist yet, but we'll generate it later on from the Linux VM command line.

Publishing and deploying the WorldCities app

Now, we can publish the `WorldCities` app and deploy it to the Linux VM server. This can be done in many ways, including the following:

- Use our existing **Folder publish profile** and then copy the files to the webserver using the SCP command-line tool
- Use our existing **Folder publish profile** and then copy the files to the webserver using a GUI-based SFTP Windows client, such as:
 - **WinSCP**: A free SFTP, SCP, S3, and FTP client for Windows: <https://winscp.net/>
 - **FileZilla FTP Client**: Another free, open-source FTP client with FTP over TLS (FTPS) and SFTP support: <https://filezilla-project.org/>
- Install an FTP/FTPS server on our web server and then set up an **FTP publish profile**
- Use the Visual Studio's **Azure Virtual Machine publish profile**

In this deployment scenario, we'll go with the first option, which is arguably the easiest one to achieve.

As for the alternative FTP/FTPS and Azure publish options, these have been explained briefly in the previous chapter on Windows deployment.

Creating the /var/www folder

The first thing we need to do is create a suitable folder to store our application's published files on the Linux VM. For this deployment scenario, we're going to use the /var/www/<AppName> folder, thereby following a typical Linux convention.

Since the Azure CentOS7 template doesn't come with an existing /var/www folder, we need to create that as well. To do this, execute the following command from the Linux VM console:

```
$ sudo mkdir /var/www
```

This /var/www/ folder will be our Linux equivalent of the Windows C:\inetpub\ folder, the directory that will contain our web applications' files.

Right after this, we can create a new /var/www/WorldCities subfolder there by means of the following command:

```
$ sudo mkdir /var/www/WorldCities
```

Adding permissions

Now, we need to add the read and write permissions to the /var/www/WorldCities folder of the Nginx default user.

To do this, use the following commands:

```
$ sudo chown -R nginx:nginx /var/www
$ sudo chmod -R 550 /var/www
```

This will make both the **Nginx** user and its corresponding **Nginx** group able to access it in read and execute mode while blocking any access to every other user/group.

In this deployment scenario, we're taking for granted the fact that the Nginx instance is running with its default **Nginx** user and **Nginx** group. In other Linux environments, the username and/or group might vary—for example, in most Linux distributions, the *Nginx* group is called **www** or **www-data**).

To determine which user Nginx is running in, use the following command:



```
$ ps -eo pid,comm,euser,supgrp | grep nginx
```

To list all available Linux users and/or groups, use the following commands:

```
$ getent passwd  
$ getent group
```

Before moving on, there's still one thing to do. Since we'll be publishing our app with the user account that we set up in MS Azure, we need to add it to the Nginx group as well; otherwise, it won't be able to write on that folder.

To do this, use the `usermod` Linux command in the following way:

```
$ sudo usermod -a -G nginx <USERNAME>
```

Replace the preceding `<USERNAME>` placeholder with the username that we previously set up on VM Azure (the same we used to log in to the VM terminal).

Copying the WorldCities publish folder

Once the `/var/www/WorldCities` folder has been properly set up on the Linux VM, we can open Command Prompt (with administrative rights) to our local development machine and issue the following SCP command to copy the local `C:\Temp\WorldCities` folder contents there:

```
> scp -r C:\Temp\WorldCities <USERNAME>@<VM. IP. ADDRESS>:/var/www
```



Remember to replace the <USERNAME> and <VM.IP.ADDRESS> placeholders with the actual values.

The SCP command will then ask us whether we want to connect to the remote folder, as shown in the following screenshot:

```
C:\ Command Prompt - scp -r C:\Temp\WorldCities DarkAngel@192.168.1.108:/var/www
C:\Users\DarkAngel>scp -r C:\Temp\WorldCities DarkAngel@192.168.1.108:/var/www
The authenticity of host '192.168.1.108 (192.168.1.108)' can't be established.
ECDSA key fingerprint is SHA256:VJyf00374140tRmshxwzLdDm9p1gYfut.
Are you sure you want to continue connecting (yes/no)?
```

Type yes to authorize the connection, and then repeat the command to copy the source folder to its destination. The SCP command will start to copy all the files from the local development machine to the VM folder, as shown in the following screenshot:

```
C:\ Command Prompt - scp -r C:\Temp\WorldCities DarkAngel@192.168.1.108:/var/www
Microsoft.CodeAnalysis.CSharp.resources.dll          100% 321KB  1.0MB/s  00:00
Microsoft.CodeAnalysis.CSharp.Workspaces.resources.dll 100% 16KB   378.1KB/s  00:00
Microsoft.CodeAnalysis.resources.dll                100% 37KB   698.9KB/s  00:00
Microsoft.CodeAnalysis.Workspaces.resources.dll     100% 81KB   778.7KB/s  00:00
IdentityModel.dll                                 100% 129KB  1.0MB/s  00:00
IdentityServer4.AspNetIdentity.dll                100% 31KB   628.0KB/s  00:00
IdentityServer4.dll                             100% 663KB  1.4MB/s  00:00
IdentityServer4.EntityFramework.dll            100% 22KB   485.9KB/s  00:00
IdentityServer4.EntityFramework.Storage.dll    100% 95KB   870.9KB/s  00:00
IdentityServer4.Storage.dll                     100% 45KB   562.7KB/s  00:00
Microsoft.CodeAnalysis.CSharp.resources.dll      100% 319KB  1.2MB/s  00:00
Microsoft.CodeAnalysis.CSharp.Workspaces.resources.dll 100% 16KB   376.7KB/s  00:00
Microsoft.CodeAnalysis.resources.dll           100% 37KB   698.5KB/s  00:00
Microsoft.CodeAnalysis.Workspaces.resources.dll 100% 80KB   741.8KB/s  00:00
Microsoft.CodeAnalysis.CSharp.resources.dll       100% 351KB  1.1MB/s  00:00
Microsoft.CodeAnalysis.CSharp.Workspaces.resources.dll 100% 16KB   368.7KB/s  00:00
Microsoft.CodeAnalysis.resources.dll           100% 39KB   729.5KB/s  00:00
Microsoft.CodeAnalysis.Workspaces.resources.dll 100% 83KB   938.6KB/s  00:00
karma.conf.js                                     100% 1023   29.2KB/s  00:00
Microsoft.CodeAnalysis.CSharp.resources.dll      0%   0     0.0KB/s  --:-- ETA
```

Now that our WorldCities app files have been copied to the Linux VM, we just need to configure the Kestrel service and then the Nginx reverse proxy to serve it.

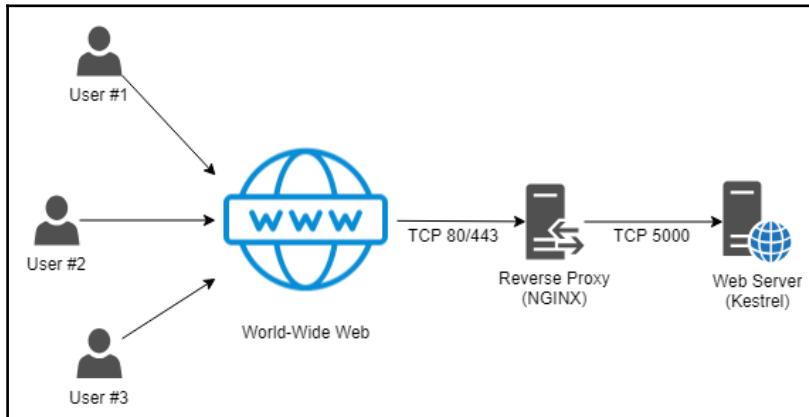
Configuring Kestrel and Nginx

Before starting up, it can be wise to quickly explain how the Kestrel service and the Nginx HTTP server will interact with each other.

The high-level architecture is quite similar to the Windows out-of-process hosting model that has been used since ASP.NET Core 2.2:

- The Kestrel service will serve our web app on TCP port 5000 (or any other TCP port; 5000 is just the default one).
- The Nginx HTTP server will act as a reverse proxy, forwarding all the incoming requests to the Kestrel web server.

This pattern is called edge-origin proxy, and can briefly be summarized by the following diagram:



Now that we've understood the general picture, let's do our best to pull it off.

Creating the self-signed SSL certificate

Since our app will be served using HTTPS, we need to either purchase and install an SSL certificate from a third-party reseller or create a self-signed one. For this deployment scenario, we'll stick to the self-signed approach, just like we did with Windows.

In Linux, we can create a self-signed certificate using the OpenSSL command-line tool.

To do this, implement the following steps from the Linux VM terminal:

1. Create the /var/ssl folder with `sudo mkdir /var/ssl`.
2. Create the self-signed SSL certificate (`worldcities.crt`) and the private key file (`worldcities.key`) with the following command:

```
$ sudo openssl req -x509 -newkey rsa:4096 -sha256 -nodes -  
keyout /var/ssl/worldcities.key -out /var/ssl/worldcities.crt  
-subj "/CN=worldcities.io" -days 3650
```

3. Once done, merge the certificate and the private key into a single `worldcities.pfx` file:

```
$ openssl pkcs12 -export -out /var/ssl/worldcities.pfx -inkey  
/var/ssl/worldcities.key -in worldcities.crt
```

4. When asked for the PFX file password, insert the same password that we specified in the `appSettings.json` file early on. This will ensure that `IdentityServer` will be able to find and use the expected key.

Right after that, set the new file and folder permissions to make them accessible from both Nginx and the app:

```
$ sudo chown -R nginx:nginx /var/ssl  
$ sudo chmod -R 550 /var/ssl
```

Last but not least, we need to change the security context of the `/var/ssl` folder (and all its containing files) so that Nginx will be able to access it:

```
$ sudo chcon -R -v --type=httpd_sys_content_t /var/ssl
```

If we don't execute the preceding command, **Security-Enhanced Linux (SELinux)** will prevent HTTPD daemons from accessing the `/var/ssl` folder, causing unwanted "permission denied" errors during the Nginx start up phase. It goes without saying that if our Linux system is not running SELinux, or we have permanently disabled it, the preceding command can be skipped. However, since it's active in the MS Azure CentOS7-based VM template, we might need to execute it.

SELinux is an access control (MAC) security mechanism implemented in the CentOS 4 kernel. It is quite similar to the Windows UAC mechanism and has strong default values that can be relaxed in case of specific requirements.



To temporarily disable it, run the `sudo setenforce 0` terminal command. Doing this can be useful when we run into permission issues to determine whether the problem may be related to SELinux.

For additional information regarding SELinux and its default security settings, check out the following URLs:

<https://wiki.centos.org/HowTos/SELinux>
<https://wiki.centos.org/TipsAndTricks/SelinuxBooleans>

Now we have a valid self-signed SSL certificate that can be used by either IdentityServer or Nginx.



For additional information regarding the OpenSSL tool, check out the following URL:

<https://www.openssl.org/docs/manmaster/man1/openssl.html>

Configuring the Kestrel service

Let's start by creating the service definition file in the `/etc/systemd/system/` folder.

To do that, we'll use `nano`, an open source text editor for Linux that can be used from a command-line interface (similar to `vim`, but much easier to use). Let's go through the following steps:

1. Execute the following command to create a

`new /etc/systemd/system/kestrel-worldcities.service` file:

```
$ sudo nano /etc/systemd/system/kestrel-worldcities.service
```

- Once done, fill the newly created file with the following content:

```
[Unit]
Description=WorldCities

[Service]
WorkingDirectory=/var/www/theaac.com
ExecStart=/usr/bin/dotnet /var/www/WorldCities/WorldCities.dll
Restart=always# Restart service after 10 seconds if the dotnet
service crashes:
RestartSec=10
KillSignal=SIGINT
SyslogIdentifier=WorldCities
User=nginx
Environment=ASPNETCORE_ENVIRONMENT=Production
Environment=DOTNET_PRINT_TELEMETRY_MESSAGE=false
Environment=ASPNETCORE_URLS=http://localhost:5000

# How many seconds to wait for the app to shut down after it
receives the initial interrupt signal.
# If the app doesn't shut down in this period, SIGKILL is
issued to terminate the app.
# The default timeout for most distributions is 90 seconds.
TimeoutStopSec=90

[Install]
WantedBy=multi-user.target
```

- Once done, press *Ctrl + X* to exit and then *Y* to save the file on disk.



The `kestrel-worldcities.service` file is available in the `/_LinuxVM_ConfigFiles/` folder of this book's GitHub repository.

As we can see, this file's contents will be used by Kestrel to configure our app's production values, such as the `ASPNETCORE_ENVIRONMENT` variable, which we've talked about early on, and the TCP port, which will be used to internally serve the app.



The preceding settings are OK for our current deployment scenario; however, they should be changed to comply with different usernames, folder names, TCP ports used, the web app's main DLL name, and so on. When hosting a different web application, be sure to update them accordingly.

4. Now that we have configured the service, we just need to start it, which can be done using the following command:

```
$ sudo systemctl start kestrel-worldcities.service
```

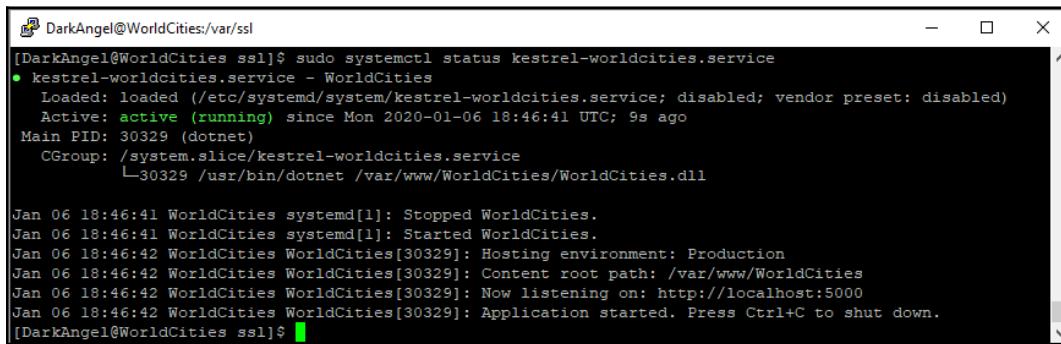
5. If we also want to make the service automatically run on each VM reboot, add the following command:

```
$ sudo systemctl enable kestrel-worldcities.service
```

6. Immediately after this, it would be wise to run the following command to check whether the service is running without issues:

```
$ sudo systemctl status kestrel-worldcities.service
```

If we see a green `active (running)` message, such as the one in the following screenshot, this most likely means that our Kestrel web service is up and running. Now, we just need to set up Nginx to reverse proxy it and we're done:



```
[DarkAngel@WorldCities ssl]$ sudo systemctl status kestrel-worldcities.service
● kestrel-worldcities.service - WorldCities
   Loaded: loaded (/etc/systemd/system/kestrel-worldcities.service; disabled; vendor preset: disabled)
   Active: active (running) since Mon 2020-01-06 18:46:41 UTC; 9s ago
     Main PID: 30329 (dotnet)
        CGroup: /system.slice/kestrel-worldcities.service
                  └─30329 /usr/bin/dotnet /var/www/WorldCities/WorldCities.dll

Jan 06 18:46:41 WorldCities systemd[1]: Stopped WorldCities.
Jan 06 18:46:41 WorldCities systemd[1]: Started WorldCities.
Jan 06 18:46:42 WorldCities WorldCities[30329]: Hosting environment: Production
Jan 06 18:46:42 WorldCities WorldCities[30329]: Content root path: /var/www/WorldCities
Jan 06 18:46:42 WorldCities WorldCities[30329]: Now listening on: http://localhost:5000
Jan 06 18:46:42 WorldCities WorldCities[30329]: Application started. Press Ctrl+C to shut down.
[DarkAngel@WorldCities ssl]$
```

If the status command shows that something's off (red lines or advices), we can troubleshoot the issue by looking at the detailed ASP.NET application error log with the following command:

```
$ sudo journalctl -u kestrel.worldcities
```

The `-u` parameter will only return messages coming for the `kestrel-worldcities` service, filtering out everything else.

Since the `journalctl` log could easily become very long, even with the preceding filter, it could also be advisable to restrict its timeframe using the `--since` parameter in the following way:

```
$ sudo journalctl -u kestrel-worldcities --since "yyyy-MM-dd HH:mm:ss"
```

Be sure to replace the `yyyy-MM-dd HH:mm:ss` placeholders with a suitable date-time value.

Last but not least, we can just output to the last logged error with the `-xe` switch:

```
$ sudo journalctl -xe
```

These commands should be very useful in troubleshooting most error scenarios on Linux in an effective manner.



For additional information regarding the `journalctl` tool, check out the following URL:

<https://www.freedesktop.org/software/systemd/man/journalctl.html>

Why are we not serving the web app with Kestrel directly?

We could be tempted to just configure the Kestrel web service on TCP port 443 (instead of TCP 5000) and get the job done now, without having to deal with Nginx and skipping the whole reverse proxy part.

Despite being 100% possible, we strongly advise against doing this for the same reasons stated by Microsoft here:

Kestrel is great for serving dynamic content from ASP.NET Core. However, the web serving capabilities aren't as feature-rich as servers such as IIS, Apache, or Nginx. A reverse proxy server can offload work such as serving static content, caching requests, compressing requests, and SSL termination from the HTTP server. A reverse proxy server may reside on a dedicated machine or may be deployed alongside an HTTP server.

[Source: <https://docs.microsoft.com/it-it/aspnet/core/host-and-deploy/linux-nginx>]

In short, Kestrel is not intended to be used on the front line. Therefore, the correct thing to do is to definitely keep it far from the edge and leave such a task to Nginx.

Configuring the Nginx reverse proxy

The last thing we need to do is to configure the Nginx HTTP server to act as a reverse proxy for our Kestrel service. Observe the following steps:

1. Type the following command to create a dedicated Nginx configuration file for this job:

```
$ sudo nano /etc/nginx/nginx-worldcities.conf
```

2. Then, fill the new file's content with the following configuration settings:

```
server {  
    listen 443 ssl http2;  
    listen [::]:443 ssl http2;  
  
    ssl_certificate /var/ssl/worldcities.crt;  
    ssl_certificate_key /var/ssl/worldcities.key;  
  
    server_name worldcities.io;  
  
    root /var/www/WorldCities/;  
    index index.html;  
    autoindex off;  
  
    location / {  
        proxy_pass http://localhost:5000;  
        proxy_http_version 1.1;  
        proxy_set_header Upgrade $http_upgrade;  
        proxy_set_header Connection keep-alive;  
        proxy_set_header Host $host;  
        proxy_cache_bypass $http_upgrade;  
        proxy_set_header X-Forwarded-For  
            $proxy_add_x_forwarded_for;  
        proxy_set_header X-Forwarded-Proto $scheme;  
    }  
}
```

3. Once done, press *Ctrl + X* to exit and then *Y* to save the file
4. Right after that, execute the following command to authorize the Nginx service to connect to the network:

```
$ sudo setsebool -P httpd_can_network_connect 1
```



The preceding command is required to change the SELinux default settings, which prevents all HTTPD daemons (such as Nginx) from accessing the local network and, hence, the Kestrel service. If our Linux system is not running SELinux, or we have permanently disabled it, we don't need to execute the preceding command.

Updating the nginx.conf file

The `nginx-worldcities.conf` file needs to be referenced within the main Nginx configuration file; otherwise, it won't be read and applied.

To do this, edit the `/etc/nginx/nginx.conf` file with the following command:

```
$ sudo nano /etc/nginx/nginx.conf
```

Then, add the following highlighted line near the end of the file, just before the final closing square bracket:

```
# ...existing code...

location / {
}

error_page 404 /404.html;
location = /40x.html {
}

error_page 500 502 503 504 /50x.html;
location = /50x.html {
}
}

include nginx-worldcities.conf;
```

```
}
```

That single `include` line will ensure that our reverse proxy configuration will work properly. The new settings will be applied as soon as Nginx is restarted, which is something that we'll do in a short while.



The `nginx.conf` and `nginx-worldcities.conf` files are both available in the `/_LinuxVM_ConfigFiles/` folder of this book's GitHub repository.

All the required deployment tasks on Linux have been completed. Now, we just have to properly test the `WorldCities` web application to see whether it works.

Testing the WorldCities application

The testing phase will be very similar to what we did at the end of the Windows deployment section. Observe the following steps:

1. Before leaving the Linux VM terminal, it would be wise to restart both the Kestrel and Nginx services in the following way:

```
$ sudo systemctl restart kestrel-worldcities  
$ sudo systemctl restart nginx
```

2. Immediately after this, check for their statuses with the following commands to ensure that they're up and running:

```
$ sudo systemctl status kestrel-worldcities  
$ sudo systemctl status nginx
```

Now, we're ready to switch to our local development machine and start the test.

Update the testing machine's HOST files

Just like we did with the `HealthCheck` app early on, the first thing we've to do is to map the `worldcities.io` hostname to our remote VM's IP address. Observe the following steps:

1. To do this, edit the `C:\Windows\System32\drivers\etc\hosts` file and add the following entry:

```
VM.IP.ADDRESS      worldcities.io
```

2. Replace the preceding `VM.IP.ADDRESS` placeholder with the VM's external IP file so that Windows will map the `worldcities.io` hostname to it

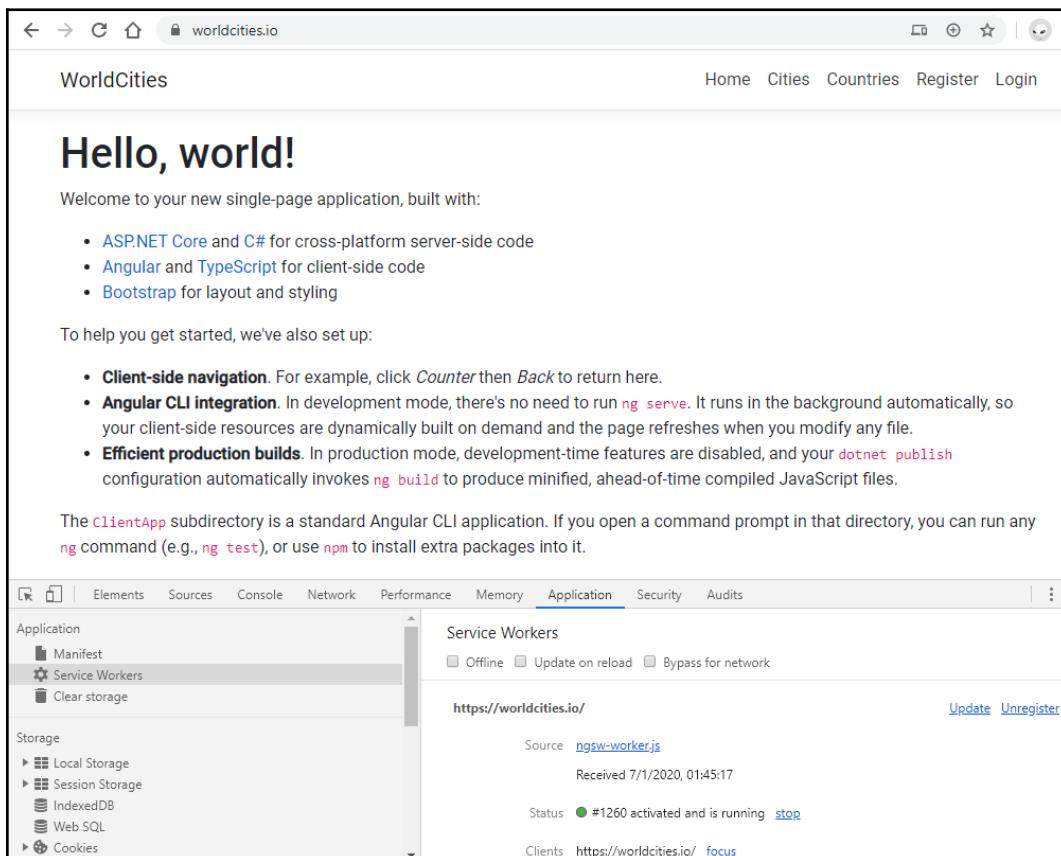
Now, we can test the app from our development machine using the Google Chrome web browser.

Testing the app with Google Chrome

Again, we're going to perform these tests using Google Chrome because of its built-in development tools that conveniently allow to check for Web App Manifest and service worker presence.

Launch Google Chrome and write the following URL in the browser's address bar:
`https://worldcities.io`

If we have done everything correctly, we should be able to see the **WorldCities** web application's **Home** view:



The screenshot shows a browser window with the URL `worldcities.io` in the address bar. The page content displays "Hello, world!" and a welcome message about the application's build with ASP.NET Core, Angular, and Bootstrap. Below this, there's a list of setup features like client-side navigation, Angular CLI integration, and efficient production builds. A note mentions the `ClientApp` subdirectory as a standard Angular CLI application. At the bottom, there's a link to the `ClientApp` directory.

Below the browser window, the Google Chrome DevTools Application tab is open. It shows the "Service Workers" section for the domain `https://worldcities.io/`. It lists a single service worker named `ngrsw-worker.js`, which was received on 7/1/2020 at 01:45:17. The status is shown as activated and running, with a "stop" button available. The "Clients" section shows a single client entry for the URL `https://worldcities.io/`.

From there, we should check for the presence/availability of the following goodies:

- The app manifest file (with all the HC icons) in the **Application | Manifest** panel of the Google Chrome Development console
- The service worker properly registered in the **Application | Service Workers** panel of the Google Chrome Development console
- The *send this page* and *install* icons in the rightmost part of the browser's address bar
- The service worker behavior when checking and unchecking the offline status to test the service worker's behavior
- Access to the SQL Database
- The **Edit City** and **Edit Country** reactive forms
- The login and registration workflows

If everything works as expected, we can say that our Linux deployment journey is over as well.

Troubleshooting

In case the web application encounters a runtime error, the production environment won't show any detailed information about the exception to the end user. For this reason, we won't be able to know anything useful about the issue unless we switch to the **Development Mode** (refer to the following screenshot):

Error.

An error occurred while processing your request.

Request ID: |3123e876-4f723ee9d56ef4e5.

Development Mode

Swapping to the **Development** environment displays detailed information about the error that occurred.

The **Development environment shouldn't be enabled for deployed applications**. It can result in displaying sensitive information from exceptions to end users. For local debugging, enable the **Development** environment by setting the **ASPNETCORE_ENVIRONMENT** environment variable to **Development** and restarting the app.

This can be done in the following way:

1. Change the `/etc/systemd/system/kestrel-worldcities.service` file's `ASPNETCORE_ENVIRONMENT` variable value to `Development`.
2. Restart the Kestrel service (and regenerate the dependency tree afterward) with the following commands:

```
$ sudo systemctl restart kestrel-worldcities
$ sudo systemctl daemon-reload
```

However, you are strongly advised to never do this in real production environments and inspect the Kestrel's journal logs with the following `journalctl` commands instead, as we suggested early on:

```
$ sudo journalctl -u kestrel-worldcities --since "yyyy-MM-dd HH:mm:ss"
$ sudo journalctl -xe
```

Such an approach will give us the same level of information without exposing our errors to the public.

That's it. Our ASP.NET Core and Angular deployment tasks have come to an end. We sincerely hope you've enjoyed the trip as much as we've enjoyed writing it.

Summary

Finally, our journey through ASP.NET Core and Angular has come to an end. Our final task involved getting our SPAs—now empowered with the most relevant features of PWAs—ready to be published in a suitable production environment.

The first thing we did was to explore some pivotal deployment tips for our *back-end* and *front-end* frameworks. Since the Visual Studio template already implemented the most important optimization tweaks, we took some valuable time to properly learn and understand the various techniques that can be used to increase our web application's performance and security when we need to publish it over the web.

Right after that, we went through Windows deployment with a step-by-step approach. We created a Windows Server 2019 VM on the MS Azure portal, and then we installed the IIS service and properly configured it in order to publish our existing `HealthCheck` app over the web. We did this with the new ASP.NET Core in-process hosting model, which is the default (and arguably the most recommended) hosting model for Windows-based platforms since ASP.NET Core 2.2.

Then, we switched to Linux, where we learned how to deploy our WorldCities app on a CentOS7-based VM. After configuring it properly, we took the opportunity to implement the out-of-process hosting model using Kestrel and Nginx, which is the standard approach for serving ASP.NET Core web applications on Linux-based platforms. To achieve this, we had to change some of our WorldCities app's *back-end* settings to ensure that they would be properly served behind a reverse proxy.

Once we did all that, we thoroughly tested the result of the preceding deployment efforts with a web browser from our development machine. For both scenarios, instead of purchasing real domain names and SSL certificates, we used self-signed certificates and host-mapping techniques, which allowed us to achieve the same outcome without spending any money.

Our adventure with ASP.NET Core and Angular has finally ended. We could have talked much longer about both frameworks, and spent much more time perfecting our apps, that's for sure. Anyhow, we should be satisfied with the results obtained and the lessons learned.

We hope you enjoyed this book. Many thanks for reading it!

Suggested topics

HTTPS, Secure Socket Layer (SSL), .NET Core Deploy, HTTP Strict Transport Security (HSTS), General Data Protection Regulation (GDPR), Content Delivery Network (CDN) MS Azure, Open Web Application Security Project (OWASP), SQL Server, SQL Server Management Studio (SSMS), Windows Server, IIS, FTP server, Publish Profiles, ASP.NET Core In-process Hosting Model, ASP.NET Core Out-of-process Hosting Model, CentOS, Kestrel, Nginx, reverse proxy, Forwarded Headers Middleware, SCP, FileZilla FTP Client, WinSCP, journalctl, nano, HOST mapping, self-signed SSL certificate, openssl, Security-Enhanced Linux (SELinux).

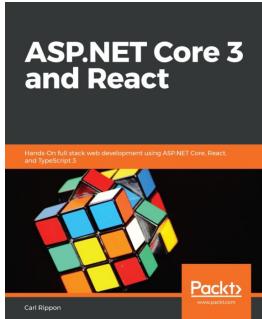
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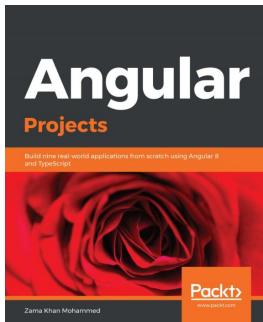


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