## [Course Overview](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658)

### [Course Overview](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658)

[Hi.](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=0) [My name's Mark Heath, and welcome to my course, Microservices Fundamentals.](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=1.8) [I work as a software architect at NICE Systems where I'm](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=13) [currently helping to create Azure-based digital evidence](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=17.666666666666664) [management systems for the police.](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=20.800000000000004) [Microservices is a style of architecture where you create autonomous,](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=24) [independently deployable services that collaborate](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=29) [together to create a software application.](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=33.25) [Microservice architectures are popular because they allow](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=37) [us to build applications that scale, perform well,](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=40.33333333333333) [and enable us to adapt quickly to changing business requirements.](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=43.75) [In this course,](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=49) [we're going to learn about the key principles and practices that will](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=49.857142857142854) [enable you to be successful with microservices.](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=54.888888888888886) [And we'll be seeing how these principles are applied by exploring an](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=58) [example e-commerce microservices architecture.](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=62.5) [We'll start off by understanding what microservices are,](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=67) [along with the problems they solve and the challenges associated with them.](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=71) [Then we'll look at how we can architect microservices,](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=76) [making good decisions about service boundaries and data ownership.](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=80) [We'll move on to consider the practical challenges of building microservices,](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=85) [including how we can ensure that developers are as productive as possible,](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=89) [and we'll look at some options for how microservices can](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=94) [communicate with each other reliably.](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=97.66666666666667) [We'll also see how we can apply the defense in depth principle](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=101) [to secure our microservices and how to automate their](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=105) [deployment and monitor them in production.](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=109.5) [By the end of this course,](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=113) [you'll be ready to design and build your own microservices](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=114) [applications and identify which technologies and practices](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=118.25) [are a good fit in your context.](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=122) [The demo application that we'll be looking at uses Docker,](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=125) [and although you don't need to have Docker installed,](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=129) [if you do,](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=131) [you'll be able to follow along and try out the demo application for yourself.](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=131.66666666666669) [So I hope you'll join me on this journey to learn about](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=137) [microservices with the Microservices Fundamentals course, at Pluralsight.](https://app.pluralsight.com/course-player?clipId=8b524842-1d66-4d35-8404-45fda98de658&startTime=140.5)

## [Introducing Microservices](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b)

### [Course Introduction](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b)

[When you're building a modern software application,](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=0) [you want it to perform well, to be resilient to errors,](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=4) [to have a flexible architecture that can adapt to new requirements,](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=9) [and to keep its data secure.](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=13) [Microservices is an architectural style that's grown](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=16) [rapidly in popularity over the last decade,](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=19.799999999999997) [and it has the potential to help us achieve these goals in](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=23) [modern distributed software applications.](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=26.8) [I'm Mark Heath, and in this course,](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=30) [we're going to explore what a microservices architecture looks like](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=32) [in practice and the benefits that it can bring.](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=37) [In this module,](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=42) [we'll start by making sure that we understand what the](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=42.75) [concept of a microservice is and what benefits it brings](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=45.99999999999999) [over a more traditional approach, often referred to as a monolith.](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=49) [We'll learn about the limitations of a monolithic architecture and see how](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=55) [microservices offer solutions to some of these problems.](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=60.5) [But we'll also learn about some of the challenges that](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=64) [adopting a microservices architecture can bring.](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=66.57142857142857) [Although microservices do solve many problems, they also introduce new ones.](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=70) [And so you do need to be aware of this before embracing](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=76) [microservices for your own applications.](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=79.42857142857142) [I'll also introduce you to a sample microservices application,](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=83) [which will serve as an example throughout this course,](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=87) [which illustrates many of the techniques and](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=90) [principles that we'll be learning about.](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=92.57142857142857) [As we move through the rest of this course,](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=96) [we'll look at architecting microservices.](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=98) [How do we decide the best way to divide overall system](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=101) [functionality into individual microservices?](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=105.39999999999998) [Then we'll look at some of the practicalities of](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=109) [actually building microservices.](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=112) [How can we ensure that our team of developers is successful and](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=115) [productive as they implement a microservice architecture,](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=118.5) [including how to effectively debug and test those microservices?](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=122) [We'll also explore in a bit more detail the options for how](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=128) [microservices can communicate with each other.](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=131.71428571428567) [In particular,](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=135) [we'll look at the approaches of synchronous and asynchronous](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=135.8888888888889) [communications and how these choices relate to overall system](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=140.33333333333331) [reliability and performance.](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=145.50000000000003) [Of course, in an era of cloud-deployed applications and data breaches,](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=148) [it's essential that we secure our microservices and](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=152) [the data that they operate on.](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=156.28571428571428) [And we'll look at some key principles and techniques that we can](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=158) [apply to protect our system from attackers.](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=161.6666666666667) [And we'll finish by briefly looking at delivering microservices.](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=165) [How can we deploy them into production and monitor them effectively?](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=170) [Right, I've already said microservices lots of times,](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=175) [but I haven't yet explained what they are. So let's talk about that next.](https://app.pluralsight.com/course-player?clipId=2db24f88-2cba-4761-8bda-5edaa2f6293b&startTime=179)

### [What Are Microservices?](https://app.pluralsight.com/course-player?clipId=c3801b25-bf88-42bd-866e-27ceb997ed85)

[What do we mean by microservices?](https://app.pluralsight.com/course-player?clipId=c3801b25-bf88-42bd-866e-27ceb997ed85&startTime=0.49066700000001584) [Microservices is an architectural style where autonomous,](https://app.pluralsight.com/course-player?clipId=c3801b25-bf88-42bd-866e-27ceb997ed85&startTime=4.490667000000016) [independently deployable services collaborate together to form](https://app.pluralsight.com/course-player?clipId=c3801b25-bf88-42bd-866e-27ceb997ed85&startTime=9.090667000000018) [a broader software application or system.](https://app.pluralsight.com/course-player?clipId=c3801b25-bf88-42bd-866e-27ceb997ed85&startTime=13.490667000000016) [And that's it.](https://app.pluralsight.com/course-player?clipId=c3801b25-bf88-42bd-866e-27ceb997ed85&startTime=16.490667000000016) [Simple, right?](https://app.pluralsight.com/course-player?clipId=c3801b25-bf88-42bd-866e-27ceb997ed85&startTime=18.29066700000002) [You might even have worked on systems that take this approach](https://app.pluralsight.com/course-player?clipId=c3801b25-bf88-42bd-866e-27ceb997ed85&startTime=19.490667000000016) [without calling it a microservices architecture.](https://app.pluralsight.com/course-player?clipId=c3801b25-bf88-42bd-866e-27ceb997ed85&startTime=22.490667000000016) [Of course,](https://app.pluralsight.com/course-player?clipId=c3801b25-bf88-42bd-866e-27ceb997ed85&startTime=26.490667000000016) [the name microservices also suggests that these services should be small,](https://app.pluralsight.com/course-player?clipId=c3801b25-bf88-42bd-866e-27ceb997ed85&startTime=27.34780985714287) [but there isn't an official size limit.](https://app.pluralsight.com/course-player?clipId=c3801b25-bf88-42bd-866e-27ceb997ed85&startTime=31.490667000000016) [Some teams try to keep them extremely small,](https://app.pluralsight.com/course-player?clipId=c3801b25-bf88-42bd-866e-27ceb997ed85&startTime=34.490667000000016) [maybe just a couple of hundred lines of code but many of the benefits of](https://app.pluralsight.com/course-player?clipId=c3801b25-bf88-42bd-866e-27ceb997ed85&startTime=37.490667000000016) [microservices still apply even if they're a bit larger than that.](https://app.pluralsight.com/course-player?clipId=c3801b25-bf88-42bd-866e-27ceb997ed85&startTime=42.0620955714286) [But why?](https://app.pluralsight.com/course-player?clipId=c3801b25-bf88-42bd-866e-27ceb997ed85&startTime=47.490667000000016) [Why do we need microservices? Let's look at some of the problems that microservices are designed to address.](https://app.pluralsight.com/course-player?clipId=c3801b25-bf88-42bd-866e-27ceb997ed85&startTime=48.34780985714288)

### [The Problem of Monoliths](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8)

[Microservice architectures are often contrasted with monoliths.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=0.6213340000000317) [A monolith is a software application that typically has all of its](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=5.621334000000032) [code in a single code base and which all developers collaborate](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=10.33561971428575) [together on that same source code repository.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=14.2880006666667) [The build artifact is usually a single executable or process that](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=17.621334000000033) [runs on a single host server or virtual machine and persists all](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=22.02133400000003) [of its data into a single database.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=26.62133400000003) [And the development environment typically uses a single consistent technology,](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=29.621334000000033) [such as what programming language or SDK you're using throughout the code base.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=35.62133400000003) [And one of the major benefits of this approach is simplicity.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=40.62133400000003) [All the code is in one place, so it's easy to find things.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=44.62133400000003) [There's only one thing that you have to build and run,](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=48.62133400000003) [so it's straightforward for a developer to work on.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=51.62133400000003) [And when you come to deploy it to production,](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=54.62133400000003) [well, there's just one application to update.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=56.62133400000003) [And there's nothing inherently wrong with this approach,](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=59.62133400000003) [and if it's working well for you,](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=62.82133400000003) [that's probably a sign that you don't need microservices.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=65.62133400000003) [Or perhaps I should say you don't need microservices yet.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=69.62133400000003) [The problem with monoliths is one of scale.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=74.62133400000003) [The monolith model works well for single developers or small](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=77.62133400000003) [teams of maybe two to three developers who are working together](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=82.28800066666669) [for just a few months maybe to build a small website that handles](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=85.51022288888895) [a modest number of visitors.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=89.76419114285717) [But what happens when our projects grow much larger?](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=92.62133400000003) [What if we've got 20 to 30 developers,](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=95.62133400000003) [and they're working for a period of several years building a system that will](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=97.62133400000003) [have thousands of users and store massive amounts of data?](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=102.28800066666669) [When we get into this kind of situation,](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=105.62133400000003) [the monolith approach becomes a big problem.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=107.62133400000003) [For one thing, as a code base grows larger,](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=111.62133400000003) [there's a tendency for it to become more difficult to maintain due to](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=114.62133400000003) [growing complexity and the accumulation of technical debt.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=119.62133400000003) [And even if you've made a concerted effort to keep your monolith modularized,](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=123.62133400000003) [often you'll find that these modules end up becoming](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=128.62133400000002) [very entangled and interdependent.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=131.62133400000002) [When it comes time to deploy your monolith,](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=135.62133400000002) [even a single line code change requires the entire application to be deployed,](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=137.62133400000002) [which is risky and usually involves a period of downtime,](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=143.62133400000002) [something that's becoming less acceptable in the modern era of cloud](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=147.62133400000002) [services that are expected to maintain high availability.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=151.33561971428568) [Scaling a monolith to meet demands of increased users or](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=155.62133400000002) [large amounts of data is also very difficult.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=159.12133400000002) [Unless great care has been taken to make your monolith stateless,](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=162.62133400000002) [you probably can't scale it out horizontally.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=166.62133400000002) [That's where you add additional servers.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=169.62133400000002) [And so your only option is to scale vertically where you](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=172.62133400000002) [provision much more powerful and expensive servers.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=176.2880006666667) [And monoliths require the entire application to be scaled out](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=179.62133400000002) [together rather than just calling the individual components that](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=184.22133400000004) [require additional processing power.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=188.221334) [Finally, with the monolith,](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=190.62133400000002) [you can very easily find yourself wedded to legacy technology.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=191.62133400000002) [Whatever tech stack you built the original version with is going to](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=196.62133400000002) [be very hard to get away from as you have to upgrade the entire](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=200.52133400000005) [application to move to a newer framework.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=205.24633400000002) [And this reduces your agility to adopt newer patterns and practices](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=207.62133400000002) [or to take advantage of innovation such as new tools and services](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=211.37133400000002) [that would benefit your application.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=216.62133400000002) [Now perhaps you're thinking, Well, my application isn't a monolith.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=219.62133400000002) [It's made up of several services that can run on different](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=223.62133400000002) [hosts and talk to each other over the network.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=227.28800066666673) [However,](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=229.62133400000002) [it's very important to understand that just because you have an architecture](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=230.12133400000002) [based on services doesn't mean you're using microservices.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=234.42133400000003) [It's possible to create a system where you have several services,](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=238.62133400000002) [but they all access data in a shared database,](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=241.62133400000002) [and they're all tightly coupled to each other in such a way](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=245.62133400000002) [that you have to deploy them all together,](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=249.62133400000002) [and any change you want to make to the system requires](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=251.62133400000002) [modifications to multiple services.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=255.12133400000002) [Systems like this are sometimes referred to as distributed monoliths,](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=257.62133400000005) [and these things are big trouble.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=262.62133400000005) [They combine all the downsides of monoliths with all the challenges of](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=265.62133400000005) [microservices and offer very few of the benefits of either approach.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=270.9546673333335) [So it is important to have a clear understanding of microservices before diving](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=274.62133400000005) [into creating them or you could end up in a world of pain.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=279.90704828571427) [Let's see next how a microservice architecture can offer a significant improvement over monoliths.](https://app.pluralsight.com/course-player?clipId=78bda0de-683f-447f-94e1-40a2279697c8&startTime=284.62133400000005)

### [The Benefits of Microservices](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959)

[We've looked at some of the drawbacks of monoliths.](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=0.8026670000000158) [So let's look now at how microservices can help us.](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=3.802667000000016) [By breaking our application into smaller pieces,](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=7.802667000000016) [each microservice can be owned by a small development team and](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=10.802667000000016) [is much easier to understand and work on.](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=15.13600033333335) [A good rule of thumb for the size of a microservice is that it's small](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=17.802667000000017) [enough to be thrown away and rewritten if necessary.](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=22.136000333333346) [Microservices allow us the freedom to adopt new technologies](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=26.802667000000017) [without needing to upgrade everything in one go and the](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=30.802667000000017) [flexibility to choose the right tool for the job.](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=34.52993972727275) [For example,](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=37.802667000000014) [one microservice might use a relational database to store its](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=38.469333666666685) [data while another uses a document database.](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=42.3740955714286) [One microservice might be written in a functional programming language](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=45.802667000000014) [while another might use an object-oriented approach.](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=48.802667000000014) [Of course,](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=52.802667000000014) [there are still benefits in using standardized approaches where possible,](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=53.469333666666685) [but there're no hard requirements.](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=57.802667000000014) [Individual microservice development teams have the freedom](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=59.802667000000014) [to use the most appropriate technology.](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=64.13600033333334) [When we create microservices,](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=66.80266700000001) [their loose coupling means that we can deploy them individually,](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=68.80266700000001) [and this is a huge benefit since it's much lower risk than](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=72.80266700000001) [upgrading everything in the entire system in one go,](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=77.05266700000001) [and it also helps us to achieve zero downtime deployments.](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=79.80266700000001) [And that's because while we're upgrading an individual microservice,](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=84.80266700000001) [it's quite possible for the rest of the system to carry on running.](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=88.80266700000001) [Microservice architectures enable teams to deploy with much greater frequency.](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=92.80266700000001) [Rather than waiting months between upgrades,](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=98.80266700000001) [as is often common with monoliths,](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=101.80266700000001) [changes to individual microservices can be pushed to](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=103.80266700000001) [production as soon as they're ready,](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=107.80266700000001) [and it's even possible to deploy microservices multiple times a day.](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=110.80266700000001) [Microservices give us much more control over scalability.](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=115.80266700000001) [We can scale out each microservice individually,](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=119.80266700000001) [which is much more cost effective than scaling a monolith.](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=123.80266700000001) [Finally, microservices make us more agile.](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=127.80266700000001) [We can adapt more rapidly to changing business requirements.](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=131.802667) [By keeping our microservices lightweight and decoupled,](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=136.802667) [they're more easily adaptable to use in new scenarios.](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=139.802667) [And these are just some of the reasons why microservices is becoming popular,](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=145.802667) [particularly for very large cloud-deployed systems.](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=149.802667) [But, unfortunately, microservices do come with some challenges of their own, so let's look at those next.](https://app.pluralsight.com/course-player?clipId=89bb05ca-0f99-4fd3-8382-f6609d0bf959&startTime=154.802667)

### [The Challenges of Microservices](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a)

[If microservices are so great, then why don't we just use them for everything?](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=0.6293340000000317) [Well, it's not a free lunch.](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=6.629334000000032) [There are some things that can be more challenging](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=8.629334000000032) [with a microservices architecture.](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=10.629334000000032) [And it's important that you understand this in order to decide whether](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=12.629334000000032) [microservices is a good fit for your application and also so that you can be](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=18.129334000000032) [prepared to deal with these challenges as they arise.](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=22.379334000000032) [One of the first challenges you'll face is how can you ensure](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=26.629334000000032) [developers are productive working on the system?](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=29.46266733333337) [Do they have to download the code for every single microservice and run it](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=32.62933400000003) [individually and configure them all to talk to each other?](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=37.25433400000003) [That could be very error prone and time consuming.](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=40.62933400000003) [You also need to have a way of working that enables developers to](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=43.62933400000003) [easily work on an individual microservice in isolation,](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=47.96266733333337) [as well as testing their microservice in the context of the whole application.](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=52.62933400000003) [And we'll be seeing some ways to achieve this later on in this course.](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=57.62933400000003) [If we break an application up into dozens of microservices,](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=62.62933400000003) [then there's potential for the interactions between those](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=66.62933400000003) [microservices to get very complex making it hard to understand](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=69.96266733333337) [the behavior of the system as a whole,](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=74.05790542857149) [and it can also lead to performance issues.](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=76.62933400000003) [If you don't take care,](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=79.62933400000003) [you can find that a single operation requires lots of inefficient,](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=81.62933400000003) [verbose communications between many microservices.](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=85.62933400000003) [And while deploying an individual microservice is a smaller](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=90.62933400000003) [and safer task than deploying a monolith,](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=95.82933400000005) [when you have many microservices,](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=98.62933400000003) [automated deployment becomes critical because you're going](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=100.62933400000003) [to have many more deployments to do.](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=104.82933400000005) [Finally, if there's a problem in production,](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=107.62933400000003) [we don't want to have to connect individually to every](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=110.62933400000003) [single microservice to examine its logs and work out which](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=113.62933400000003) [one is the cause of our troubles.](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=117.7202430909091) [So it's essential that you have a great monitoring solution](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=119.62933400000003) [enabling you to view logs and telemetry for all of your](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=123.62933400000003) [microservices in a centralized place.](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=127.20076257142861) [The good news is that there's a growing body of tools and](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=130.62933400000003) [practices available to help you succeed with microservices and](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=134.429334) [overcome these challenges and we'll be learning about many of these as we progress through this course.](https://app.pluralsight.com/course-player?clipId=f08f54c0-1cfd-4cb2-9566-8c7c16f6853a&startTime=138.37933400000003)

### [Introducing the Demo Application](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f)

[Now,](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=2.14) [I don't want this course to be purely theoretical, so we're](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=2.45) [going to be referring to a real microservices application](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=5.8) [as we go through this course,](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=9.67) [which will illustrate the principles that we're learning about.](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=11.62) [And, rather than me spending a few months creating](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=15.44) [my own microservices application,](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=18.15) [I've decided to use a preexisting reference microservices](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=20.61) [implementation called eShopOnContainers,](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=25.03) [which is open source and available here on GitHub. And there's a few](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=28.94) [reasons why I picked this example to use in this course.](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=34.29) [First of all, ecommerce is a well‑known problem domain.](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=38.24) [We've all used a shopping website, and so it should be fairly straightforward](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=42.34) [for you to understand what the responsibilities of the various microservices](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=46.36) [such as the basket, catalog, and ordering services are.](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=51.17) [But it's also a non‑trivial example.](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=56.34) [As you can see from this system architecture diagram,](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=59.04) [there are three client applications, two websites and a](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=62.47) [mobile app, and six microservices,](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=66.16) [making use of a few different database technologies](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=69.08) [and communicating via an event bus.](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=72.91) [And this sample also makes use of a pattern known as an](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=76.24) [API Gateway, or Backend for Frontend,](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=79.49) [that we'll discuss later on in this course. It's also being](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=82.9) [actively maintained and it's regularly updated with newer](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=86.92) [technologies and practices.](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=90.89) [In fact, it's had 96 different contributors at the time of recording,](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=93.24) [making it representative of what it's like to work on a](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=97.71) [real‑world microservice system where you have many](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=100.31) [developers collaborating together.](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=103.45) [It's also containerized,](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=106.64) [which means it's really easy for you to run the code on your local](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=108.26) [development machine if you want to try it out.](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=111.71) [And there are detailed instructions provided on GitHub](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=115.04) [explaining how to run it locally, whether you're Windows or Mac‑based.](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=117.73) [Finally, it's very well documented,](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=122.84) [including a couple of excellent free ebooks that you can download to help you](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=125.31) [fully understand the architecture, and they give the rationale behind many of](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=130.06) [the decisions that have been made in this project.](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=135.33) [And that's important because even if you choose microservices,](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=138.84) [you're still going to have a lot of choices ahead of you.](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=142.65) [Microservices don't dictate what programming language you use,](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=147.04) [what type of database you'll use,](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=151.54) [whether you communicate synchronously or asynchronously or what authentication](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=153.97) [mechanism you're going to use, and that means you're completely free to pick the](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=158.82) [ones that you're most familiar with and meet your needs. And we'll be discussing](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=163.32) [some of the factors that will help you make these decisions as we progress](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=168.2) [through this course. By the way,](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=172.14) [don't worry too much about the specific technology choices in the](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=174.53) [sample eShopOnContainers application. Because it's a reference](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=178.48) [application produced by Microsoft,](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=182.53) [it uses the .NET Framework and has scripts to help you deploy the](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=184.84) [application to Azure. But it doesn't matter if you're not a .NET](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=189.06) [developer or you use a different cloud other than Azure,](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=193.13) [we're going to be focusing in this course much more on the overall](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=197.06) [architecture rather than on the specific technology choices.](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=200.71) [So, you'll have no problem following along if you prefer to write](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=204.89) [your code in Java or Python or you like to host your applications](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=208.27) [in AWS or on Google Cloud Platform.](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=212.29) [Let's wrap up what we've learned so far. In this first module,](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=216.74) [we learned about what a microservices architecture is](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=220.4) [and how it differs from a monolith.](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=224.02) [We've seen some of the benefits,](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=226.94) [as well as challenges that microservices can bring.](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=228.54) [And in our next module, we're going to start looking at how we can architect a microservices solution.](https://app.pluralsight.com/course-player?clipId=321806c9-0277-4890-bd01-a1f3db31e81f&startTime=232.38)

## [Architecting Microservices](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008)

### [Module Introduction](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008)

[Whether you're planning to migrate an existing application to](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008&startTime=0) [microservices or adopt a microservices architecture from the](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008&startTime=5.428571428571427) [start of a brand new project,](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008&startTime=8.75) [there are some very important architectural decisions](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008&startTime=11) [that you need to make up front.](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008&startTime=14) [My name is Mark Heath, and in this module,](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008&startTime=16) [we'll discuss some of the key architectural principles](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008&startTime=19) [for how we define a microservice, and its components.](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008&startTime=22) [We'll begin by discussing the fact that you don't](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008&startTime=27) [have to start with microservices.](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008&startTime=29.857142857142854) [It's possible to evolve an existing application towards them.](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008&startTime=32) [We'll look in a bit more detail at some of the key](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008&startTime=37) [definitions of a microservice,](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008&startTime=40.222222222222214) [including the fact that a microservice should be autonomous,](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008&startTime=42) [which means it owns its own data.](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008&startTime=46) [And a microservice should be independently deployable,](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008&startTime=49) [which means it needs to have a clearly defined and](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008&startTime=53) [backwards-compatible public interface.](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008&startTime=56.75) [Finally,](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008&startTime=59) [we'll discuss the tricky challenge of how we can identify](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008&startTime=59.5) [suitable service boundaries for our microservices.](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008&startTime=63.875) [We'll look at some guidelines for breaking applications into microservices, including the idea of identifying bounded contexts.](https://app.pluralsight.com/course-player?clipId=cc3ff491-5d74-4353-848c-5cd207d31008&startTime=67)

### [Evolving Towards Microservices](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a)

[It's quite possible that you already have an existing](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=1.5226670000000013) [application with a monolithic architecture.](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=5.094095571428572) [Or maybe you've even got what we described in the](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=7.522667000000001) [previous module as a distributed monolith,](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=11.272667000000002) [where you've got several services that are tightly coupled](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=13.522667000000002) [together and not independently deployable.](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=17.122667) [The good news is that it's perfectly possible to evolve](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=19.522667000000002) [towards a microservices architecture.](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=23.856000333333338) [You can augment a monolith with microservices where](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=26.522667000000002) [every time you add a new capability, you create a new microservice.](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=29.897667000000002) [And you can decompose a monolith into microservices where you](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=34.522667) [identify existing capabilities that should be extracted out into](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=39.722667) [their own independent microservices.](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=44.122667) [In fact,](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=46.522667) [some people argue that you should avoid starting a brand new](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=46.922667000000004) [project with a microservices architecture.](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=50.189333666666684) [The benefits of microservices are not typically seen in small, new projects.](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=52.522667) [And it can be very hard to get your service boundaries right.](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=57.522667) [So it might be better to allow a system to grow a bit until it](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=61.522667) [becomes apparent what an appropriate segregation of](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=65.772667) [responsibilities into microservices would be.](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=69.35600033333333) [Now, of course, when you are using microservices,](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=73.522667) [at some point you're going to need to identify the responsibilities of a](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=76.522667) [microservice and define what its public interface should be.](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=80.92266699999998) [So let's look next at some of the key principles of microservices that help us make these sorts of decisions.](https://app.pluralsight.com/course-player?clipId=f88b5952-993b-4065-b79c-9ce9c61af61a&startTime=85.522667)

### [Microservices Own Their Own Data](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea)

[Earlier in this course,](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=1.0426670000000158) [we said that microservices are autonomous and independently deployable.](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=3.0426670000000158) [And a key part of achieving these goals is ensuring](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=9.042667000000016) [that a microservice owns its own data.](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=11.931555888888905) [In other words,](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=15.042667000000016) [we're not allowed to have this sort of situation where multiple](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=16.042667000000016) [microservices both read or write from the same data store.](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=19.89980985714287) [Instead, each microservice should have its own data store,](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=24.042667000000016) [and any other microservice wishing to access needs to do so via](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=29.042667000000016) [the public API of the microservice that owns it.](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=34.67903063636364) [Now there are some obvious trade-offs here.](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=39.042667000000016) [By splitting our data out,](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=42.042667000000016) [it means that we can no longer perform database joins across the](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=43.292667000000016) [data that's owned by two different microservices.](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=48.542667000000016) [Instead, we're going to have to make separate calls to each database.](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=52.042667000000016) [And we can no longer update two tables owned by different](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=57.042667000000016) [microservices within a single database transaction.](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=61.542667000000016) [Instead, we'd either have to use distributed transactions,](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=65.04266700000002) [which are very complex to implement, or,](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=69.04266700000002) [more commonly,](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=72.54266700000002) [design our system to work in what's called an eventually](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=73.54266700000002) [consistent manner where we may have to wait a while for the](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=78.15377811111112) [overall state of the data to be fully consistent.](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=81.76993972727274) [What this means in practice is that when a single business](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=85.04266700000002) [operation requires updates to more than one data store,](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=88.6140955714286) [there's going to be a short window of time when the change has](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=92.04266700000002) [been made in one data store but not the others.](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=95.24266700000001) [And so you need to develop your application in a way that is](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=98.04266700000002) [able to cope with this temporary inconsistency.](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=102.15377811111114) [Now there are ways to mitigate these issues.](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=106.04266700000002) [If we define our service boundaries well,](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=109.04266700000002) [we can minimize the need to aggregate data from multiple](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=112.04266700000002) [microservices to perform a single operation.](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=116.29266700000002) [Another approach is that one microservice might hold its own cache of a](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=120.04266700000002) [subset of the data that's owned by another microservice.](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=124.58812154545454) [An example of this might be that rather than having to constantly talk to a user](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=129.04266700000002) [profile service to get the name or email address of a user,](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=134.54266700000002) [we could maintain our own cached copies of this data.](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=139.04266700000002) [And this approach greatly improves performance because it removes the](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=143.04266700000002) [need for lots of chatty network communication and improves availability](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=147.41766700000002) [since now our microservice is able to do its job even when the user](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=152.04266700000002) [profile service is unavailable.](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=158.04266700000002) [It's important that when you're considering how to break](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=160.04266700000002) [your application into microservices,](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=163.75695271428577) [that you identify natural seams in the database schema,](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=166.04266700000002) [and this will help you avoid the performance penalties of having to involve multiple microservices in a single business operation.](https://app.pluralsight.com/course-player?clipId=737c9219-3fd3-4323-b6d2-fa8cbc1859ea&startTime=170.04266700000002)

### [EShopOnContainers Architecture](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1)

[To illustrate how microservices should own their own data,](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=0.9093340000000316) [let's take a look at the eShopOnContainers sample](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=4.909334000000031) [application that we introduced in the last module.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=8.464889555555587) [We can see that the Catalog service uses a SQL Server database.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=12.909334000000031) [The Ordering service also uses SQL Server, but it's a different database.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=17.909334000000033) [Neither of these services can see or access each other's](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=22.909334000000033) [data by going directly to the database.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=26.409334000000033) [The Basket service uses a Redis cache,](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=29.909334000000033) [and this is a more appropriate choice for short-lived data.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=32.90933400000003) [We can also see that document databases such as Cosmos DB or Mongo have been](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=36.90933400000003) [chosen by some of the other microservices in this application.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=42.509334000000024) [And so this architecture illustrates two key microservice characteristics.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=46.90933400000003) [First, each microservice in eShopOnContainers owns its own data.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=51.90933400000003) [And, second,](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=56.90933400000003) [each microservice is free to use the most appropriate database](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=58.24266733333336) [technology for the type of data it needs to store.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=63.48076257142861) [This breakdown of microservices also highlights a way to approach](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=65.90933400000003) [one of the difficulties that we just discussed.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=70.57600066666669) [The Ordering Microservice has got a concept of an OrderItem,](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=73.90933400000003) [which represents a single item in your order.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=77.90933400000003) [The OrderItem entity contains a ProductId, a ProductName, and a UnitPrice.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=80.90933400000003) [Now, hang on a minute,](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=87.90933400000003) [shouldn't the Catalog microservice be responsible for](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=88.90933400000003) [owning product names and prices?](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=92.40933400000003) [And yes, indeed, the Catalog microservice has got an entity called CatalogItem,](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=94.90933400000003) [which has an Id, a name, and a price.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=100.90933400000003) [So when you order something,](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=103.90933400000003) [the Ordering microservice records not only the Id of the product you ordered,](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=105.90933400000003) [but also takes a copy of its name and price.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=110.90933400000003) [And so we've actually got duplicate information,](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=114.90933400000003) [which is sometimes referred to as denormalization in databases.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=117.90933400000003) [Now this means that if we were to update a product's name](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=122.90933400000003) [or price in the Catalog microservice,](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=125.90933400000003) [then the information in the OrderItem would become stale.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=127.90933400000003) [So wouldn't it be better then if the Ordering microservice](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=131.90933400000003) [didn't store the product name and price,](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=134.90933400000003) [and instead asked the Catalog microservice whenever it needed it.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=137.90933400000003) [Well, actually, maybe not.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=142.90933400000003) [For one thing,](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=145.90933400000003) [that wouldn't perform quite so well as now we've](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=146.90933400000006) [introduced another network call.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=150.19504828571428) [But another consideration is that it might actually be a good thing](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=151.90933400000003) [for your order to include the name and the price of the product as it](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=154.90933400000003) [was at the time when you placed the order.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=160.4547885454546) [In other words,](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=162.90933400000003) [the Ordering microservice doesn't really care about what the](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=163.90933400000006) [current price and name of the product are.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=167.15933400000003) [What's it cares about is what they were at the time you placed the order.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=169.90933400000003) [And so, in fact, this isn't really duplicate information.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=173.90933400000003) [These pieces of data have different meanings within](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=176.90933400000003) [the context of each microservice.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=180.40933400000003) [And so duplication of data between microservices and the inability to do a](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=182.90933400000003) [direct database join between the data owned by two microservices is not necessarily the problem that it might first appear to be.](https://app.pluralsight.com/course-player?clipId=6a144509-e6b7-439b-b019-ac42a7f9c0b1&startTime=188.9093340000001)

### [Components of a Microservice](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663)

[The fact that a microservice owns its own data leads us to the](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=1.4720010000000474) [realization that a microservice is not necessarily a single](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=5.972001000000048) [process running on a single host.](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=9.972001000000047) [Often at a minimum, there's your code, perhaps implemented as a web API,](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=12.472001000000047) [and the database.](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=18.47200100000005) [So that's at least two processes, and, often,](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=19.47200100000005) [they're not running on the same host.](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=23.138667666666713) [If we scale out,](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=25.47200100000005) [now we've got multiple replicas of our code running on different](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=26.47200100000005) [hosts and sharing access to a single database.](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=30.22200100000005) [And if we were to configure our database for replication or sharding,](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=34.47200100000005) [that too might be running on more than one host.](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=38.30533433333338) [A microservice might also have a cron job working on a schedule](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=42.47200100000005) [to perform some kind of data maintenance.](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=45.47200100000005) [And maybe it has another process that's listening for messages on](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=48.47200100000005) [a cue that trigger various other data updates.](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=52.6148581428572) [So, in fact,](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=56.47200100000005) [there may be several different hosts and processes involved in a microservice.](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=57.472001000000056) [But conceptually, together they form a single microservice,](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=62.47200100000005) [and it's only these components that are allowed to access the shared data.](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=66.47200100000005) [We can see this illustrated again in the eShopOnContainers sample application.](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=72.47200100000005) [If we look at the Ordering service,](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=77.47200100000005) [we can see that it not only contains a web API called Ordering.API,](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=80.47200100000005) [but there's a separate process to implement background](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=85.47200100000005) [tasks called Ordering.BackgroundTasks,](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=88.97200100000005) [which is used to provide a grace period feature.](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=92.47200100000005) [And this is a perfectly acceptable design for a microservice.](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=96.47200100000005) [You're not forced to have all of the microservice](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=100.47200100000005) [code running in a single process.](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=103.47200100000003) [The important thing is that conceptually,](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=105.47200100000005) [a microservice has a clearly defined boundary with a public interface,](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=108.47200100000005) [and its data can only be accessed through that public interface. Let's talk about microservice interfaces next.](https://app.pluralsight.com/course-player?clipId=75df8c5e-71ea-4eab-b23f-f30341c3f663&startTime=113.47200100000005)

### [Microservices Are Independently Deployable](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e)

[When we say that microservices are independently deployable,](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=0.7253340000000317) [we mean that it's possible to upgrade a single](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=5.725334000000031) [microservice without requiring the clients of that](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=8.425334000000031) [microservice to be upgraded at the same time.](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=11.296762571428605) [And this requires great care because it means that you must never make a](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=14.725334000000032) [breaking change to the public interface of a microservice.](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=19.225334000000032) [In fact, it's a good idea to call the public interface a contract,](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=23.725334000000032) [which expresses the idea that it's an agreement between two](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=27.725334000000032) [parties that cannot be unilaterally changed.](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=31.39200066666669) [Now you might be wondering how is it even possible to](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=34.72533400000003) [never make a breaking change to your API?](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=38.169778444444475) [Well, the simplest solution is only to make additive changes to your APIs.](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=41.72533400000003) [You could add new endpoints,](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=46.72533400000003) [and you can usually add new properties to data transfer objects](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=49.72533400000003) [as most serializers can be configured to simply ignore additional](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=53.72533400000003) [fields that they aren't expecting.](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=58.12533400000004) [In some cases,](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=60.72533400000003) [you might find that you need to publish a version 2 of your public API,](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=61.54351581818185) [but if you do so, you still need to keep supporting version 1.](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=65.72533400000003) [Initially, your clients will carry on calling version 1 of your API,](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=70.72533400000003) [but over time, they can be updated to call version 2.](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=74.72533400000003) [Unfortunately,](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=78.72533400000003) [it's all too easy for developers to forget about this principle and](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=79.15390542857146) [make a breaking change to both the microservice API,](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=84.02533400000003) [but also update the clients at the same time.](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=86.72533400000003) [When they test this running locally on their development machine,](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=90.72533400000003) [everything works just fine.](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=93.72533400000003) [But now we've got ourselves into a situation where we're forced to upgrade](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=95.72533400000003) [both the microservice and its clients simultaneously.](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=100.60033400000003) [How can we avoid this?](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=104.72533400000003) [One approach that helps is by making individual teams responsible for owning](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=106.72533400000003) [microservices rather than just allowing all developers to dive into the code](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=112.05866733333337) [for any microservice that they want to change.](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=116.72533400000003) [That way,](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=119.72533400000003) [a client must first ask the owners of the microservice to add a new capability,](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=120.29676257142862) [then wait for it to become available and deploy to production,](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=125.72533400000003) [and only then upgrade their client code to make use of that new feature.](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=129.72533400000003) [Another very helpful practice is to create automated tests around your](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=134.72533400000003) [microservices that explicitly attempt to call using any previous version](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=140.22533400000003) [of the clients that need to be supported.](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=144.39200066666677) [These tests need to be automated as part of a](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=147.72533400000003) [continuous integration build process.](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=151.22533400000003) [And if they fail,](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=152.72533400000003) [you should fail the build so everyone is aware that there's](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=154.0586673333334) [a problem with backwards compatibility.](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=157.22533400000003) [One pattern to be aware of is introducing shared code that both](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=159.72533400000003) [the clients and the microservice itself use.](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=164.61422288888895) [Now this can be very convenient for a microservice to produce a client](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=167.72533400000003) [package that simplifies the task of calling the service.](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=172.4396197142857) [But if you do take that approach,](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=176.72533400000003) [then you need to take great care to avoid any logic being added into that](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=177.72533400000003) [package that would result in tightly coupling the microservice to its clients and forcing them to be upgraded simultaneously.](https://app.pluralsight.com/course-player?clipId=145b27e4-1bda-4a19-9829-4af0a15d7a4e&startTime=182.39200066666677)

### [Identifying Microservice Boundaries](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85)

[How can we work out the best way to break our system into microservices?](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=0.9840010000000475) [This is a difficult task and easy to get wrong.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=5.984001000000047) [Drawing service boundaries in the wrong place can result in](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=9.984001000000047) [poor system performance and are hard to change once those](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=13.484001000000047) [services are running in production.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=16.73400100000005) [So it's worth dedicating some time to considering](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=18.98400100000005) [what your options are in this area.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=21.872889888888935) [In some ways,](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=24.98400100000005) [your task is easier if you're starting from an existing monolithic application.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=25.412572428571476) [Very often, there will already be some modularization,](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=30.98400100000005) [and some of those modules might be suitable candidates](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=33.98400100000005) [for converting into microservices,](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=36.98400100000005) [especially if they're loosely coupled from the rest of](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=39.98400100000005) [the system through a clear interface.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=42.98400100000005) [Since microservices own their own data,](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=45.98400100000005) [looking for seams in the database is often a good idea.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=48.98400100000005) [Are there certain groups of tables that conceptually belong together?](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=52.98400100000005) [If so,](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=56.98400100000005) [identify all the places in the code that will read and write from those tables](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=57.65066766666672) [and see whether they can be extracted to form a microservice.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=61.98400100000005) [A helpful guideline is that microservices should be](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=65.98400100000005) [organized around business capabilities.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=69.98400100000005) [You may be familiar with the concept of domain-driven design.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=71.98400100000005) [This encourages us to identify bounded contexts within our applications.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=75.98400100000005) [This is a way of breaking up the domain model for a large system with](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=81.98400100000005) [each bounded context having its own ubiquitous language and relating to](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=86.85900100000005) [one specific business capability or subdomain.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=92.26971528571434) [And often these will map onto the organizational structure of the business.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=94.98400100000005) [You then define some models that apply within your bounded context,](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=99.98400100000005) [and this means that different microservices will use different models and](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=104.98400100000005) [even might use different terminology for the same thing.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=109.48400100000005) [We saw that earlier where the products that eShopOnContainers](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=112.98400100000005) [sells are called OrderItems by the Ordering microservice and](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=117.48400100000005) [CatalogItems by the Catalog microservice.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=121.65066766666672) [Although they both relate to a product sold by the shop,](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=124.98400100000005) [they're being used in different contexts.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=128.58400100000006) [And so they have different properties,](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=130.98400100000003) [and they're free to use different names for the same piece of information.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=132.98400100000003) [Now it can be daunting to come up with good service boundaries.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=137.98400100000003) [So a great approach to testing your ideas is to sketch them on a](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=141.98400100000003) [whiteboard and then run through some real-world use cases for your](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=145.6982867142857) [application and see which services would be involved.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=150.31733433333335) [That can help you identify potential problems if too many](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=153.98400100000003) [services are required to collaborate together to achieve a](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=157.98400100000006) [single business capability.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=161.984001) [Now in just a couple of minutes,](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=163.98400100000003) [there's no way I can do justice to the concept of domain-driven design.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=164.98400100000003) [And if you'd like to learn more about it,](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=169.98400100000003) [then there are several excellent courses available here on](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=172.98400100000003) [Pluralsight that cover it in a lot more detail,](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=175.84114385714287) [including a whole learning path by Vladimir Khorikov.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=178.98400100000003) [There are some pitfalls that you can run into when](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=183.98400100000003) [choosing your microservice boundaries.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=186.58400100000003) [One is if you simply take all the nouns in your](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=188.98400100000003) [domain and turn them into services.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=191.73400100000003) [This often ends up with you creating what are](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=193.98400100000003) [sometimes called anemic CRUD services,](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=197.1268581428572) [which are little more than wrappers around tables in a](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=199.98400100000003) [database with methods to add and update entities,](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=203.31733433333335) [while the logic related to those entities remains](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=205.98400100000003) [distributed across the rest of the system.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=209.48400100000003) [Another sign that your boundary is not quite right is when you have circular](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=212.98400100000003) [dependencies between your microservices or clusters of microservices which all need to communicate frequently with one another.](https://app.pluralsight.com/course-player?clipId=50a78fe3-c09a-4a4d-a478-bd9e53e6bc85&startTime=216.65066766666675)

### [EShopOnContainers Service Boundaries](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4)

[Let's take a look at the choices made by the architects of](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=1.1306680000000633) [the eShopOnContainers sample application to see some of](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=4.730668000000063) [these principles in action.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=9.130668000000064) [There's a Catalog microservice responsible for storing](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=11.130668000000064) [details of the products available in the shop.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=14.630668000000064) [Another microservice tracks what the customers have got in their basket.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=18.130668000000064) [And then there's an Ordering microservice,](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=22.130668000000064) [which is responsible for handling the orders that we've placed in the shop.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=24.130668000000064) [These three services relate to three distinct parts](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=29.130668000000064) [of the online shopping experience.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=32.908445777777835) [The Catalog microservice supports browsing for products.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=35.130668000000064) [The Basket microservice deals with preparing for a purchase.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=40.130668000000064) [And the Ordering microservice deals with the](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=44.130668000000064) [business process of handling an order.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=47.13066800000007) [And this separation of responsibilities makes a lot of sense.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=49.130668000000064) [For one thing,](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=54.130668000000064) [it helps with resilience as customers will be able to browse for](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=55.416382285714356) [products to buy and put them in their basket,](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=59.31248618181825) [even if the Ordering microservice is temporarily unavailable.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=62.130668000000064) [It also makes sense from a scalability perspective.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=66.13066800000006) [Each of these microservices is dealing with very different](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=70.13066800000006) [volumes of data and access patterns.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=73.38066800000006) [For example,](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=76.13066800000006) [the catalog is potentially very large and needs to support](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=77.13066800000006) [flexible queries as customers are searching for items that they](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=81.46400133333337) [want to buy based on various criteria.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=84.31248618181819) [That means it makes sense for the Catalog microservice to store its](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=87.13066800000006) [data in a database that supports rich querying.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=92.22157709090914) [And we can see here that it's using SQL Server,](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=95.13066800000006) [which makes a lot of sense for this kind of use case,](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=98.13066800000006) [whereas the Basket service deals with very short-lived data,](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=102.13066800000006) [so it may not even need to be written to a database.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=106.13066800000006) [And, in fact, eShopOnContainers actually uses Redis,](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=109.13066800000006) [a memory cache to store basket data.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=113.13066800000006) [The Ordering microservice is mostly writing new data to the](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=116.13066800000006) [database whenever a customer places an order.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=119.75566800000006) [It's got very strict requirements for reliability.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=123.13066800000006) [We certainly don't want to lose any orders.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=127.13066800000006) [And it's also handling extremely sensitive data such as](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=130.13066800000007) [people's addresses and payment information.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=132.9878108571429) [So its security requirements are very different from those of the](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=135.13066800000007) [Catalog service whose data is freely visible to everyone.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=139.46400133333344) [There's another microservice here that handles identity,](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=143.13066800000007) [and this helps deal with authentication concerns.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=147.13066800000007) [And we'll see why that choice has been made later on in](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=150.13066800000007) [this course when we look at security.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=153.3306680000001) [The Marketing microservice relates to a completely different part of the](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=156.13066800000007) [business from the Basket and Ordering microservices.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=159.7973346666668) [This microservice sends out email campaigns,](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=163.13066800000007) [which requires knowing where in the world our potential customers are located.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=165.13066800000007) [And we can see here that there's a Location](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=170.13066800000007) [microservice that handles this responsibility.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=172.83066800000017) [Obviously,](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=176.13066800000007) [the architects felt that this was a sufficiently complex](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=176.33066800000006) [component to warrant its own microservice.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=179.63066800000007) [And, of course,](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=184.13066800000007) [this isn't the only way that you could break this](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=184.79733466666676) [domain down into microservices.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=188.13066800000007) [But on the whole, I think that some good choices have been made here.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=190.13066800000007) [And, in fact,](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=194.13066800000007) [this might be a good time for you to pause this video and take some time](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=194.67612254545463) [to think about the project that you're working on.](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=198.01955688888899) [How would you break it up into microservices?](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=201.13066800000007) [What responsibility would you give to each one? And what data would each of those microservices own?](https://app.pluralsight.com/course-player?clipId=2fd40e8c-49aa-43d3-93a4-e2ef38c6edb4&startTime=204.13066800000007)

### [Module Summary](https://app.pluralsight.com/course-player?clipId=5cc6b046-3476-439c-8e03-77595324dad8)

[In this module,](https://app.pluralsight.com/course-player?clipId=5cc6b046-3476-439c-8e03-77595324dad8&startTime=0.14666800000006333) [we've looked at some of the key considerations involved in](https://app.pluralsight.com/course-player?clipId=5cc6b046-3476-439c-8e03-77595324dad8&startTime=1.1466680000000633) [architecting a microservices application.](https://app.pluralsight.com/course-player?clipId=5cc6b046-3476-439c-8e03-77595324dad8&startTime=5.480001333333397) [You can evolve an existing system towards microservices by](https://app.pluralsight.com/course-player?clipId=5cc6b046-3476-439c-8e03-77595324dad8&startTime=8.146668000000064) [augmenting it with new microservices or by extracting existing](https://app.pluralsight.com/course-player?clipId=5cc6b046-3476-439c-8e03-77595324dad8&startTime=12.646668000000064) [functionality into microservices.](https://app.pluralsight.com/course-player?clipId=5cc6b046-3476-439c-8e03-77595324dad8&startTime=18.575239428571493) [We saw that microservices should own their own data,](https://app.pluralsight.com/course-player?clipId=5cc6b046-3476-439c-8e03-77595324dad8&startTime=21.146668000000062) [and they may consist of more than one process.](https://app.pluralsight.com/course-player?clipId=5cc6b046-3476-439c-8e03-77595324dad8&startTime=24.146668000000062) [Microservices need to be independently deployable.](https://app.pluralsight.com/course-player?clipId=5cc6b046-3476-439c-8e03-77595324dad8&startTime=28.146668000000062) [This requires taking care not to make breaking changes to the API or](https://app.pluralsight.com/course-player?clipId=5cc6b046-3476-439c-8e03-77595324dad8&startTime=31.146668000000062) [doing anything else that forces the clients of a microservice to be](https://app.pluralsight.com/course-player?clipId=5cc6b046-3476-439c-8e03-77595324dad8&startTime=35.860953714285785) [upgraded simultaneously with the service.](https://app.pluralsight.com/course-player?clipId=5cc6b046-3476-439c-8e03-77595324dad8&startTime=40.2895251428572) [The concept of bounded contexts from domain-driven design should be](https://app.pluralsight.com/course-player?clipId=5cc6b046-3476-439c-8e03-77595324dad8&startTime=43.14666800000006) [applied to identify suitable boundaries for a microservice.](https://app.pluralsight.com/course-player?clipId=5cc6b046-3476-439c-8e03-77595324dad8&startTime=47.64666800000006) [And getting those boundaries right is a critical factor in](https://app.pluralsight.com/course-player?clipId=5cc6b046-3476-439c-8e03-77595324dad8&startTime=51.14666800000006) [being successful with microservices.](https://app.pluralsight.com/course-player?clipId=5cc6b046-3476-439c-8e03-77595324dad8&startTime=54.94666800000006) [In the next module,](https://app.pluralsight.com/course-player?clipId=5cc6b046-3476-439c-8e03-77595324dad8&startTime=58.14666800000006) [we'll start to look at the practicalities of building](https://app.pluralsight.com/course-player?clipId=5cc6b046-3476-439c-8e03-77595324dad8&startTime=59.14666800000006) [microservices and what day-to-day development on a microservices project might look like.](https://app.pluralsight.com/course-player?clipId=5cc6b046-3476-439c-8e03-77595324dad8&startTime=62.48000133333339)

## [Building Microservices](https://app.pluralsight.com/course-player?clipId=19988f31-8f9d-4800-bbee-781e3840d214)

### [Module Introduction](https://app.pluralsight.com/course-player?clipId=19988f31-8f9d-4800-bbee-781e3840d214)

[What does the day-to-day development experience look like](https://app.pluralsight.com/course-player?clipId=19988f31-8f9d-4800-bbee-781e3840d214&startTime=0) [when you're working on microservices?](https://app.pluralsight.com/course-player?clipId=19988f31-8f9d-4800-bbee-781e3840d214&startTime=5.142857142857142) [I'm Mark Heath, and in this module,](https://app.pluralsight.com/course-player?clipId=19988f31-8f9d-4800-bbee-781e3840d214&startTime=8) [we'll look at some of the practicalities of building microservices.](https://app.pluralsight.com/course-player?clipId=19988f31-8f9d-4800-bbee-781e3840d214&startTime=9.909090909090914) [We'll start off by talking about some of the options](https://app.pluralsight.com/course-player?clipId=19988f31-8f9d-4800-bbee-781e3840d214&startTime=15) [for how microservices are hosted, as this has implications for development.](https://app.pluralsight.com/course-player?clipId=19988f31-8f9d-4800-bbee-781e3840d214&startTime=18) [In particular, we'll see why containerized microservices are so popular.](https://app.pluralsight.com/course-player?clipId=19988f31-8f9d-4800-bbee-781e3840d214&startTime=24) [We'll discuss the source control and build requirements for a microservice,](https://app.pluralsight.com/course-player?clipId=19988f31-8f9d-4800-bbee-781e3840d214&startTime=30) [as well as some of the standard features that should](https://app.pluralsight.com/course-player?clipId=19988f31-8f9d-4800-bbee-781e3840d214&startTime=34) [be present on every microservice.](https://app.pluralsight.com/course-player?clipId=19988f31-8f9d-4800-bbee-781e3840d214&startTime=37.85714285714286) [We'll look at the value of having a service template to work from,](https://app.pluralsight.com/course-player?clipId=19988f31-8f9d-4800-bbee-781e3840d214&startTime=40) [as well as a standard way of working that enables developers to](https://app.pluralsight.com/course-player?clipId=19988f31-8f9d-4800-bbee-781e3840d214&startTime=43.81818181818182) [productively debug and test their microservices in isolation, as well as in the context of the wider application.](https://app.pluralsight.com/course-player?clipId=19988f31-8f9d-4800-bbee-781e3840d214&startTime=48.400000000000006)

### [Hosting Microservices](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab)

[When we develop a microservice application,](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=0.3173329999999987) [we typically want to run it in a variety of environments.](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=4.317332999999999) [Developers want to be able to run and debug the code](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=9.317332999999998) [locally on their development laptop.](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=12.067332999999998) [Testers might want to run the application in a staging environment,](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=14.317332999999998) [maybe in the cloud.](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=18.317332999999998) [And, of course, we also want to be able to run our application in production.](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=20.317332999999998) [But how should we host the microservices?](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=25.317332999999998) [What should they run on?](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=28.317332999999998) [There are lots of choices here,](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=30.317332999999998) [and microservices don't dictate which option you go for.](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=32.567333) [The traditional option is to use virtual machines.](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=36.317333) [You could go for one virtual machine per microservice,](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=40.317333) [but that can get very expensive,](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=44.317333) [especially if you opt for having lots of small microservices.](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=46.317333) [So, alternatively,](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=51.317333) [you might decide to pack several microservices onto a single virtual machine,](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=52.067333) [but that can get a bit messy as each microservice might](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=57.317333) [have different requirements for frameworks or](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=61.03161871428572) [dependencies that need to be installed.](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=63.65066633333333) [And there are several other operational challenges with using virtual machines,](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=66.317333) [such as how each microservice can know where to find the others.](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=70.317333) [Another option is to target Platform as a Service, or PaaS.](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=75.317333) [Many cloud providers offer hosted services where you simply](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=80.317333) [provide the code for your microservices and they take care of a](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=84.31733299999999) [lot of the management and infrastructure,](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=88.317333) [providing you with automatic scale-out and DNS entries for each](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=91.317333) [microservice with load balancing built in.](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=96.067333) [They often also provide security and monitoring features as standard.](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=98.317333) [Serverless platforms fall into this category and are especially good](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=104.317333) [at supporting what might be called nano-services,](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=108.65066633333332) [which are extremely small microservices that just do a single task.](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=112.317333) [And I've actually created several courses here on Pluralsight](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=117.317333) [about serverless architecture and Azure Functions,](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=121.31733300000002) [which is a serverless platform for Azure.](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=124.317333) [So feel free to check those out if you're interested in](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=127.317333) [learning more about this approach.](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=129.817333) [A third option that's emerged as one of the most popular](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=132.317333) [approaches to implementing microservices,](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=135.91733299999999) [is to use containers.](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=138.317333) [Containers let you package up an application along with all](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=141.317333) [of its dependencies in such a way that it's easily portable](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=144.68096936363636) [to run on any container host.](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=148.7459044285714) [That container host could be running in the cloud,](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=151.317333) [but it could also be your local development laptop,](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=154.317333) [and this greatly simplifies the task for a developer who wants to](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=157.317333) [get all of the microservices running locally.](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=162.21733300000002) [And tools like Docker Compose that we're going to be](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=164.317333) [seeing later give us a really straightforward way of launching a group of microservices.](https://app.pluralsight.com/course-player?clipId=5434bf1f-05a5-4b6e-ab43-95d1dfe994ab&startTime=167.74590442857138)

### [Demo: Running Microservices Locally in Containers](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7)

[Let's see how containerizing our microservices can make life much simpler for](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=2.04) [us as developers. We're going to be using the eShopOnContainers sample](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=7.05) [application that we've been looking at throughout this course to see how](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=11.83) [containerization greatly simplifies the development experience and enables us](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=15.74) [to easily run the whole application locally. First, let me quickly tell you](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=21.06) [how I've set up my development machine in order to run this demo. I've](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=26.39) [installed Docker Desktop,](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=31.3) [which allows me to run containers on Windows. And this actually](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=33.24) [supports running both Linux and Windows containers.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=37.31) [We're going to be using Linux containers for this demo, and](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=41.44) [this means that if you're using a Mac,](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=45.23) [you can also install Docker Desktop and run exactly the same containers.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=47.03) [I've cloned the eShopOnContainers source code from GitHub onto my](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=52.54) [local machine. And there were a couple of prerequisites steps on](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=56.5) [Windows that I needed to perform.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=60.6) [One was that I enabled the WSL 2 based engine in the Docker Desktop](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=62.94) [General settings dialog. Another one was to add a Windows firewall](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=68.72) [rule that opens up some ports, and there's a helpful PowerShell](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=73.38) [script provided to do that.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=77.65) [So, here I am at the Windows command prompt, and I'm going to use a](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=80.24) [tool called Docker Compose to work on this project.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=83.91) [And the first thing I want to do is build all of the source code for](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=87.74) [my microservice into some Docker container images.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=90.79) [And so I'm going to use the docker‑compose build command to do that, and when I](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=94.74) [run this, it's going to go and build a Docker container image for each of the](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=99.43) [microservices in my application. And this is going to work regardless of](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=103.86) [whether I've got the .NET Core SDKs installed on my machine or not because it's](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=108.26) [going to build the code inside another Docker container that's got all of the](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=113.02) [necessary SDKs installed.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=117.6) [Now,](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=120.34) [the first time you run this it is going to take quite a long time, it took](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=120.57) [about 10 minutes on my machine, and that's primarily because it's got to](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=124.19) [download a large number of container images that it's going to use as the](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=127.92) [basis for the containers that it's created.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=132.35) [So I fast forwarded this to the point where it's finished building all of](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=135.44) [my microservice container images. And if we want to, we can use the docker](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=139.59) [image list command to see the images that we've now got on our system, and](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=144.63) [you can see it's built a whole load of stuff, including images for each of](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=149.82) [the microservices.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=153.94) [Now to actually run our application,](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=156.04) [we again can use Docker Compose, and Docker Compose has got this really](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=158.26) [handy docker‑compose up command that will start a container for each of](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=162.14) [the services in the application. And again,](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=166.92) [the first time we run this,](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=170.56) [it will be a little bit slower as it needs to pull down some](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=171.86) [additional images for the third‑party containers, like SQL](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=174.98) [Server, Redis, and RabbitMQ.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=179.23) [But the great thing about this is I don't need to have any of those](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=182.64) [applications running locally on my development machine.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=185.57) [My microservices are going to be storing their data in](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=188.84) [containerized databases. And once it's downloaded the](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=192.21) [images for all of those dependencies,](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=195.81) [it's going to start up a container for each microservice, as](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=197.99) [well as for each of those dependencies that we've containerized,](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=201.39) [and that will happen really quickly.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=204.61) [So here you can see it started them all up, and it's also started to](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=206.94) [show us the log output from each of these containers.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=210.71) [Now, if you're wondering how docker‑compose up knew what services to start, well,](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=214.84) [all it does is it looks at a YAML file that lists all the containers](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=219.6) [that need to be started, along with any specific configuration or](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=223.79) [environment variables that they need.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=228.07) [And, these files might look a little bit intimidating if you've never seen them](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=230.74) [before, but they're actually relatively straightforward and it's very easy to](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=234.6) [add in an additional service to the list that needs to be started. By](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=238.83) [convention, the file that Docker Compose looks for is called](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=243.79) [docker‑compose.yml. And each of these containers actually comes with a variety](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=247.22) [of different override YAML files that can build on top of the base](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=252.3) [docker‑compose.yml file which allows you to easily start the application in a](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=256.51) [variety of different configurations.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=261.48) [As you can see here in this file,](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=264.44) [it lists all the services that make up the overall application.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=266.24) [There's an entry here for each container, so here we can see a](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=270.64) [SQL Server and a MongoDB container, which are used for the](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=274.12) [databases when we're running locally.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=278.02) [There's also a Redis Cache and RabbitMQ for the message bus. For](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=280.94) [production, we might not run any of these services in containers and](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=286.11) [prefer to point at cloud‑hosted databases or event buses.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=289.88) [But for local development, this is brilliant.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=293.86) [If we scroll down a bit further,](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=297.34) [we can see the entries for each of our microservices, starting with the](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=298.95) [identity microservice and then the basket microservice.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=303.1) [You can see that these point at the Dockerfile that can be used to create the](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=307.64) [image for each microservice if it's not already available.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=311.52) [And that's what was happening when we ran the docker‑compose build](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=315.54) [command earlier. Because it didn't have a local container image, it used](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=318.78) [that Dockerfile to build the container image.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=323.32) [And if I scroll down a bit further, here we can see the](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=326.64) [catalog and ordering microservice definitions.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=329.27) [Now, these containers should already have started up by now, so if I go](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=333.44) [to my web browser and we visit host.docker.internal on port 5100, we](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=338.35) [should see that the eShopOnContainers website is up and running. And we](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=345.36) [can see here on the shop home page that we can explore a range of](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=350.6) [programming‑related merchandise.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=354.27) [Let's log in, and the system comes preconfigured with a demo user that we can](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=357.34) [log in as, so I'll just copy in the username and password.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=362.07) [And once we finish logging in, we can choose an item](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=366.84) [to buy and place it into our cart.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=370.26) [Now let's go and look inside our shopping cart, and we'll click Checkout,](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=373.74) [we'll except these default shipping and payment details, and we'll place](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=379.24) [our order. And so now we've added an order to the system, and if we want](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=383.3) [to take a look at the order details,](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=388.2) [we can do so here. And so as you can see, it was very easy to get](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=390.36) [this up and running, and those steps we just ran through exercised a](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=394.58) [number of the microservices in our overall application. And if you](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=398.09) [want to try this out yourself,](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=402.88) [you can do that really easily whether you're on Windows or Mac,](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=404.27) [you just need to follow these getting started instructions that you](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=408.08) [can find on the eShopOnContainers GitHub page.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=411.37) [And this has got detailed instructions of all the steps that you](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=415.14) [need to complete, as well as some troubleshooting hints as well for](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=417.94) [common problems that you might run into.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=421.68) [Now, I can't overemphasize how much of a game changer this](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=425.24) [sort of setup can be for developers.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=428.79) [Imagine if I'd had to separately build and run each of those](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=431.13) [individual microservices, as well as install all of the](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=434.47) [third‑party software like SQL Server and RabbitMQ and configure](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=437.66) [everything to talk to each other.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=442.69) [That would be a really painful process and probably take](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=444.74) [the best part of a day to complete.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=447.43) [But using containers and Docker Compose locally makes](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=450.04) [it really trivial to get started.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=453.38) [We were up and running in just a few minutes.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=455.47) [Another great thing about this setup is that many modern development](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=458.54) [tools will allow you to attach a debugger to code that's running](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=461.84) [inside a container, and so I can get a very rich local development](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=466.11) [experience with this kind of setup.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=469.99) [Now obviously containers are not a requirement for microservices,](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=473.24) [but if you are planning to host your microservices on virtual machines or](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=477.32) [Platform as a Service, then you'll probably need to invest some time into](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=481.6) [automating the process for developers of getting everything up and running](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=485.61) [and configured on their local machines.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=489.69) [Because if you don't, as the number of microservices grows larger,](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=492.14) [the productivity of developers will drop off dramatically.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=496.32) [So having something like Docker Compose that gives us a one‑command way to start everything up really is invaluable.](https://app.pluralsight.com/course-player?clipId=ecb498b0-620b-4413-96cf-aec0095bd7e7&startTime=500.04)

### [Creating a New Microservice](https://app.pluralsight.com/course-player?clipId=8025d3b3-d357-450a-b711-c8e5e25c1d69)

[What are the steps involved in creating a new microservice for your application?](https://app.pluralsight.com/course-player?clipId=8025d3b3-d357-450a-b711-c8e5e25c1d69&startTime=0.4773329999999842) [Well, first of all,](https://app.pluralsight.com/course-player?clipId=8025d3b3-d357-450a-b711-c8e5e25c1d69&startTime=6.477332999999984) [you'll typically want to create a new source control](https://app.pluralsight.com/course-player?clipId=8025d3b3-d357-450a-b711-c8e5e25c1d69&startTime=7.20460572727271) [repository for your microservice code.](https://app.pluralsight.com/course-player?clipId=8025d3b3-d357-450a-b711-c8e5e25c1d69&startTime=9.620190142857126) [While it is technically possible to keep the code for all](https://app.pluralsight.com/course-player?clipId=8025d3b3-d357-450a-b711-c8e5e25c1d69&startTime=12.477332999999984) [your microservices in a single repository,](https://app.pluralsight.com/course-player?clipId=8025d3b3-d357-450a-b711-c8e5e25c1d69&startTime=16.227332999999984) [that can become very unwieldy if you have many microservices,](https://app.pluralsight.com/course-player?clipId=8025d3b3-d357-450a-b711-c8e5e25c1d69&startTime=18.477332999999984) [and it also greatly increases the risk of introducing](https://app.pluralsight.com/course-player?clipId=8025d3b3-d357-450a-b711-c8e5e25c1d69&startTime=21.477332999999984) [tight coupling between your microservices,](https://app.pluralsight.com/course-player?clipId=8025d3b3-d357-450a-b711-c8e5e25c1d69&startTime=25.477332999999984) [which is something you really want to avoid.](https://app.pluralsight.com/course-player?clipId=8025d3b3-d357-450a-b711-c8e5e25c1d69&startTime=28.477332999999984) [You should also set up a continuous integration build,](https://app.pluralsight.com/course-player?clipId=8025d3b3-d357-450a-b711-c8e5e25c1d69&startTime=31.477332999999984) [which will build a new version of your microservice every time someone](https://app.pluralsight.com/course-player?clipId=8025d3b3-d357-450a-b711-c8e5e25c1d69&startTime=34.47733299999999) [commits code into the source control repository.](https://app.pluralsight.com/course-player?clipId=8025d3b3-d357-450a-b711-c8e5e25c1d69&startTime=38.67733299999998) [And this build should also run any automated tests you've created,](https://app.pluralsight.com/course-player?clipId=8025d3b3-d357-450a-b711-c8e5e25c1d69&startTime=41.47733299999999) [and the build should fail if those tests don't pass.](https://app.pluralsight.com/course-player?clipId=8025d3b3-d357-450a-b711-c8e5e25c1d69&startTime=44.93187845454544) [In fact, tests are a super important part of building microservices, so let's talk about them next.](https://app.pluralsight.com/course-player?clipId=8025d3b3-d357-450a-b711-c8e5e25c1d69&startTime=49.47733299999999)

### [Testing Microservices](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8)

[Automated tests are a critical part of being successful with microservices.](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=1.008) [We're not actually going to go into them in great depth on this course](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=6.008) [because other courses on the microservices learning path here on](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=10.008000000000001) [Pluralsight are going to cover them in a lot more detail,](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=13.208000000000002) [but I do want to quickly mention three very important types of](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=16.258) [tests that you should be aware of and be creating.](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=20.508) [The first is unit tests.](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=24.008) [These operate at the code level, and they're typically very fast to run.](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=26.008) [If you're following a test-driven development,](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=31.008) [or TDD process, then you'll already be creating these,](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=33.008) [and you typically want lots of unit tests and for them](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=37.008) [to have very good code coverage, especially any business-specific rules or logic.](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=41.00800000000001) [The second is service-level tests, or sometimes called integration tests.](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=47.008) [We want to be able to test an individual microservice](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=52.008) [in isolation from all the others.](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=56.008) [And these tests often require us to deploy an instance of the](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=58.008) [microservice to a host and configure it to talk to stubbed out or](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=62.55345454545455) [mocked versions of its collaborators,](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=66.78577777777777) [although it will talk to a real version of whatever](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=69.008) [database it's using to store it's data.](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=72.6443636363636) [Then you run a series of tests that call it's public API and verify that](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=75.008) [you're getting the expected responses from those end points.](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=80.258) [And these sorts of tests are harder to write than unit tests,](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=84.008) [but they are tremendously valuable,](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=88.133) [so it's worth investing the time to create a framework that](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=90.008) [allows you to create these service-level integration tests](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=94.29371428571429) [for each of your microservices.](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=97.15085714285713) [And these tests too ought to be run as part of an automated build process.](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=100.008) [Finally, there are end-to-end level tests,](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=105.008) [and these are where you test all of your microservices running](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=109.008) [together in a production-like environment,](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=112.508) [and you automate some key journeys through your application](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=115.008) [from the user interface that exercise as many parts of the](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=119.008) [system working together as possible.](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=122.86514285714286) [And these types of tests can be much more challenging to write,](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=125.008) [to maintain,](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=128.60800000000003) [as they tend to be fragile and brittle and prone to](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=129.20800000000006) [failure due to transient problems.](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=133.00800000000004) [So try to verify as much functionality as possible](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=135.008) [with the other types of tests,](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=138.008) [but end-to-end tests are still very valuable even if you're just](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=140.008) [using them as what's called a smoke test that helps you determine](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=143.67466666666664) [that your system isn't completely broken,](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=148.008) [but is still able to provide some of the key bits of functionality end to end. Rather than starting from a blank sheet of paper](https://app.pluralsight.com/course-player?clipId=5c72645f-55bc-4aa7-ac9d-73d3e0b833c8&startTime=150.008)

### [Microservice Templates](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2)

[for every microservice, it's a great idea to have some kind of standard template.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=3.936) [This could be an actual template that you maintain in its](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=8.936) [own code repository that's used as the starting point for](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=12.793142857142858) [every new microservice you create,](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=16.935999999999996) [or it could be that you nominate a particular microservice as an exemplar.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=18.936) [In other words, it demonstrates a pattern that other microservices should follow.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=23.936) [And the reason for doing this is that there are many things that it's a](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=28.936) [good idea to standardize across all your microservices.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=31.436) [Let me give you a few examples.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=35.936) [Logging.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=37.936) [All of your microservices should be emitting logs in the same format](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=39.936) [and sending those logs to a centralized location.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=43.936) [Health checks.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=47.936) [It's a great idea for every microservice to have a](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=48.936) [way of reporting its own health.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=52.57236363636367) [Is it up and running yet,](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=54.936) [and can it talk to its downstream dependencies such as](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=55.936) [databases or maybe other microservices?](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=60.07885714285714) [Configuration.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=62.936) [It's a good idea for all of your microservices to take the same](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=64.936) [approach to accessing sequence and configuration.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=68.936) [Authentication.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=71.936) [You might have some standard middleware that sets up the necessary](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=74.936) [authentication pipeline for your technology of choice,](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=79.07885714285716) [such as ASP.NET or Node.js, and by having a standard approach to that,](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=82.436) [you've reduced the risk of developers accidentally misconfiguring](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=87.936) [authentication and leaving a microservice unsecured.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=91.26933333333335) [Build scripts.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=95.936) [It's a good idea for there to be a standard way for](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=96.936) [developers to build the code.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=100.26933333333334) [In the example we've been looking at, it's been using containers,](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=101.936) [so each microservice needs to have a Docker file](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=104.936) [that produces the container image.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=107.936) [And, of course,](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=110.936) [there may be some additional things that you want every](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=111.60266666666669) [microservice in your application to have by default,](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=114.53600000000003) [so include those in your template or exemplar as well.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=117.936) [Now by providing all of these things out of the box,](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=121.936) [you're going to greatly reduce the time needed to get](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=125.936) [a new microservice up and running,](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=128.436) [and you'll also ensure consistency across your product.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=129.936) [Now, of course,](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=133.936) [this type of standardization might constrain some of the](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=135.26933333333338) [freedom that we discussed earlier that microservices give](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=138.686) [you to adopt new technologies.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=141.436) [For example,](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=143.936) [you might decide that you're going to standardize on using one particular](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=144.6026666666667) [programming language across all your microservices,](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=149.0788571428571) [and that makes quite a bit of sense as it allows developers to more](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=151.936) [easily move between working on different microservices,](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=155.436) [but do try not to be so rigid with your standardization that you prevent](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=158.936) [teams from being able to choose the best tools for the job.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=163.36457142857142) [The end goal of this is to provide a friction-free development environment.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=166.936) [In other words,](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=171.936) [we want developers on our microservices application to be as productive as](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=172.93600000000004) [possible and to be able to spend their time focusing on implementing the](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=177.5074285714285) [business requirements of the microservice rather than all the plumbing and](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=181.13600000000002) [infrastructure surrounding microservices.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=185.936) [It should be possible for each developer to work on a microservice in isolation,](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=188.936) [running service-level integration tests against it to](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=193.936) [check that it still honors its contracts,](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=197.311) [but it should also be possible for each developer to test](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=199.936) [their work in the context of a full system.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=202.84509090909094) [Depending on the size of your microservices application,](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=206.936) [it might be possible for developers to run everything](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=209.936) [locally on their development machine,](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=213.061) [just like we saw with the eShopOnContainers application in Docker Compose.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=214.936) [Or you might decide to take a different approach where your developers](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=219.936) [connect to shared services running in the cloud.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=223.79314285714284) [Whichever option you choose, try to ensure that the process is as streamlined and automated as possible.](https://app.pluralsight.com/course-player?clipId=2fe51a0e-f2a8-404a-8a60-88a11e87aca2&startTime=226.936)

### [Module Summary](https://app.pluralsight.com/course-player?clipId=89afee39-c295-4c21-8e16-d81b7df48508)

[In this module,](https://app.pluralsight.com/course-player?clipId=89afee39-c295-4c21-8e16-d81b7df48508&startTime=0.76) [we looked at a few different options for how microservices can be hosted,](https://app.pluralsight.com/course-player?clipId=89afee39-c295-4c21-8e16-d81b7df48508&startTime=1.6600000000000001) [and we saw how containers can offer us a particularly](https://app.pluralsight.com/course-player?clipId=89afee39-c295-4c21-8e16-d81b7df48508&startTime=6.76) [good local development experience.](https://app.pluralsight.com/course-player?clipId=89afee39-c295-4c21-8e16-d81b7df48508&startTime=10.093333333333332) [We discussed the fact that each microservice should have its own source](https://app.pluralsight.com/course-player?clipId=89afee39-c295-4c21-8e16-d81b7df48508&startTime=12.76) [control repository and continuous integration build configured.](https://app.pluralsight.com/course-player?clipId=89afee39-c295-4c21-8e16-d81b7df48508&startTime=16.902857142857144) [Automated tests are vitally important for microservices,](https://app.pluralsight.com/course-player?clipId=89afee39-c295-4c21-8e16-d81b7df48508&startTime=20.76) [and we said that each microservice should have its own unit tests,](https://app.pluralsight.com/course-player?clipId=89afee39-c295-4c21-8e16-d81b7df48508&startTime=24.76) [as well as service-level integration tests.](https://app.pluralsight.com/course-player?clipId=89afee39-c295-4c21-8e16-d81b7df48508&startTime=28.76) [And there's also the need for end-to-end tests that verify that the](https://app.pluralsight.com/course-player?clipId=89afee39-c295-4c21-8e16-d81b7df48508&startTime=31.76) [microservices integrate with one another successfully.](https://app.pluralsight.com/course-player?clipId=89afee39-c295-4c21-8e16-d81b7df48508&startTime=36.160000000000004) [We saw that there are several things that are worth](https://app.pluralsight.com/course-player?clipId=89afee39-c295-4c21-8e16-d81b7df48508&startTime=39.76) [standardizing across all your microservices,](https://app.pluralsight.com/course-player?clipId=89afee39-c295-4c21-8e16-d81b7df48508&startTime=41.76) [such as the approach to logging or authentication,](https://app.pluralsight.com/course-player?clipId=89afee39-c295-4c21-8e16-d81b7df48508&startTime=44.76) [and a great way to achieve that is by using service templates which serve](https://app.pluralsight.com/course-player?clipId=89afee39-c295-4c21-8e16-d81b7df48508&startTime=47.76) [as a starting point for creating a new microservice.](https://app.pluralsight.com/course-player?clipId=89afee39-c295-4c21-8e16-d81b7df48508&startTime=51.76) [In our next module,](https://app.pluralsight.com/course-player?clipId=89afee39-c295-4c21-8e16-d81b7df48508&startTime=55.76) [we'll explore the options for how microservices can communicate with one another.](https://app.pluralsight.com/course-player?clipId=89afee39-c295-4c21-8e16-d81b7df48508&startTime=57.26)

## [Communicating Between Microservices](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc)

### [Module Introduction](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc)

[How should our microservices communicate with each other?](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=0) [As always with microservices,](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=5) [there's a lot of choice available to us including both](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=7) [synchronous and asynchronous communication patterns.](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=10.666666666666668) [I'm Mark Heath, and in this module,](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=15) [we'll explore several approaches to reliable](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=17) [communication between microservices.](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=21) [We'll start off by looking at the big picture of](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=24) [communication between microservices.](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=26.75) [Should any microservice be allowed to communicate with any other?](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=29) [And what about client-facing applications such as](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=33) [websites and mobile applications?](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=37) [Can they simply call whatever microservice they want to?](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=39) [We'll learn about how API gateways can be used to decouple](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=43) [front-end applications from back-end microservices.](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=47) [We'll see that microservices can use either synchronous](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=52) [or asynchronous communication styles.](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=55) [And, in fact,](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=58) [many microservice architectures make use of a combination of both approaches.](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=59.125) [We'll look at RESTful APIs over HTTP,](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=64) [which is one of the most popular patterns for exposing microservice APIs.](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=68) [And we'll see how message brokers support asynchronous](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=74) [messaging patterns and why that's beneficial.](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=76.5) [For both synchronous and asynchronous communication styles,](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=80) [we'll also learn about some of the patterns that support resilient](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=84) [communications to ensure that even when things temporarily go wrong,](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=88.5) [your system is able to cope with the problem and recover from it.](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=93) [And, finally, we'll look at the challenge of service discovery.](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=97) [How can microservices know where to find each other? We'll see how the service registry pattern can help us out here.](https://app.pluralsight.com/course-player?clipId=7a0a05fe-ec15-4e93-b05d-4e400f94bccc&startTime=101)

### [Microservice Communication Patterns](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640)

[Are there any rules that govern which microservices](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=1.648) [should be allowed to talk to each other?](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=4.648) [For example, if I've got a few microservices,](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=7.648) [is it okay for them all to just call each other whenever it's necessary?](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=10.648) [And if I've got a front-end application,](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=15.648) [like a website or a mobile application,](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=17.648) [should that also be allowed to call directly to any](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=20.648) [of the microservices it wants to?](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=23.648) [Well, once again, microservices doesn't stipulate any hard or fast rules here,](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=26.648) [but there are some difficulties with allowing a](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=32.648) [complete free-for-all situation like this.](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=35.148) [You can end up creating a mess of tangled dependencies between](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=37.648) [services that can result in cascading failures where one microservice](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=41.048) [failing causes the others to fail as well,](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=45.933714285714295) [and you can also end up with poor performance if making a](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=49.648) [call to one microservice ends up requiring multiple hops to](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=53.50514285714286) [call additional microservices.](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=57.398) [And if that's what's happening in your architecture,](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=59.648) [that might actually suggest that you've got some](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=61.648) [service boundaries in the wrong place.](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=64.848) [A better approach is to minimize calls between microservices.](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=66.648) [Instead,](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=71.648) [your microservices could publish messages to a shared event bus](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=72.148) [and also subscribe to messages on that bus.](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=76.648) [This promotes asynchronous communication between microservices,](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=79.648) [and we'll be discussing the benefits of that later in this module.](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=83.398) [When we're dealing with front-end applications,](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=88.648) [particularly with mobile applications or single-page](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=90.648) [applications where calls are coming into our microservices](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=94.648) [directly from a client-side application,](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=98.273) [then we might prefer to avoid the client application needing to know](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=100.648) [how to connect to all our different microservices.](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=105.44800000000001) [Instead,](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=108.648) [a pattern can be used called an API gateway where all the calls from](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=109.148) [the front-end client application go through the gateway and are](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=115.87022222222221) [routed through to the correct microservice.](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=119.648) [This offers several benefits.](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=122.648) [It means we can implementation authentication at the API gateway level,](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=124.648) [and generally it makes security easier to reason about if all the](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=129.648) [external traffic enters the system at a single point.](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=133.773) [This approach also decouples the client application from the](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=137.648) [specifics of our back-end APIS giving us freedom to be more](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=142.50514285714283) [flexible with changes to our microservices while maintaining a](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=146.64800000000005) [consistent public-facing API.](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=150.64799999999997) [And this is especially important if third parties are](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=152.648) [creating the client applications for our APIs,](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=156.148) [meaning that we aren't in control of their upgrade schedules.](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=158.98133333333337) [A closely related pattern called Back-end for Front-end builds on this idea.](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=164.648) [You can create an API gateway for each of your front-end applications,](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=170.648) [and this might even turn one incoming HTTP request into two back-end calls](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=174.648) [whose responses are aggregated or transformed into just the right format to](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=180.648) [meet the needs of the front-end application.](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=186.148) [Let's see what approach the eShopOnContainers sample app takes.](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=189.648) [First of all,](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=194.648) [we can see that they've embraced the concept of back-ends for front-ends,](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=195.46618181818184) [or API gateways,](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=199.93371428571433) [and both the mobile application and the two websites](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=201.648) [communicate through the API gateways.](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=205.648) [We can see that the microservices don't call each other but instead](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=208.648) [are raising integration events to an event bus,](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=212.648) [and this event bus is implemented either as RabbitMQ for](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=215.648) [when we're running locally or Azure Service Bus for when](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=219.98133333333334) [we're running in the cloud.](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=223.50514285714283) [And then these messages are subscribed to by the other](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=225.648) [microservices and handled asynchronously.](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=229.148) [And so this architecture is a good illustration of the fact that you can](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=231.648) [combine a few different approaches to communication patterns within the](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=236.28436363636368) [same system using each one where appropriate.](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=240.5051428571429) [So let's dive a little bit deeper now into our options for both synchronous and asynchronous communications between microservices.](https://app.pluralsight.com/course-player?clipId=5cdf607b-58e4-4b4d-8275-87ef60b0d640&startTime=244.648)

### [Synchronous Communication](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9)

[By synchronous communications,](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=1.3786670000000159) [we mean making a direct call to a microservice and](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=3.3786670000000156) [waiting for it to respond to us.](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=6.753667000000016) [A good example of when we need to do this is when](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=9.378667000000016) [the front-end is making a query.](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=12.878667000000016) [Say, for example, in the eShopForContainers web page,](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=14.378667000000016) [we want to show the top 10 most popular products available.](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=18.378667000000014) [To implement this,](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=22.378667000000014) [we'd make a request through the API gateway and into the Catalog microservice,](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=23.664381285714295) [and then that microservice fetches data from its database](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=30.378667000000014) [which is a SQL database in eShopOnContainers and returns it](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=33.128667000000014) [all the way back to the web page.](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=36.60088922222223) [And because this is a synchronous communication,](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=40.378667000000014) [it's important that this operation is optimized to](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=43.378667000000014) [complete as quickly as possible.](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=46.0453336666667) [We don't want customers to be put off shopping with us by](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=48.378667000000014) [experiencing slow load times on our home page.](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=51.82311144444446) [And although there are many communication mechanisms](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=55.378667000000014) [available for calling microservices, HTTP is by far the most popular mechanism,](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=58.71200033333334) [and that's because it's an industry standard available in all](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=64.37866700000002) [mainstream programming languages including JavaScript,](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=69.17866700000003) [meaning that any web page or mobile application can](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=71.71200033333336) [easily call our microservices.](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=75.97866700000002) [In addition,](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=78.37866700000002) [we can take advantage of some of the other characteristics of HTTP](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=79.04533366666668) [such as standardized approaches to reporting errors and the ability](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=83.37866700000002) [to cache responses or use proxies.](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=88.04533366666668) [The payload of a HTTP request in response to our](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=91.37866700000002) [microservices is typically going to be in JSON,](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=95.37866700000002) [although other options are available including XML.](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=99.37866700000002) [One of the advantages of JSON is its wide support across the](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=103.37866700000002) [vast majority of programming languages,](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=106.87866700000002) [but also that it's the native format that JavaScript likes to work with,](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=109.37866700000002) [so it's really great when you're calling your microservices from web pages.](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=114.2358098571429) [Another pattern very often associated with microservice architectures is](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=119.37866700000002) [to implement your API as a set of RESTful resources.](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=123.83321245454547) [The RESTful approach to API design encourages you to represent the](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=128.378667) [information that your service works with as resources.](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=133.878667) [In eShopOnContainers, a resource might be a CatalogItem or an Order.](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=137.378667) [Each of those resources is then manipulated using the standard](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=143.378667) [HTTP verbs such as GET to retrieve a resource,](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=148.178667) [POST to create a new resource, or PUT to update a resource.](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=152.378667) [RESTful API design also encourages making good use of HTTP features](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=158.378667) [such as meaningful response codes and using media types to specify](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=163.253667) [how our resources should be represented.](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=168.37866700000006) [Now REST is a very big topic,](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=171.378667) [and we don't have the time in this course to explain](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=174.378667) [all of the philosophy behind it.](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=177.128667) [But, fortunately,](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=179.378667) [Pluralsight has several excellent courses in its library that](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=180.52152414285717) [will explain to you how to design a RESTful API and implement](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=184.71200033333338) [it in your technology of choice.](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=189.128667) [Some of my favorite courses on this topic in the](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=191.378667) [Pluralsight library are these ones by Kevin,](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=194.378667) [which will give you a very thorough overview of working with](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=197.378667) [REST and are especially useful if you're planning to implement your RESTful APIs in ASP.NET Core.](https://app.pluralsight.com/course-player?clipId=02e53f12-7ab4-41d0-b028-e56a5d9613b9&startTime=200.128667)

### [Asynchronous Communication](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2)

[Sometimes we might want to ask a microservice to do](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=0.7013340000000317) [something that we don't need to wait for.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=4.301334000000032) [A good example in the eShopOnContainers website would be](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=6.701334000000032) [the process of submitting an order.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=10.451334000000031) [When we submit an order,](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=12.701334000000031) [there might be all kinds of tasks that need to be done by the back-end](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=14.701334000000031) [systems including taking payments from a payment provider,](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=19.36800066666669) [maybe ordering additional stock from a supplier,](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=22.70133400000003) [and then initiating the shipping process from the warehouse.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=25.701334000000028) [And this process might take a few days to complete,](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=29.70133400000003) [and so we can't expect the user of the website to wait all](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=32.70133400000003) [that time to get an order confirmation.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=35.90133400000003) [They just need to know that their order has been accepted and](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=38.70133400000003) [they can come back later to check its progress.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=42.03466733333337) [We might even send them email updates to keep them updated on their order](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=45.70133400000003) [status and let them know once it's out for delivery.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=50.32633400000003) [And we can achieve this by making use of asynchronous communication patterns.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=53.70133400000003) [It is possible to implement asynchronous communication patterns over HTTP.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=57.70133400000003) [For example, when a customer submits a new order,](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=64.70133400000003) [our Ordering microservice could return a 202 Accepted HTTP response](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=67.70133400000003) [code rather than a regular HTTP 200 OK response code.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=73.86800066666667) [202 means that you've accepted a request to do some work](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=79.70133400000003) [but you haven't carried it out yet.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=82.70133400000003) [And in the response body,](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=85.70133400000003) [you often send an ID of some sort so that the client can then pull for](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=86.70133400000005) [the status of that work to find out if it's completed.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=91.59022288888895) [In our example, that ID might just be the order number.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=94.70133400000003) [You might also want to combine this technique with the use](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=98.70133400000003) [of webhooks where the microservice itself reports back](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=102.50133400000001) [when it's completed the task.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=105.70133400000003) [In this model, when a client calls your microservice,](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=108.70133400000003) [they can register a callback URL on which they'd](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=111.70133400000003) [like to receive any notifications.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=115.57633400000003) [But another very common pattern for asynchronous communications is for](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=118.70133400000003) [microservices to publish messages to an event bus.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=122.70133400000003) [Rather than directly calling the other microservices,](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=126.70133400000003) [they simply create a message and send it to a message broker,](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=130.70133400000003) [which serves as an intermediary.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=134.70133400000003) [Other microservices then subscribe to those messages.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=136.70133400000003) [And this pattern has a number of advantages.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=140.70133400000003) [First of all, it completely decouples the microservices from each other.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=144.70133400000003) [So instead of one service directly calling the next service,](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=149.70133400000003) [instead it simply talks to the message broker.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=153.70133400000003) [This means that if the second service is temporarily unavailable,](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=156.70133400000003) [then the first service is still able to function,](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=160.70133400000003) [and the second service can just process any queued-up](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=163.70133400000003) [messages once it's online again.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=167.20133400000003) [This approach is also very beneficial for supporting](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=169.70133400000003) [more advanced scaling patterns.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=173.03466733333335) [If the number of unprocessed messages for a microservice is building up,](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=175.70133400000003) [you can scale that microservice out to multiple instances to help](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=179.70133400000003) [work through the backlog of messages quickly.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=184.36800066666675) [And many serverless hosting platforms do this automatically for you.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=187.70133400000003) [But with containerized solutions,](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=192.70133400000003) [it's also possible to achieve the same thing by configuring some](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=193.70133400000003) [automatic scaling roles for the cluster of virtual machines that](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=198.20133400000003) [your containers are running on.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=202.03466733333337) [There are several different types of messages that you can use.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=203.70133400000003) [Two of the most important types of message are commands and events.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=208.70133400000003) [A command message is a request for a particular action to be performed.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=213.70133400000003) [You can think of a command message as saying, Do this please.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=218.70133400000003) [Imagine you have a microservice that sends out emails.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=223.70133400000003) [That doesn't necessarily need to work synchronously,](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=226.70133400000003) [so it's a good fit for asynchronous patterns.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=229.70133400000003) [We could post a command message that specified the](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=232.70133400000003) [details of the email that should be sent,](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=235.55847685714286) [and the email microservice could pick that up and send the message.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=238.70133400000003) [Maybe the email microservice could get a bit behind if we](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=242.70133400000003) [posted large numbers of these command messages to its queue](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=246.36800066666672) [but it would eventually catch up.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=250.0346673333334) [The other type of message is an event.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=252.70133400000003) [An event message is simply a way of announcing that something has happened.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=254.70133400000003) [Events are in the past tense and are not directed at](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=259.70133400000003) [any one microservice in particular.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=263.7013339999999) [When you publish events,](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=265.70133400000003) [you're allowing any other microservices in your system that](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=267.70133400000003) [are interested to subscribe to that event and perform their](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=271.20133400000003) [own custom actions when it occurs.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=276.0346673333334) [For example,](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=278.70133400000003) [if there was an OrderPlaced event in an e-commerce](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=279.45133400000003) [system like eShopOnContainers,](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=283.20133400000003) [then several actions might need to occur as a result of that event.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=284.70133400000003) [For example, charging your credit card, sending a confirmation email,](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=289.70133400000003) [or checking on stock levels.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=294.70133400000003) [And so each microservice that needs to perform an action](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=296.70133400000003) [when an order is placed will be triggered by that single](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=299.70133400000003) [event being posted to the event bus.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=303.4156197142857) [And if you're interested in learning more about messaging patterns,](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=306.70133400000003) [then a great book to look at is called Enterprise Integration Patterns,](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=310.70133400000003) [and there are also several practical courses here on Pluralsight that](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=314.70133400000003) [will show you how to implement those patterns using various message](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=318.701334) [brokers such as RabbitMQ or Azure Service Bus. So do check those out if you're interested in learning more about messaging.](https://app.pluralsight.com/course-player?clipId=fda8447e-cbd6-4ec5-a3f3-9c59b84cb7e2&startTime=323.20133400000003)

### [Resilient Communication Patterns](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c)

[We can't assume in a distributed system that all the](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=1.6480010000000476) [microservices will be up and running the whole time.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=5.5051438571429046) [We can't even assume that the network is going to be reliable.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=8.648001000000047) [So we must expect from time to time that communication from service](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=12.648001000000047) [to service will fail due to transient issues.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=16.148001000000047) [And it's very important that we handle these failures well as they can result in](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=20.648001000000047) [cascading failures that are very difficult to recover from.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=25.790858142857182) [And there are several techniques and patterns that we can apply to increase](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=29.648001000000047) [the resilience of our service-to-service communication.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=33.14800100000005) [I'll just mention a few of them.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=36.64800100000005) [If you're making any kind of network call,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=38.64800100000005) [such as a regular HTTP request to another service or](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=41.64800100000005) [maybe making a query to a database,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=45.02300100000005) [then it's a great idea to build in retries with back-off.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=47.64800100000005) [This means that if your first attempt fails,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=51.64800100000005) [then you just wait a few seconds and try again,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=53.64800100000005) [and if that fails, then you wait a bit longer and make another attempt.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=56.64800100000005) [And this simple technique can often be all that's necessary to](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=61.64800100000005) [handle various transient service outtakes.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=65.14800100000005) [And you might find that your programming framework of choice has](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=68.64800100000005) [got built-in support for this functionality.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=72.07657242857148) [For example,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=74.64800100000005) [in .NET there's a great library called Polly that](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=75.44800100000006) [makes this very easy to implement.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=79.07657242857148) [However, if too many retries are attempted,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=81.64800100000005) [you can end up making the situation worse,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=84.64800100000005) [and potentially you end up effectively issuing a denial of](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=87.64800100000005) [service attack on your downstream services because you're](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=91.93371528571434) [calling them so frequently.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=94.64800100000005) [And so another pattern that can help us with this is called a circuit breaker.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=96.64800100000005) [A circuit breaker sits in between the client and the server,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=101.64800100000005) [and initially it allows all calls through.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=105.64800100000005) [And we call this being in the closed state.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=108.64800100000005) [However, if it detects any errors,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=111.64800100000005) [maybe the server is returning error codes or it isn't responding at all,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=114.64800100000005) [then the circuit breaker opens, which means now whenever the client makes a call,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=118.64800100000005) [it's going to fail fast rather than passing on that request to the server.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=123.64800100000005) [But after a configured timeout has elapsed,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=128.64800100000005) [the circuit breaker allows a few calls through again to see](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=130.64800100000005) [if the downstream service has recovered.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=134.39800100000005) [If so, then the circuit break closes, and it allows all calls through again.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=136.64800100000005) [If the downstream service hasn't recovered,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=142.64800100000005) [then it remains in the open state a bit longer,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=144.64800100000005) [again quickly rejecting any incoming requests.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=146.64800100000005) [And this is a very simple but powerful technique.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=151.64800100000005) [And, again,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=154.64800100000005) [many programming frameworks will have ready-made implementations of a](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=155.44800100000006) [circuit breaker that you can take advantage of.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=159.44800100000006) [Caching can also be a valuable part of a resilient strategy.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=162.64800100000005) [If you cache the data that you receive from a downstream service,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=167.64800100000005) [then if that service is unavailable for a short period,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=171.64800100000005) [you might be able to fall back to the data in your cache.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=174.64800100000005) [Of course,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=178.64800100000005) [that assumes that you have thought about the implications of using stale data.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=179.14800100000005) [One of the reasons message brokers are so popular in microservice](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=185.64800100000005) [architectures is that they have inherent support for resilience.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=189.98133433333336) [We can post messages to the message broker,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=193.64800100000005) [and it doesn't matter if our downstream services are not currently online.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=196.64800100000005) [When they start up again,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=201.64800100000005) [they can catch up on the backlog of messages that are waiting for them.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=202.7591121111112) [Message brokers also often support the ability to retry sending a message.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=206.64800100000005) [If a message handler fails for any reason,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=212.64800100000005) [the message can be returned to the message broker to be redelivered later,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=215.39800100000005) [and this effectively means that you get a certain number of](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=219.64800100000005) [retries for free simply by using messaging patterns.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=223.4480010000001) [Of course,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=227.64800100000005) [you don't want to get stuck in an infinite loop attempting to](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=228.14800100000005) [process the same message again and again.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=231.53688988888896) [So usually after a certain number of retries,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=234.64800100000005) [the message broker will consider this message to be](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=237.64800100000005) [poisoned and put it into a dead-letter queue.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=240.64800100000005) [Now there are some challenges associated with](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=244.64800100000005) [messaging that you do need to consider.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=247.02300100000005) [One is it's very hard to guarantee that messages](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=249.64800100000005) [will always be received in order.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=252.64800100000005) [So you need to take care that your message handlers will do the right](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=255.64800100000005) [thing even if they receive messages out of order.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=258.42577877777785) [It's also possible to receive a message more than once.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=261.648001) [One example of when this can happen is when you](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=265.648001) [receive a message for the first time,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=268.54800100000006) [maybe you only got part way through handling it and something went wrong,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=270.648001) [and so the message got returned to the queue.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=274.648001) [And now later, you receive that same message again as a retry.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=277.648001) [And this scenario is why it's really important to ensure](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=282.648001) [that your message handlers are idempotent.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=285.648001) [A message handler is idempotent if calling it twice with the same message](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=288.648001) [has essentially the same effect as calling it once.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=293.648001) [A good example in our e-commerce sample application would be handling an order.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=298.648001) [We only want to charge your credit card once,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=303.648001) [and we only want to ship your order once.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=306.648001) [So if the order received message gets processed twice for whatever reason,](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=308.648001) [we need to make sure that we've got good checks in place in our code to protect us from charging you twice or shipping your order twice.](https://app.pluralsight.com/course-player?clipId=16a246ea-54e4-47b7-9fc3-3ad3128c964c&startTime=313.648001)

### [Service Discovery](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00)

[For our microservices to be able to communicate with each other,](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=2.768001000000164) [each microservice needs to have an address.](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=6.268001000000164) [But how can we find out what address all the other microservices are located at?](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=9.768001000000163) [Let's imagine we've got three virtual machines and we've got](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=15.768001000000163) [various microservices running on each machine.](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=18.76800100000016) [Maybe we've even got multiple instances of some of the microservices running](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=21.768001000000165) [on different machines in our cluster of virtual machines.](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=26.768001000000165) [Now we don't want to have to hardcode IP addresses in as that](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=30.768001000000165) [gives us poor flexibility to dynamically move our microservices](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=34.43466766666683) [between virtual machines in the cluster,](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=38.76800100000016) [which is necessary in the cloud as machines do need to be taken](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=40.76800100000016) [down from time to time for servicing purposes.](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=44.51800100000016) [Now there are a few ways that we can solve this problem.](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=48.76800100000016) [And one is to make use of what's called a service registry.](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=51.76800100000016) [This is a central service that knows where all the](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=54.76800100000016) [other microservices are located.](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=58.990223222222376) [Sometimes this works by each service reporting its location to the service](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=60.76800100000016) [registry when it starts up and keeping in touch to allow the service registry](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=65.89300100000017) [to know that it's still available at that address.](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=70.76800100000017) [That means that whenever you want to communicate with another microservice,](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=73.76800100000017) [you can ask the service registry to tell you where](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=77.76800100000017) [that microservice can be found.](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=81.54577877777794) [And the service registry itself is typically distributed](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=83.76800100000017) [across all the machines in your cluster,](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=87.05371528571446) [which makes it simple for you to be able to contact the service registry.](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=89.43466766666685) [But you don't necessarily need to build your own service registry.](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=93.76800100000017) [A number of microservice hosting platforms solve this](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=97.76800100000017) [tricky problem for us by means of DNS.](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=101.21244544444461) [For example, if you're using a PaaS platform to host your microservices,](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=104.76800100000017) [then often each microservice you deploy will automatically be](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=109.76800100000017) [allocated a DNS name that points to a load balancer sitting in front](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=113.48228671428588) [of the actual instances of your microservice.](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=118.65688988888905) [And that means you can just use the DNS name to communicate with](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=121.76800100000017) [your microservice and not have to worry about the actual IP](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=125.96800100000019) [addresses of the individual virtual machines that are running the](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=129.4680010000002) [service and might change over time.](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=133.3680010000002) [Or if you're using a container orchestration platform,](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=135.76800100000017) [like Kubernetes,](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=138.76800100000017) [then you can simply refer to the other services just by their service name.](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=139.625143857143) [Kubernetes has got its own built-in DNS,](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=145.76800100000017) [and that means you don't need to know the IP addresses of each container.](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=148.76800100000017) [You just need to know the name of the service you want to talk to,](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=152.76800100000017) [and it takes care of routing traffic to the container that's](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=156.76800100000017) [running your service and load balancing if necessary.](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=160.48228671428583) [So the challenge of service discovery tends to be much easier if](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=163.76800100000017) [you're planning to host your microservices application on a modern microservice-friendly platform.](https://app.pluralsight.com/course-player?clipId=4efbb135-f6b4-4dfe-a039-03a469059f00&startTime=168.19657242857156)

### [Module Summary](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6)

[In this module,](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=0.6013340000002645) [we've learned about several different ways that](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=1.6013340000002643) [microservices can communicate with each other.](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=4.172762571428836) [There are no hard and fast rules about what you have to use,](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=7.601334000000264) [but two of the most common mechanisms are implementing RESTful APIs,](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=11.601334000000264) [which allow your clients to make synchronous HTTP calls to your microservices,](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=16.601334000000264) [and publishing messages to an event bus,](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=21.601334000000264) [which allows asynchronous communication patterns.](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=24.601334000000264) [And these two approaches are not mutually exclusive,](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=27.601334000000264) [and it's quite acceptable to use them both in the same system.](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=30.601334000000264) [We also learned about the API gateway or back-end for front-end](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=35.601334000000264) [pattern where we put an intermediate proxy between our front-end](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=40.20133400000026) [applications and our back-end services.](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=45.101334000000264) [We also looked at some techniques that support resilient communication patterns,](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=47.601334000000264) [including the use of retries, circuit breakers,](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=52.601334000000264) [and caching with synchronous communication.](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=56.601334000000264) [And for asynchronous communication,](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=59.601334000000264) [we saw how we can take advantage of message retries and that we need](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=61.601334000000264) [to make sure our message handlers are idempotent.](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=65.17276257142882) [Finally,](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=69.60133400000026) [we learned that service discovery can be implemented using a service](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=69.93466733333359) [registry and that many modern PaaS microservice hosting platforms and](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=74.10133400000026) [container orchestrators like Kubernetes can solve this problem](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=79.20133400000026) [automatically for us making our lives much simpler.](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=83.31561971428599) [Now we've not yet discussed the very important problem](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=86.60133400000026) [of how to secure our microservices. So let's look at that next.](https://app.pluralsight.com/course-player?clipId=43fd9bf6-8681-47be-87c4-d22bd0f18ef6&startTime=89.60133400000026)

## [Securing Microservices](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8)

### [Module Introduction](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8)

[Modern distributed cloud applications often store and](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=0) [process large amounts of sensitive data,](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=5.571428571428571) [and it's of the utmost importance that we protect that data](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=9) [ensuring that only authorized users can access it.](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=12.5) [I'm Mark Heath, and in this module,](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=17) [we'll be learning about some techniques and principles that we can apply to](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=19) [ensure that the microservices we create are properly secured.](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=23.428571428571427) [We'll start off by discussing the importance of encryption.](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=28) [We want sensitive data to be encrypted in transit and at rest.](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=32) [Next, we'll look at authentication.](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=38) [When a microservice receives an incoming HTTP request,](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=41) [how does it know that the request has come from a trusted caller?](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=45) [And just because we know who the caller is doesn't necessarily mean that](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=50) [they're allowed to perform the action that they've requested.](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=54.285714285714285) [So we'll also be looking at the related concept of authorization.](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=57) [And we'll see how industry standard protocols such as OAuth 2.0](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=63) [and OpenID Connect can help us with authenticating and](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=67.71428571428572) [authorizing the callers of our microservices.](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=71.57142857142857) [Next, we'll explore some of the options for securing the network,](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=75) [including the use of virtual networks, IP whitelisting,](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=80) [and firewalls.](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=84) [And, finally,](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=86) [we'll learn about the implications of the defense-in-depth](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=86.85714285714286) [principle where we apply several levels of security rather](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=91.25) [than just relying on one.](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=95.33333333333333) [And some of the additional security mechanisms that we can](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=97) [add are arranging for penetration testing,](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=101.33333333333333) [setting up alerts when attacks are detected, and auditing everything.](https://app.pluralsight.com/course-player?clipId=8bda19eb-6f3a-423c-bf0b-1922b1d93ea8&startTime=104)

### [Encrypting Data](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a)

[Modern microservice applications often store and process large amounts of data.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=0.88) [Not all of that data will be sensitive.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=7.88) [For example, in our eShopOnContainers sample application,](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=10.88) [there's a Catalog microservice.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=14.88) [And the Catalog microservice deals with all the products that the store sells,](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=17.88) [but this isn't sensitive data.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=22.88) [We're happy for all of our customers to be able to](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=24.88) [explore all of the catalog data.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=28.479999999999993) [However,](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=30.88) [the Ordering microservice holds details of which](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=31.38) [customer has ordered which items.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=35.02285714285714) [It may also hold details of their shipping address or payment details.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=37.88) [And these are very sensitive pieces of information.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=41.88) [And to leak them would have very serious consequences.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=44.88) [So it's imperative that steps are taken to secure any](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=48.88) [microservice that deals with sensitive data.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=53.38) [And encryption plays an important role in protecting our data.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=56.88) [At a minimum, we want to ensure that data is encrypted in transit.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=61.88) [That means that as it's transferred across the network,](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=66.88) [it should be encrypted so that no intermediate party is able to listen in.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=70.88) [Of course, the encryption algorithms you use should be up-to-date,](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=75.88) [industry standard algorithms.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=80.88000000000001) [You should never attempt to invent your own encryption algorithms.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=82.88) [For HTTP communications,](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=87.88) [encryption can be achieved by configuring Transport Layer Security,](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=89.5942857142857) [or TLS, so that all requests are made using HTTPS.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=94.73714285714284) [Now this does require you to configure SSL certificates,](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=100.88) [which can be a complex process since you need to get one issued by a](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=104.88) [trusted certificate authority for each of your services and to have a](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=110.07999999999998) [mechanism for updating them when they expire.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=114.88) [Fortunately,](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=118.88) [many cloud microservice hosting platforms provide mechanisms that](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=119.54666666666667) [simplify the process of configuring HTTPS for your services.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=124.38) [You may also find that your customers require data to be encrypted at rest.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=129.88) [This means that whenever it's stored on disk, those disks should be encrypted.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=135.88) [This can also be complex to configure as you'll need a](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=140.88) [secure way to manage the encryption keys.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=144.3345454545455) [But an increasing number of cloud providers are offering encryption at](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=146.88) [rest as a standard feature for file storage in databases.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=151.27999999999997) [If you're considering using encryption at rest,](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=155.88) [don't forget that any backups you make of the data from your system should also be encrypted.](https://app.pluralsight.com/course-player?clipId=7c65d944-dbfd-48a3-9649-6c97fad5f29a&startTime=158.88)

### [Authentication](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f)

[Just because you're using encryption in transit with HTTP](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=0.6746670000000158) [requests being made using TLS doesn't mean that you can](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=5.103238428571444) [trust the caller of your service.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=9.924667000000015) [Each incoming request needs a way to tell us who the caller is so we can](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=12.674667000000015) [make a decision as to whether they're authorized or not.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=17.77466700000002) [And there are several different ways we can achieve this.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=22.674667000000017) [With HTTP,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=25.674667000000017) [the most common approach is to include an](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=26.674667000000017) [authorization header in each HTTP request.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=30.674667000000017) [For example, this might contain a username and password,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=34.674667000000014) [which is a technique known as basic authentication.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=38.674667000000014) [This approach is sometimes used when the front-end client](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=42.674667000000014) [application provides the ability for the user to log in.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=46.27466700000001) [And so we send the credentials that they've entered in the](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=49.674667000000014) [header in order to authenticate them.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=52.674667000000014) [The trouble with this approach is it means our microservices now have](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=55.674667000000014) [the responsibility of securely storing user passwords,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=59.785778111111114) [and if we're doing that,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=63.674667000000014) [we need to take great care to follow the best](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=64.67466700000001) [practices for hashing those passwords.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=67.40193972727268) [And that's probably something we'd rather not have to do ourselves if possible.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=70.67466700000001) [Alternatively, when one microservice calls through to another,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=75.67466700000001) [the authorization header might contain an API key.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=80.47466700000003) [With this approach,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=84.67466700000001) [you give each valid client of your microservice their own API key.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=85.42466700000001) [However,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=90.67466700000001) [that's again more secrets that you need to manage and](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=91.07466700000002) [potentially rotate if they get compromised.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=94.92466700000001) [Another option that you might see is the use of client certificates.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=98.67466700000001) [By using public-key cryptography,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=102.67466700000001) [a certificate gives us a very secure way to allow a](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=105.67466700000001) [caller to prove their identity.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=109.79966700000001) [However, certificates also can be quite complex to install and manage.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=111.67466700000001) [So is there a better way?](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=117.67466700000001) [Well,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=120.67466700000001) [one of the most promising approaches is for microservices to build on some](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=120.9603812857143) [industry-standard protocols such as OAuth 2.0 and OpenID Connect.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=126.17466700000001) [And this introduces the concept of an authorization server.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=131.67466700000003) [The authorization server,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=135.67466700000003) [which is called the identity server in our eShopOnContainers sample application,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=137.67466700000003) [so I'll be referring to it as an identity server in this module,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=142.67466700000003) [takes care of a lot of the complexities of authenticating and](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=147.67466700000003) [authorizing the callers of our microservices.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=151.17466700000003) [The way this works is that, first,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=154.67466700000003) [the clients of our microservices authenticate themselves with the](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=157.67466700000003) [identity server by sending credentials of some sort,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=161.67466700000003) [and then the identity server returns an access token](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=165.67466700000003) [which has got a limited lifetime.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=169.67466700000003) [That access token can then be passed in an authorization HTTP request](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=172.67466700000003) [header as part of the call to the microservice.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=178.0080003333333) [And these tokens are signed using public key cryptography,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=181.67466700000003) [meaning that it's possible to verify that the token](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=185.67466700000003) [really was issued by the identity server.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=188.54966700000003) [And this approach,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=192.67466700000003) [which I've only really given you a simplified explanation of here,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=193.3413336666667) [turns out to have a lot of benefits.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=196.67466700000003) [For one thing,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=199.67466700000003) [it means that only one service has the job of authenticating](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=200.67466700000006) [users and managing their credentials securely.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=205.17466700000003) [And because the identity server is implementing industry standard protocols,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=208.67466700000003) [like OpenID Connect,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=213.67466700000003) [that means that you don't need to write this component yourself,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=215.67466700000003) [you can make use of a third-party solution,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=218.67466700000003) [which is great because writing your own identity server is a lot of work.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=221.67466700000003) [And that's why the eShopOnContainers sample application makes use of an](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=227.67466700000003) [open source product called IdentityServer4 which is an OpenID Connect](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=232.81752414285714) [and OAuth 2.0 framework for ASP.NET Core.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=238.67466700000003) [Now if you're planning to adopt this approach to](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=242.67466700000003) [microservice authentication and authorization,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=246.27466700000002) [I recommend that you invest some time in learning more about the underlying](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=248.67466700000003) [protocols we've mentioned such as OAuth 2.0 and OpenID Connect,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=253.17466700000003) [as well as how to best make use of them in your own language of choice.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=257.674667) [And there's plenty of excellent courses here on](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=262.674667) [Pluralsight that can help you with this.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=265.3413336666665) [A good starting point would be the Getting Started](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=267.674667) [with OAuth 2.0 course by Scott Brady.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=270.8968892222223) [And if, like me, you're a .NET developer,](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=274.674667) [then these two courses on securing ASP.NET Core replications would be excellent choices to follow up with.](https://app.pluralsight.com/course-player?clipId=f6d402bc-ab75-4c0c-8e6c-0af4d177914f&startTime=277.674667)

### [Authorization](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826)

[When a user is authenticated, that simply means that we know who they are.](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=1.4693340000000317) [But we also need to check that they're authorized to](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=7.469334000000032) [perform the action that they've requested.](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=10.612191142857178) [For example, if I log in to eShopOnContainers,](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=13.469334000000032) [then I'm authorized to view my own order history,](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=17.469334000000032) [but I shouldn't be authorized to view your order history.](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=21.469334000000032) [Many web API frameworks, like ASP.NET Core,](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=25.469334000000032) [which eShopOnContainers uses,](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=28.469334000000032) [provide built-in mechanisms that help you perform authorization](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=31.469334000000032) [by checking various things about the user such as whether](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=35.46933400000003) [they've got a particular role or not.](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=39.36933400000002) [And it's your responsibility as a developer to think very carefully](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=41.46933400000003) [about every single endpoint of the public API of your microservices](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=46.46933400000003) [and consider what actions each potential user of the service should or](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=51.46933400000003) [shouldn't be allowed to perform.](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=56.469334000000025) [There's one authorization gotcha that I particularly want to highlight](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=58.46933400000003) [as it applies especially in microservices scenarios,](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=62.46933400000003) [and this is a problem sometimes known as the confused deputy.](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=66.46933400000003) [Suppose I, as an end user, make a call to a microservice.](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=71.46933400000003) [Let's say it's the Ordering microservice.](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=76.46933400000003) [But that microservice, as part of what it's doing,](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=78.46933400000003) [makes an ongoing call to another microservice.](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=81.46933400000003) [Let's say the Payment service.](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=84.46933400000003) [Now when I call the Ordering service,](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=87.46933400000003) [the credentials or access token that I supply are](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=90.46933400000003) [going to indicate that it's me, Mark, who's making the call.](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=93.71933400000003) [The Ordering service can then decide whether or not I'm allowed to](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=97.46933400000003) [perform the particular action that I've requested.](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=101.86933400000007) [However, when the Ordering service calls the Payment service,](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=105.46933400000003) [it might send credentials that simply say that this is](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=109.46933400000003) [the Ordering service making the call.](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=113.46933400000002) [And because the Payment service trusts the Ordering service,](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=115.46933400000003) [it assumes that it's safe to perform whatever action has been requested.](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=118.46933400000003) [But this could be risky because what if I could somehow trick the](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=123.46933400000003) [Ordering service to ask the Payment service to pay for my order but](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=127.86933400000001) [using someone else's credit card details?](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=133.46933400000003) [Now there are a few ways to address this issue,](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=136.46933400000003) [but one solution is by issuing on behalf of access tokens.](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=138.46933400000003) [This way, when the Ordering service calls the Payment service,](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=143.46933400000003) [it still identifies itself as the Ordering service,](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=147.46933400000003) [but it also tells the Payment service that this is a](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=150.46933400000003) [call being made on behalf of Mark.](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=154.1836197142857) [And that gives the Payment service more information to go on,](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=157.46933400000003) [and it can reject the request if it recognizes that I'm asking to pay with a credit card that doesn't belong to me.](https://app.pluralsight.com/course-player?clipId=e3435ff0-3677-457a-b370-ddfe4d09d826&startTime=160.46933400000006)

### [Securing the Network](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945)

[Another important form of defense is to make use of](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=1.2346670000000157) [networking features such as firewalls, IP whitelisting,](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=5.377524142857159) [and virtual networks to secure your microservices.](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=9.234667000000016) [In this diagram, we can see three microservices communicating with each other.](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=13.234667000000016) [And if we can place them inside a virtual network,](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=19.234667000000016) [then we have the ability to reject any incoming traffic from outside the virtual](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=22.234667000000016) [network and only allow them to communicate with each other.](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=26.83466700000001) [And this type of approach is a great idea to help](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=31.234667000000016) [protect your back-end services, which may need to communicate between themselves,](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=34.234667000000016) [but you don't necessarily need access to them from outside.](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=39.234667000000016) [But what about those situations where you do need to](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=44.234667000000016) [accept traffic from the internet?](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=46.66323842857144) [For example, if you've got a website implemented as a single-page application,](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=49.234667000000016) [then it will want to make requests to your microservices.](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=54.234667000000016) [So does that mean you have to forego any kind of network](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=59.234667000000016) [restrictions and just open everything up?](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=62.83466700000001) [Well,](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=65.23466700000002) [this is actually an example of where the pattern that](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=65.53466700000001) [we discussed earlier in this course, the API gateway or back-end for front-end,](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=68.66323842857145) [can be really helpful.](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=74.23466700000002) [We can have an API gateway that accepts incoming requests from the public](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=76.23466700000002) [internet but is also connected to the virtual network and so is able to pass](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=81.73466700000002) [on incoming requests to the back-end microservices.](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=88.23466699999999) [And this means we can be very selective about exactly which](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=92.23466700000002) [back-end APIs are able to be called from the outside.](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=96.034667) [It also means that we've got a single point of entry.](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=100.23466700000002) [Some cloud API gateways can also be configured with a firewall or other](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=104.23466700000002) [types of attack protection such as guarding against distributed](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=109.45688922222223) [denial-of-service attacks or SQL injection attacks.](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=113.23466700000002) [Often, in a microservices application, there's a public-facing website,](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=118.23466700000002) [like the eShopOnContainers store website.](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=123.23466700000002) [But there may also be additional websites intended for use by a smaller](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=127.23466700000002) [targeted group of users such as system administrators.](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=132.4568892222223) [For example,](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=136.234667) [the eShopOnContainers application supports creating marketing campaigns,](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=137.434667) [which are sent out to customers by email.](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=142.234667) [And if there was a marketing website that allowed](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=146.234667) [them to create these campaigns,](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=148.80609557142856) [the only people authorized to access that website are staff from our company.](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=150.234667) [So we might decide to apply IP address whitelisting so that this website](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=156.234667) [rejects any traffic that doesn't come from certain known IP addresses such](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=161.3775241428571) [as the IP addresses of the marketing officers.](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=166.67911144444446) [Now so far in this module,](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=170.234667) [we've talked about quite a few different techniques](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=172.234667) [for securing our microservices,](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=175.234667) [and you might be wondering whether you need to use all of them](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=177.234667) [or whether you can just pick one or two.](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=181.0203812857143) [And this is where the defense-in-depth principle comes in.](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=184.234667) [This principle encourages us to avoid relying solely on a](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=188.234667) [single layer of protection and to use multiple layers of](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=192.234667) [security wherever possible. So let's discuss the idea of defense in depth in a bit more detail.](https://app.pluralsight.com/course-player?clipId=ae8163a1-7db8-41c5-9c14-de8144659945&startTime=196.90133366666674)

### [Defense in Depth](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c)

[We've discussed a number of techniques in this](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=0.6533340000000316) [module to secure our microservices.](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=3.7961911428571744) [By using encryption in transit with TLS,](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=6.653334000000032) [the traffic to and from our microservice can't be](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=10.653334000000031) [listened into by unauthorized third parties.](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=13.653334000000031) [By using access tokens issued by an identity server to](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=17.653334000000033) [authenticate ourselves in the requests,](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=22.153334000000033) [our microservices can reject any incoming calls from unauthorized clients.](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=24.653334000000033) [And by using virtual networks and IP whitelisting,](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=30.653334000000033) [we can reject any calls to our microservices that come](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=33.77833400000003) [from an unauthorized network location.](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=37.65333400000003) [And the defense-in-depth principle states that you shouldn't rely](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=41.65333400000003) [entirely on a single technique to secure your application,](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=45.45333400000004) [and that's because if that one defense is breached,](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=49.65333400000003) [then everything is lost, and your attacker has gained free access to everything.](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=52.65333400000003) [So by combining several different layers of security,](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=58.65333400000003) [we can significantly reduce the possibility of a data breach.](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=62.65333400000003) [And the more sensitive the data that you're dealing with,](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=67.65333400000003) [the more important it is that you apply several layers of protection.](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=70.65333400000003) [And certainly these three techniques that we've just discussed I](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=76.65333400000003) [would consider to be essential for securing any microservices](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=79.98666733333336) [application that deals with sensitive data.](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=84.053334) [But there are some additional defensive measures that we can take.](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=87.65333400000003) [For one thing,](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=91.65333400000003) [modern hackers have a variety of very sophisticated](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=92.85333400000005) [tools and techniques at their disposal,](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=96.22476257142861) [and so often software developers aren't aware of all of](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=98.65333400000003) [these attack techniques and don't have the knowledge of how](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=102.52833400000003) [best to mitigate against them.](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=105.51047685714289) [And for that reason,](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=107.65333400000003) [it's a very good idea to arrange for penetration testing to be](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=108.54222288888894) [performed by a team of infosec experts who can test the defenses of](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=113.32000066666669) [your application against state-of-the-art hacking techniques and can](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=118.90333400000003) [also give you some expert advice on how to increase the security of](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=123.15333400000003) [your applications.](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=128.3200006666667) [I also recommend that you create automated tests that verify](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=129.65333400000003) [that your security is working as expected.](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=133.76444511111112) [Don't just assume that you've configured your virtual](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=137.65333400000003) [networking or access token validation correctly.](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=141.32000066666674) [Run some tests that prove that unauthorized users](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=144.65333400000003) [are not able to call your APIs.](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=147.65333400000003) [It may also be possible to detect when an attack is in progress.](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=150.65333400000003) [Plot scanning, repeated login attempts, HTTP requests,](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=156.65333400000003) [phishing for sensitive files, SQL injection attack attempts,](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=160.65333400000003) [all of these things can be detected in real time.](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=165.65333400000003) [And you should configure alerts so that you know when they're happening,](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=168.65333400000003) [and this allows you to proactively make the decision either to block traffic](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=172.65333400000003) [from the attacker's IP address or maybe even to temporarily shut down part](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=177.43111177777786) [of your system to protect against the attack.](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=181.65333400000003) [Finally,](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=186.65333400000003) [you should have good logging and auditing of all of the](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=186.98666733333337) [actions being performed in the system.](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=190.6533340000001) [This way it's possible to review exactly who did what and when they did it.](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=192.65333400000003) [And that way, if there is a data breach,](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=198.65333400000003) [you'll have a much better chance of understanding how it happened, as well as exactly what data has been compromised.](https://app.pluralsight.com/course-player?clipId=2d35e3cd-5fcd-4aa6-88e9-dade401b6c8c&startTime=199.65333400000003)

### [Module Summary](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29)

[Securing our microservices should be one of our highest priorities.](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=1.400001000000164) [The stakes can be very high when you're working on a](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=5.400001000000164) [system that deals with sensitive data.](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=8.650001000000163) [And that's why, in this module, we emphasized a defense-in-depth approach.](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=11.400001000000163) [And the techniques that we should consider applying wherever](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=17.400001000000163) [possible include encrypting data in transit with TLS,](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=19.971429571428736) [encrypting data at rest in files and databases,](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=24.7333343333335) [authenticating users,](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=29.400001000000163) [ideally by means of industry standard protocols such](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=30.600001000000166) [as OAuth 2.0 and OpenID Connect,](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=35.8285724285716) [and ensuring that we also correctly authorize access to our](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=38.40000100000017) [microservices so that users can only perform the actions](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=42.733334333333495) [that they have permission for.](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=46.40000100000017) [In addition,](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=48.40000100000017) [we can configure various network level security such as virtual networks,](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=49.28888988888905) [IP address whitelisting, firewalls,](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=54.685715285714444) [and making use of API gateways that can create a single](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=56.971429571428736) [point of entry for external traffic.](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=62.27500100000017) [It's also a great idea to make use of security experts to perform](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=65.40000100000016) [penetration testing and provide feedback on our system design.](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=70.40000100000016) [And we should configure alerts for attack detection and](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=74.40000100000016) [regularly review the system audit logs to identify any](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=78.40000100000016) [suspicious access patterns or behavior.](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=83.27500100000016) [In our next module,](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=86.40000100000016) [we're going to look at how we can deliver microservices](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=87.40000100000016) [focusing in particular at the challenges of deploying and monitoring our microservices.](https://app.pluralsight.com/course-player?clipId=05cb9a20-442c-483c-827a-d3b3df6bdb29&startTime=91.40000100000016)

## [Delivering Microservices](https://app.pluralsight.com/course-player?clipId=fbcebf78-c5f5-424f-bb59-e9ddda861ef4)

### [Module Introduction](https://app.pluralsight.com/course-player?clipId=fbcebf78-c5f5-424f-bb59-e9ddda861ef4)

[In this course,](https://app.pluralsight.com/course-player?clipId=fbcebf78-c5f5-424f-bb59-e9ddda861ef4&startTime=0) [we've talked a lot about how to architect and build microservice applications.](https://app.pluralsight.com/course-player?clipId=fbcebf78-c5f5-424f-bb59-e9ddda861ef4&startTime=1.2857142857142856) [But, of course, before long,](https://app.pluralsight.com/course-player?clipId=fbcebf78-c5f5-424f-bb59-e9ddda861ef4&startTime=8) [you are going to want to deploy your microservices to production.](https://app.pluralsight.com/course-player?clipId=fbcebf78-c5f5-424f-bb59-e9ddda861ef4&startTime=10) [And while they're in production,](https://app.pluralsight.com/course-player?clipId=fbcebf78-c5f5-424f-bb59-e9ddda861ef4&startTime=13.857142857142858) [you'll also need a way to monitor them and ensure](https://app.pluralsight.com/course-player?clipId=fbcebf78-c5f5-424f-bb59-e9ddda861ef4&startTime=16) [that they're functioning correctly.](https://app.pluralsight.com/course-player?clipId=fbcebf78-c5f5-424f-bb59-e9ddda861ef4&startTime=19) [I'm Mark Heath, and in this module,](https://app.pluralsight.com/course-player?clipId=fbcebf78-c5f5-424f-bb59-e9ddda861ef4&startTime=21) [we're going to learn about some good practices for how you](https://app.pluralsight.com/course-player?clipId=fbcebf78-c5f5-424f-bb59-e9ddda861ef4&startTime=24) [deliver your microservices into production.](https://app.pluralsight.com/course-player?clipId=fbcebf78-c5f5-424f-bb59-e9ddda861ef4&startTime=27.875) [We'll start off by looking at how we deploy microservices.](https://app.pluralsight.com/course-player?clipId=fbcebf78-c5f5-424f-bb59-e9ddda861ef4&startTime=31) [It's really important that we set up an automated process that can](https://app.pluralsight.com/course-player?clipId=fbcebf78-c5f5-424f-bb59-e9ddda861ef4&startTime=35) [repeatedly and reliably upgrade individual microservices.](https://app.pluralsight.com/course-player?clipId=fbcebf78-c5f5-424f-bb59-e9ddda861ef4&startTime=39.66666666666667) [And we can achieve this by setting up a pipeline that can](https://app.pluralsight.com/course-player?clipId=fbcebf78-c5f5-424f-bb59-e9ddda861ef4&startTime=45) [deploy code into one or more environments.](https://app.pluralsight.com/course-player?clipId=fbcebf78-c5f5-424f-bb59-e9ddda861ef4&startTime=50.111111111111114) [It's also important that once our microservices are running in](https://app.pluralsight.com/course-player?clipId=fbcebf78-c5f5-424f-bb59-e9ddda861ef4&startTime=54) [production that we have a good way of monitoring them,](https://app.pluralsight.com/course-player?clipId=fbcebf78-c5f5-424f-bb59-e9ddda861ef4&startTime=57.75) [and we'll see how having standardized health checks and aggregated logs can benefit us greatly when we're diagnosing issues in production.](https://app.pluralsight.com/course-player?clipId=fbcebf78-c5f5-424f-bb59-e9ddda861ef4&startTime=62)

### [Automated Deployment](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e)

[In the traditional world of monolithic applications,](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=0.896) [it's not uncommon for deployments to be a manual process often where](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=4.896) [you follow a step-by-step Word document that explains how to upgrade](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=9.896) [to a new version of your software.](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=14.896) [But once you've moved to microservices,](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=17.896) [a manual process simply isn't going to work anymore.](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=19.896) [You've got far more things to deploy,](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=23.896) [and you also want to deploy much more frequently.](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=26.896) [And so microservices pushes us very strongly in the](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=29.896) [direction of automating our deployments,](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=35.03885714285714) [and that's a good thing.](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=37.896) [If we've got a reliable and repeatable deployment process for our microservices,](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=38.896) [that allows us to upgrade them frequently as soon as new](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=44.896) [features or bug fixes become available.](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=48.896) [In fact, some teams using microservices deploy multiple times a day.](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=51.896) [So how can we achieve this?](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=56.896) [Well,](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=58.896) [we've already discussed how a continuous integration server can be used to](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=59.396) [automatically build our code whenever we check it in,](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=65.396) [and it's also very common for that CI server to run unit tests as well.](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=67.896) [But we can take this idea further.](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=73.896) [The CI server can trigger what's sometimes called a release pipeline.](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=76.896) [A release pipeline starts off where the CI build has finished.](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=81.896) [It's built the code and run the unit tests.](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=86.896) [But, next, we want to actually deploy the microservice.](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=89.896) [maybe to a virtual machine running on-premises or to a cloud-deployed resource.](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=94.896) [Once we've deployed the microservice,](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=100.896) [this is a great opportunity to run the service-level integration](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=102.896) [tests that we discussed earlier on in this course where we're](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=106.396) [testing that microservice in isolation.](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=111.03885714285714) [If it passes those tests,](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=113.896) [the next step might be to deploy the microservice into a QA environment](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=115.896) [where it can be tested as part of the entire system.](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=120.896) [And this is the point at which you'd run any automated end-to-end tests.](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=124.896) [Now at this point, there's often what's called a release gate.](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=130.896) [Just because our microservice has successfully passed all of](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=134.896) [its automated tests doesn't necessarily mean that we're ready](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=138.396) [to push it straight to production.](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=142.89600000000002) [There may be the need for some additional manual testing or some kind](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=144.896) [of risk assessment or customer sign off before,](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=148.89600000000002) [finally, we're ready for this code to go to production.](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=152.396) [Once you reach the stage of being ready to push a microservice into production,](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=155.896) [it's really important that you use exactly the same procedure](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=160.696) [that you used to deliver it to the QA or staging environment for pushing it to production.](https://app.pluralsight.com/course-player?clipId=0b7529a7-33eb-4c8b-8977-751a28581c0e&startTime=164.896)

### [Deployment Environments](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04)

[It's very common that we want to be able to deploy our](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=1.3146669999999867) [microservices to different environments.](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=4.814666999999987) [A developer might have their own virtual machine that they want](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=7.314666999999987) [to run a microservice on during development and that will allow](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=11.064666999999988) [them to debug their code locally.](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=14.028952714285706) [And as we've just said,](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=17.314666999999986) [you might have a QA environment in which you're going to run your](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=18.314666999999986) [end-to-end tests or perform some manual testing.](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=22.64800033333331) [Sometimes you might have other environments dedicated to](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=25.314666999999986) [penetration testing or performance testing.](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=28.981333666666654) [And, of course,](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=32.314666999999986) [another really important environment is production where our](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=33.60038128571428) [code is actually being used by the end users.](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=36.64800033333333) [And in some scenarios, you have multiple production environments,](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=41.314666999999986) [maybe one for each of your customers or one running in](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=44.314666999999986) [each of a few geographical regions.](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=49.114667) [So it's really helpful to parameterize our automated](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=52.314666999999986) [deployment scripts making the process of deploying to any of](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=55.98133366666664) [these environments as simple as possible.](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=60.648000333333314) [A common approach to dealing with this is to define each](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=63.314666999999986) [environment in a configuration file,](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=66.91466700000001) [and JSON or YAML are very popular choices here.](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=70.31466699999999) [These configuration files essentially express what's different](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=74.31466699999999) [about the environment we're deploying to.](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=78.31466699999999) [So here I'm showing an imaginary configuration file that](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=81.31466699999999) [expresses that the QA environment should be deployed in](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=85.64800033333331) [the West Europe cloud region,](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=88.81466699999999) [it should use medium-sized virtual machines and scale between a minimum of](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=91.31466699999999) [2 and a maximum of 5 instances of the virtual machine.](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=96.02895271428574) [And configuration files like this are often used in conjunction with other](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=101.31466699999999) [deployments scripts and manifests to allow you to deploy a specific version](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=106.42577811111109) [of a microservice into a specific environment.](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=111.31466699999999) [For example,](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=116.31466699999999) [it would be really nice if we would run a command like this where we're](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=116.88609557142857) [asking to deploy version 1.0 .4 of the Ordering microservice into the](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=121.31466699999999) [environment that's defined in the qa.yaml file.](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=127.4257781111111) [But, of course, this is just a simplified made-up example here,](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=131.314667) [but there are all kinds of tools that you could use to achieve this](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=135.314667) [including Docker Compose that we saw earlier,](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=139.314667) [or if you're using Kubernetes,](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=142.314667) [that's got its own tool called kubectl that can apply the contents of a](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=144.314667) [configuration file with a command that looks a bit like this.](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=149.814667) [There are also technologies like Terraform and Azure ARM templates,](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=154.314667) [which allow you to template the creation of the cloud](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=158.314667) [infrastructure you need to host your microservices,](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=162.31466700000001) [and that might include virtual machines,](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=165.314667) [databases, or blob storage accounts and virtual networks.](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=167.314667) [And these too allow you to define a hierarchical set of](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=172.314667) [scripts with base templates that are overridden with environment-specific configuration.](https://app.pluralsight.com/course-player?clipId=26c3dea4-787a-4046-aedd-2850cd32ab04&startTime=175.91466699999998)

### [Artifact Registries](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd)

[To allow the deployment scripts to easily deploy](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=1.2773340000000317) [any version of our microservices,](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=3.7773340000000317) [we need the build artifacts to be stored in some kind of registry.](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=6.277334000000032) [That way we can easily deploy the latest version of our](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=11.277334000000032) [microservice or roll back to a specific previous version.](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=14.9440006666667) [In the eShopOnContainers application that we've been looking at in this course,](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=19.27733400000003) [they've made the choice to build every microservice as a Docker container image.](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=24.27733400000003) [And using containers has many benefits,](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=30.27733400000003) [but one of them is the way that they are named and versioned in a](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=33.27733400000003) [standard way and can be stored in a container registry.](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=37.47733400000002) [And that means it's really easy when you're using Docker to](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=41.27733400000003) [identify which container you want to be deployed.](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=44.721778444444475) [Here's an example of what name and tag we might give to version 1.3 .1](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=48.27733400000003) [of the Ordering service in our e-commerce example.](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=53.27733400000003) [Because the eShopOnContainers application is using](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=58.27733400000003) [containers as a delivery mechanism,](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=61.13447685714289) [it's ideal for deploying to a container orchestrator such as Kubernetes.](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=63.27733400000003) [If you have a Kubernetes cluster,](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=69.27733400000002) [then you can define all the microservices in your](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=71.27733400000002) [application with some YAML manifest files.](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=75.27733400000002) [Kubernetes actually operates using a desired state strategy.](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=78.27733400000002) [Your manifest files define what microservices should be](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=83.27733400000002) [running and how they should be configured.](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=86.65233400000002) [And then Kubernetes compares what your manifests have asked for with](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=89.27733400000002) [what's actually happening right now on the cluster.](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=93.61066733333334) [If there's a difference,](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=97.27733400000002) [then it will add or remove containers until what's](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=98.27733400000002) [running matches what you asked for.](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=102.13447685714287) [And this means that upgrading to a new version of a service or,](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=105.27733400000002) [indeed,](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=109.87733400000005) [changing any other property of a service such as an](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=110.27733400000002) [environment variable or the number of replicas simply becomes](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=113.47733400000004) [a case of changing the manifest files.](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=116.61066733333332) [And if you'd like to dive deeper into Kubernetes,](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=119.27733400000002) [I highly recommend that you watch some of the excellent courses here on](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=123.27733400000002) [Pluralsight that will guide you through how it works.](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=127.84876257142861) [A really good place to start would be this Kubernetes for Developers course by Dan Wahlin.](https://app.pluralsight.com/course-player?clipId=7f9816f8-2246-4658-a4da-68d89aecb5dd&startTime=130.27733400000002)

### [Independent Upgrades](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a)

[We've mentioned before in this course how important it is that](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=0.6586670000000159) [we can independently upgrade microservices.](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=5.325333666666682) [We don't want them to be tightly coupled in such a way that](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=8.658667000000015) [upgrading a single microservice requires all the others to](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=12.880889222222239) [be upgraded at the same time.](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=16.476848818181832) [And that means our automated process needs to be able to update just one](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=18.658667000000015) [microservice at a time even if it can deploy them all at once,](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=24.283667000000015) [for example, if we were doing a fresh deployment of the entire application.](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=28.658667000000015) [So it's very important that you think about how you're going](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=33.658667000000015) [to upgrade an individual microservice.](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=36.658667000000015) [You might think that it's a simple case of just stopping](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=40.658667000000015) [the old one and starting the new one, and that's certainly a valid approach.](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=42.65866700000002) [However, it does cause a small period of service unavailability.](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=47.658667000000015) [And depending on what that microservice is responsible for,](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=52.658667000000015) [that may or may not be acceptable.](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=56.658667000000015) [But there are a number of other techniques that you can use to](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=58.658667000000015) [reduce downtime when you're upgrading a service.](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=62.80152414285717) [One is called a blue green swap where you run the old and new](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=65.65866700000002) [versions of the service simultaneously and then swap traffic from](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=70.40866700000002) [one to the other by means of a load balancer.](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=74.88088922222224) [And that means you don't have downtime while you're waiting for](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=78.65866700000002) [the new version of the service to start up,](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=81.80152414285719) [and so you should be able to get near-instantaneous swap over.](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=84.65866700000002) [Another option, if you've got multiple replicas of a service running,](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=89.65866700000002) [is to replace the instances one by one.](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=93.32533366666671) [So if I've got three instances of version 1 all load balanced,](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=96.65866700000002) [I might, one at a time,](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=100.65866700000002) [add new instances of version 2 and remove instances of](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=102.658667) [version 1 until all three are upgraded.](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=107.15866700000002) [Now this does assume that you've written your code in such](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=110.65866700000002) [a way that having both versions running at the same time](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=113.99200033333332) [doesn't cause any problems.](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=117.65866700000002) [If you are using a platform designed to host microservices,](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=119.65866700000002) [such as Kubernetes,](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=123.65866700000002) [then many of these more advanced upgrade strategies](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=124.65866700000002) [are available to you out of the box.](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=128.658667) [Another thing to consider is how seamlessly you can roll back to](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=131.658667) [the previous version if anything goes wrong.](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=136.158667) [This is another thing that a container orchestrator like](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=139.658667) [Kubernetes can help you with since rolling back is simply a](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=142.158667) [matter of updating our manifest files to point at the previous](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=146.37295271428567) [tagged version of our microservice.](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=150.8015241428571) [Now, of course,](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=153.658667) [you're only going to do a rollback if you've been able to detect that](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=154.25866699999997) [something about the new version isn't working correctly.](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=158.10311144444447) [And so that brings us onto another really important topic of how we can monitor our microservices.](https://app.pluralsight.com/course-player?clipId=53ca1acc-940d-43e9-8aa7-5d4100b0918a&startTime=161.658667)

### [Monitoring Microservices](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b)

[One of the big challenges of microservices is that there](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=0.68) [are more things for us to monitor.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=4.58) [Your microservices might be running as dozens of different](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=6.68) [processes across many different host machines,](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=10.280000000000001) [and you don't want to have to individually connect to every](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=12.68) [worker node in your virtual machine cluster and examine](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=16.568888888888885) [individual log files for every microservice.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=20.479999999999997) [Instead, what we want is a system where all of our monitoring,](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=23.68) [telemetry, and logs are available in a centralized place.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=28.68) [Ideally,](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=32.68) [we want a dashboard that gives us an instant view of the](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=33.28) [overall health of the system and the ability to dive in](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=37.53714285714286) [deeper if a problem is detected.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=41.680000000000014) [Let's have a think about some of the things that we want to be able to monitor.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=43.68) [First of all, we want to be able to capture host metrics.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=48.68) [This includes things like CPU and memory usage.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=52.68) [By tracking these metrics,](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=56.68) [we can detect if we need to scale out to meet increased demand.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=58.68) [Many cloud providers offer the ability to set up alerts](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=63.68) [based on these sort of metrics so you can be notified if](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=66.88) [there are any potential problems.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=71.40727272727273) [Secondly, we want to track metrics at the application level.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=73.68) [So for a web API, this would be tracking the number of HTTP requests,](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=77.68) [including the number of failures, and tracking what the errors codes were.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=81.805) [For example, if there were lots of 401 Unauthorized response codes,](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=86.68) [then maybe our system is under attack by hackers or maybe](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=91.68) [we've just misconfigured something.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=95.68) [If there are lots of 500 errors, then that points to a bug somewhere in our code.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=97.68) [If you're using a message broker,](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=103.68) [then you'll want to track whether large numbers of](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=105.68) [messages are backing up in the queues, in which case,](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=108.055) [again, we might need to scale out.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=111.88000000000002) [And you'll also want to track whether messages are](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=114.68) [being sent to a dead-letter queue,](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=116.9657142857143) [which indicates that you've got a problem processing your messages.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=118.68) [One particularly helpful approach is for each of your](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=123.68) [microservices to support a health check endpoint.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=126.34666666666665) [This is a web API that can be periodically called to check your](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=130.68) [service is running and functioning correctly.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=135.01333333333338) [It might be as simple as just reporting OK to indicate](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=137.68) [that it started up successfully.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=140.82285714285717) [But it can also be useful for your health check endpoints to return](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=143.68) [additional information such as whether any downstream dependencies](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=147.68) [like databases are currently accessible.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=151.68) [Third, we need the logs to be easily accessible.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=154.68) [Each microservice should be emitting logs,](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=158.68) [and if those logs are aggregated into a centralized place,](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=161.68) [that will make your life a whole lot easier.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=165.68) [One nice thing about using containers is that they already have](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=168.68) [a standardized approach to capturing logs.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=172.555) [So it's relatively straightforward to aggregate the logs from](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=175.68) [all the containers into a single place.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=178.93) [And there are many products that can help you achieve this.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=182.68) [A couple that I've used in the past are sending logs to](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=185.68) [Elasticsearch and then using Kibana to view them,](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=189.28000000000003) [or in Azure, using Application Insights.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=192.68) [Many microservice hosting platforms or the serverless PaaS platforms like Azure](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=196.68) [Functions or container orchestrators like Kubernetes already come with lots of](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=203.055) [easily enabled monitoring and logging capabilities.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=208.555) [And that's another reason why it's a great idea when you're using](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=211.68) [microservices to take advantage of these kind of observability features](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=216.34666666666675) [rather than having to spend a lot of time creating your own customized](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=220.68) [solution to these common problems that everyone who's building](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=225.18) [microservices is going to need a solution to.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=228.68) [Let's take a look next at how the eShopOnContainers sample application allows us to easily monitor what's going on with our microservices.](https://app.pluralsight.com/course-player?clipId=04475dd8-d6d0-4201-b786-afbe8758466b&startTime=232.68)

### [Demo: Centralized Logging and Health Checks](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1)

[In this demo,](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=2.04) [we'll see how the eShopOnContainers sample application that we've been looking](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=3.06) [at throughout this course sends its logs to a centralist service called Seq](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=7.6) [and implements health check APIs for each microservice that are aggregated](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=12.82) [together into an overall health dashboard.](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=18.19) [I'm going to start up the eShopOnContainers application locally with the](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=21.94) [docker‑compose up command that we saw earlier in this course,](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=26.32) [and this will start up a container for each of our](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=31.04) [microservices along with some additional containers for the](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=33.5) [databases and other supporting services.](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=37.31) [And we can see that these containers start very quickly because the](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=40.74) [images are all available locally on my machine.](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=44.32) [And, docker‑compose up, by default,](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=48.04) [will actually emit all the container logs to the console,](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=50.45) [so we can already see some of the logging here.](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=54.04) [But if I quickly go to my browser and visit localhost port 5107,](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=57.34) [then what we can see here is a health check dashboard.](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=63.34) [And what this is doing is calling the health check endpoints on](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=66.4) [each microservice in the system. Of course,](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=70.55) [because we've only just started up,](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=73.91) [not all of the microservices have finished their startup yet. And this page](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=75.92) [is supposed to auto refresh, but for some reason it's not working at the](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=81.73) [moment. So I'll manually refresh, and we can see that nearly everything is](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=85.85) [up and running now with the exception of WebMVC. What's even nicer about](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=90.91) [this dashboard is that I can drill down into each of the microservices and](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=97.43) [it will tell me whether it's able to contact the dependencies of that](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=102.07) [microservice or not.](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=106.1) [And this is incredibly helpful as it can be possible for a microservice to](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=108.14) [start successfully but for it not to be able to do its job properly because](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=112.19) [it can't communicate with a downstream service, and that might be due to a](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=117.09) [configuration problem or maybe a transient network issue. Here we can see](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=121.69) [that the WebMVC service, which is the main website, has started up okay.](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=127.49) [But it also needs to be able to communicate with the identity microservice,](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=133.04) [which currently isn't responding. But pretty soon,](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=137.75) [if I refresh again, we'll see that everything is now working.](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=141.61) [Not only are all our services up and running,](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=145.52) [but they're also able to communicate with their dependencies.](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=148.66) [And so a dashboard like this is a really great way to get a quick, high‑level](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=153.34) [view of the overall health of your microservices application.](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=157.66) [What about the logs?](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=162.84) [Well,](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=164.74) [I can visit localhost port 5340, and we can see here a dashboard showing](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=165.14) [the aggregated log output from all of our microservices.](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=171.34) [And this is possible because all of the containers have been](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=175.94) [configured to send their logs to an application called Seq.](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=178.72) [Now, this is a commercial product, so you do need to license](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=183.44) [it if you want to use it in production,](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=186.77) [but it is free for use in development scenarios.](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=189.05) [And from this page, I can drill down to see more details of each log message.](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=193.24) [Seq is designed to support structured logging. So the](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=198.34) [logs aren't just lines of text,](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=201.83) [but they can contain additional key value pairs of useful information.](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=203.64) [So here it's showing us which specific event was being](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=208.74) [handled when this log message was emitted.](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=212.08) [And Seq also supports many additional useful features,](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=216.14) [such as the ability to search and filter the log messages.](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=219.73) [And Seq is just one example of a product that helps us explore the logs](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=224.14) [from all of our microservices in a centralized place.](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=228.3) [And there are several other alternatives that you could choose, but whichever](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=232.54) [one you select, it will be a huge timesaver compared to having to access the logs for each microservice in a different place.](https://app.pluralsight.com/course-player?clipId=6ae393d9-c0bc-4a3b-92cc-329b7ccf97e1&startTime=236.42)

### [Course Conclusion](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a)

[In this module,](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=0.2213330000001006) [we looked at some of the challenges of getting our](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=1.0784758571429576) [microservices running in production.](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=4.935618714285814) [We saw how important it is to automate our deployments as](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=7.221333000000101) [when you've got lots of microservices,](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=11.507047285714387) [a manual process is just going to be too cumbersome.](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=13.2213330000001) [We saw that you ideally want to set up a release pipeline that allows](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=17.2213330000001) [you to deploy your code into different environments,](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=21.507047285714386) [and run your automated tests in those environments,](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=24.2213330000001) [and then, finally, release it into production once you're ready.](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=28.2213330000001) [We saw that microservices should be independently deployable,](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=32.2213330000001) [and there are several approaches to how you upgrade a](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=36.2213330000001) [microservice such as rolling upgrades or blue green swaps that](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=39.88799966666678) [allow you to achieve minimal or zero downtime and the ability to](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=43.649904428571524) [roll back if something goes wrong.](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=48.821333000000095) [Finally, we looked at how important it is that our microservices are observable.](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=51.2213330000001) [We need to be able to monitor host and application metrics,](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=57.2213330000001) [set up alerts to warn us if things go wrong,](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=62.2213330000001) [and to easily examine the logs of each microservice in a centralized place.](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=65.2213330000001) [And we also saw how implementing health check endpoints on each](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=71.2213330000001) [microservice is a great way to enable you to get a quick picture](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=74.79276157142868) [of the overall health of your system.](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=79.2213330000001) [And that brings us to the end of this course.](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=82.2213330000001) [I hope I've been able to give you lots of practical ideas for how you can](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=84.2213330000001) [be successful with microservices in your own projects.](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=88.55466633333342) [Before we wrap up, let me just end with a few final thoughts.](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=92.2213330000001) [First, as we've said before, microservices give you lots of options.](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=97.2213330000001) [In this course, we've talked about things like containers,](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=102.2213330000001) [RESTful APIs, and back-end for front-ends.](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=105.7213330000001) [But none of these technologies are required for microservices.](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=108.2213330000001) [You're free to choose the ones that make the most sense for your context,](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=113.2213330000001) [and that's important because every context is different.](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=118.2213330000001) [Your task now, if you want to adopt microservices,](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=121.2213330000001) [is to identify the patterns and technologies that make the most](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=125.2213330000001) [sense for the application that you're building.](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=128.79276157142866) [And that's going to take into account the skills and experience of](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=131.2213330000001) [the team that are going to be developing it.](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=134.42133300000012) [Third, in this course,](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=138.2213330000001) [we've only had time to scratch the surface of microservices.](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=139.2213330000001) [And it's also an area that's changing very fast with lots of rapid innovation,](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=143.2213330000001) [and many new tools and frameworks are being designed with the goal of](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=148.2213330000001) [improving the experience of building microservices.](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=152.4713330000001) [So I do encourage you to keep learning.](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=156.2213330000001) [Do check out the rest of the courses on the](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=158.2213330000001) [microservices learning path here at Pluralsight,](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=161.2213330000001) [and I can also recommend this excellent book on](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=164.2213330000001) [Building Microservices by Sam Newman,](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=166.88799966666676) [which has recently been released in a second edition.](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=170.2213330000001) [And, finally,](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=173.2213330000001) [it's likely that your first attempts at building](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=173.9713330000001) [microservices are not going to be perfect,](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=177.55466633333342) [but don't be discouraged about that.](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=180.2213330000001) [One of the best ways to be successful with microservices is to keep](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=182.2213330000001) [evaluating the architecture that you've currently got and gradually](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=186.7213330000001) [evolving it towards some of the improved patterns and practices that we've been learning about in this course.](https://app.pluralsight.com/course-player?clipId=8a4caffb-fe45-4c42-a966-f2355ee0299a&startTime=191.2213330000001)