ATHENS UNIVERSITY OF ECONOMICS AND BUSINESS

INTERNSHIP REPORT

Comparison of ReactJs and Angular

Author:
Kleio Fragkedaki

Supervisor:
Prof. Panagiotis Louridas

Internship report and Thesis submitted as part of Bachelor degree

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Contents

List of Abbreviations

CEO	**C**hief **E**xecutive **O**fficer
SMT	**S**enior **M**anagement **T**eam
B2B	**B**usiness To **B**usiness
B2C	**B**usiness To **C**ustomer
CX	**C**ustomer **E**xperience
DOM	**D**ocument **O**bject **M**odel
HTML	**H**yper **T**ext **M**arkup **L**anguage
JSON	**J**avaScript **O**bject **N**otation
RPC	**R**emote **P**rocedure **C**all
SPA	**S**ingle **P**age **A**pplication
UI	**U**ser **I**nterface
URI	**U**niform **R**esource **I**dentifier
REST	**R**epresentational **S**tate **T**ransfer
MVC	**M**odel **V**iew **C**ontroller
Ajax	**A**synchronous **J**avaScript **A**nd **X**ML
CLI	**C**ommand **L**ine **I**nterface
Framework	Reusable software environment to build applications.
JavaScript	High-level programming language.
TypeScript	Superset of JavaScript which adds optional typing to JavaScript.
Angular	JavaScript framework maintained by Google.
React	JavaScript library maintained by Facebook.
Node.js	Run-time environment for server-side JavaScript.
NPM	Package manager for Node.js modules.

Part I

Internship Report

Chapter 1

Introduction

As part of my Bachelor degree, I did an internship for three months in Beat, a company that started as a Greek startup about 5 years ago. From March 18th 2019 until June 18th 2019, I contributed as a Software Developer intern in several projects that was referred to a product named "BeatHotels".

1.1 Company Description

Beat is a company that is developing a mobile application for taxi cab and peer-to-peer-ridesharing. The app is based on the idea of establishing a direct connection between drivers and passengers by offering both sides a modern alternative to conventional booking processes. First known as a greek startup named Taxibeat, the company was founded in 2011 by Nikos Drandakis in collaboration with associates Kostis Sakkas, Nikos Damilakis and Michael Sfictos. Taxibeat was acquired in February 2017 by MyTaxi, a subsidiary of the automotive manufacturer Daimler AG, and renamed to Beat. Nowadays, Beat is part of the FreeNow group and its CEO is Nikos Drandakis. The FreeNow group is the ride hailing joint venture from Daimler and BMW, and consists of the services MyTaxi, Beat, Kapten, Clever and Hive, the e-Scooter service.

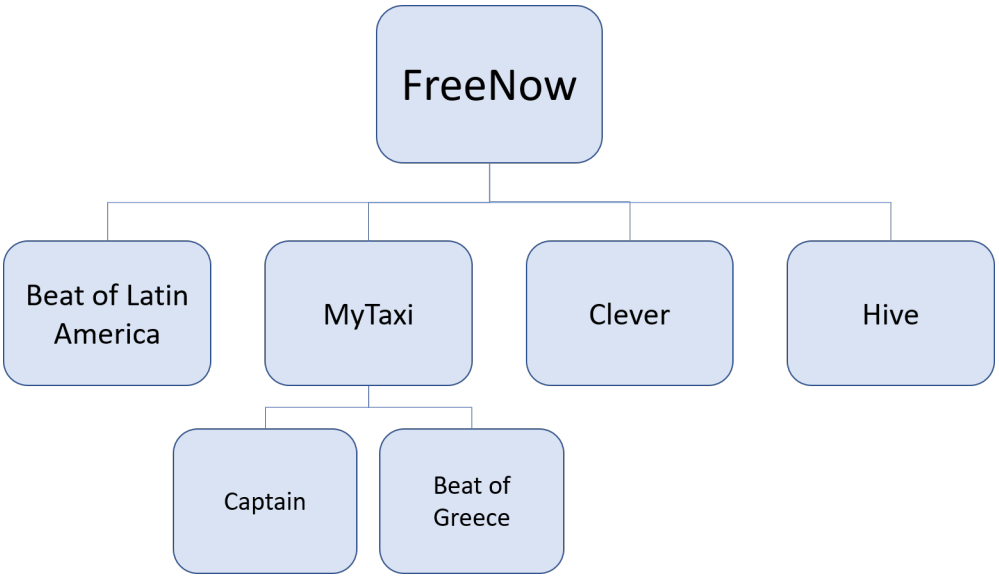


FIGURE 1.1: FreeNow's structure

Beat headquarters in Athens, Greece, while additional development and operation offices are located in Lima, Santiago, Cali, Medellín, Bogotá and Mexico City. It currently has more than 580 employees all over the world, with approximately 400 of them being in Greece. Company's teams work in small, autonomous groups of people following agile methodologies.

As regards Beat's structure, it is slightly different after its buyout. More specifically, the firm is separated in two parts based on its market targets, Beat of Latin America and Beat of Greece. This separation is because Greek market is basically part of MyTaxi group, while Latin America Market is only part of FreeNow, as shown at the driagram above. So, Beat has eight main departments, Business Operations, Finance, Engineering, Greek Market, People Operations, Marketing, Operating Office and Senior Management Team. The last department mentioned is conducted by Nikos Drandakis and his team as picture bellow reveals.

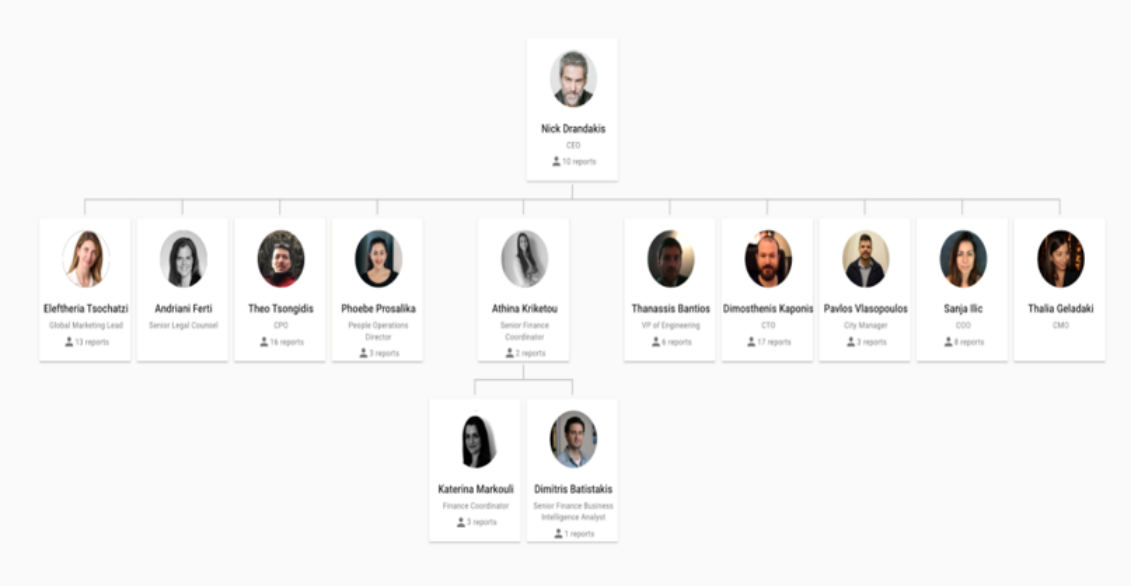


FIGURE 1.2: Beat's SMT Department

Products provided by Beat are mainly three in number. Beat App, with the extended service of peer-to-peer-ridesharing in Latin America Marketplace, Beat Hotels, B2B service only provided in Greece, and Hive, e-scooter services in Greek Market.

1.1.1 Beat App

Beat App is a B2C service provided in both Androids and IOS operating systems. This service is a connection between drivers and candidate passengers.

In other words, someone looking for a cup can find the closest one without any extra costs by using passenger's Beat app. Anyone that has downloaded the app can call a cup from any place, be able to see driver's rating from other Beat passengers, their personal data such as name, plates and more car details or services provided. In addition, before ride starts, an estimated price is given,

FIGURE 1.3: Beat App

list of the closest drivers is shown, and the candidate passenger has the ability to choose one of them based on the details and services provided, and to rate when ride is completed.

On the other hand, driver use another app through which the connection between two-sides is succeed. Available drivers can be located and the closest ones are shown to the candidate passenger. Driver can also accept or reject a ride, see the recommended route and see where passenger is before departure.

1.1.2 Beat Hotels

Beat Hotels is a B2B service that has the same aim with Beat App, the connection between candidate passengers, in this case people staying in a Hotel and request for a taxi, and drivers. The difference between these two services is, except from the aimed passengers, the virtual queues of drivers created in each Hotel.

There is a driver app, different from Beat driver's app, created in React Native and Node.js. This app is used from the driver in order to check the available Hotel queues and how much complete they are, get in a queue and start a ride.

On the other side, Hotel's have a customized dashboard, written in ReactJs and Node.js. Through this dashboard, they can call a taxi for a customer, see where the taxi is any time and get statistics of rides and revenue they have from rides completed.

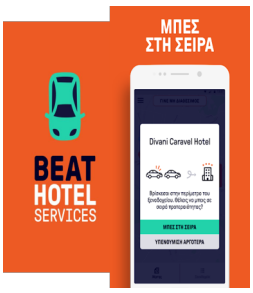


FIGURE 1.4: Beat Hotels

Finally, a similar dashboard is developed for the agents of Beat with all the informations of each Hotel that Beat's corporate. The agents have the permissions also to change the amount of a ride if it is needed, check all completed rides, or block a driver with inappropriate behavior.

1.1.3 Hive

Hive is an e-scooter sharing system service. Scooters are made available to use for short-term rentals and can be dropped off or picked up from arbitrary locations in the service area. Hive has an app through which a candidate user, can find where e-scooters are in the map, how much battery they have and their cost, scan the barcode of the e-scooter, unlock and rent it.

However, as regards Beat's part in Hive service is limited. Beat only provide customer experience services by receiving e-mails from users and resolving their issues occurred either from e-scooters or the app. Beat also is responsible of placing the e-scooters in the right places and charge them.

FIGURE 1.5: Hive

1.2 Internship Goal

As regards internship's goal, is to gain experience as a Software Developer, learning tools like React, Redux and Node.js, understanding how an application works in production. Learning how to code in Javascript and improving a web site for BeatHotel's agents by completing tasks given, and creating npm packages, were my main responsibilities as an intern.

1.3 Report's Structure

The internship's report is an overview of what I have been interacted with during my internship, analyzing the projects and results, skills that I have gained or used, and my role as an intern in general.

Chapter 2

Basic Characteristics

In the following section I will describe the basic characteristics of my Department's structure and my role as an intern.

2.1 Department

The Department that I am part of is the Greek Market. Greek Market is managing the marketplace of Greece and is also referred as the Beat of Greece as mentioned in the previous chapter.

2.1.1 Role in the Company

The Greek Market is the only department focused on Greece. Its role inside the company is to manage any demands referred to this marketplace. Demands on marketing, finance, business analysis, customer experience and the development of product BeatHotels that is provided only in Greece, are all responsibility of this department.

The Beat App is developed by other departments and any changes required for the greek marketplace are forwarded from the Greek Market to the Engineering Department of Beat.

2.1.2 Department's structure

Greek Market is constituted by five teams, Operations, Costumer Experience, the Engineer's of Beat Hotels named as GR Squad team, Marketing and Finance team. The General Manager of this Department is Vasilis Danias and the total number of people working in it is 37.

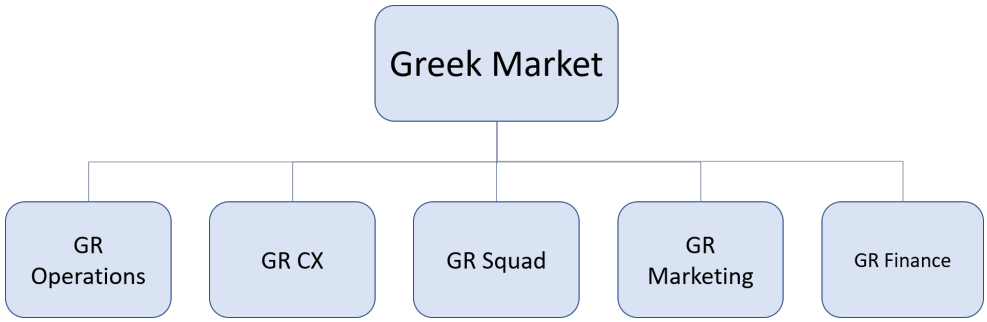


FIGURE 2.1: Greek Market's structure

2.1.3 Basic Procedures

Department's basic procedures are based on the management of three products in the borders of greek market, Hive, Beat App and Beat Hotels.

In more details, each team has different responsibilities. CX team is responsible for training drivers, resolving tickets and detecting any problems regarding these three products. The term tickets is any calls or visits made, or emails sent by either a passenger or driver.

Operations team is responsible for designing and controlling the process of production and redesigning business operations in terms of using as few resources as needed and meeting customer requirements. Marketing is creating, communicating, delivering, and exchanging offerings that have value for both customers and society in total. Competitions, sponsorships, banners, products or videos created for advertisement and social media management are made by this team.

Finance is responsible for beat driver's payments, while GR Squad is the team responsible for developing BeatHotels service.

2.1.4 GR Squad

GR Squad ia a newly conducted team which is responsible for the development of BeatHotel. Team is consisted by eight people, three front-end developers, including myself, three back-end, one Product Owner and one Scrum Master following the agile culture as the other Beat teams.

BeatHotel is a service provided only in Greece and started about seven months ago. The technologies that are used for the development of BeatHotel's driver app, dashboards for each Hotel and Agents' dashboard, are React Native, ReactJS, Node.js and for databases Firebase and Redis.

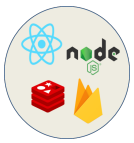


FIGURE 2.2: Technologies Used for BeatHotels

2.2 My Role

As a Software Developer Intern in GR Squad team, my role is releasing code that have immediate impact on BeatHotel service's users.

At the first one and a half month of my internship, I was a full stack developer and had the opportunity to work on both front and back-end elements of BeatHotel system. During this period, I was responsible to deliver npm packages, code in Node.js and ReactJS in order to complete requested projects for Agent's and Hotels' Dashboards, improve and extend tests and code coverage.

After this period of coding in Javascript for both back and front-end, getting familiar with BeatHotel service, my team and the way things flow, I had to choose between front-end and back-end developer. So, as a front-end I started to deliver tasks only referred to client-side development in order to maintain and extend existing web-site dashboards in ReactJS.

2.2.1 Skills Required

The skills required for this internship are enumerated below.

- Ability to produce high quality, maintainable and reusable Javascript code in React and Node.js
- Ability to build a three-layer web application
- Good knowledge of Unix based Systems
- Basic understanding of both Sql and N0-Sql databases
- Ability of problem solving and understanding algorithms complexity
- Familiar with GitHub Usage
- Ability to work in a team, communicate ideas, be an active member and deliver on time

Chapter 3

Projects/Activities

3.1 Introduction

3.2 Project 1

3.3 Project 2

3.4 Project 3

3.5 Project 4

Chapter 4

Results

4.1 Project 1

4.1.1 Description

4.1.2 Best Practices

4.1.3 Schedule

4.1.4 Problems occurred

4.2 Project 2

4.2.1 Description

4.2.2 Best Practices

4.2.3 Schedule

4.2.4 Problems occurred

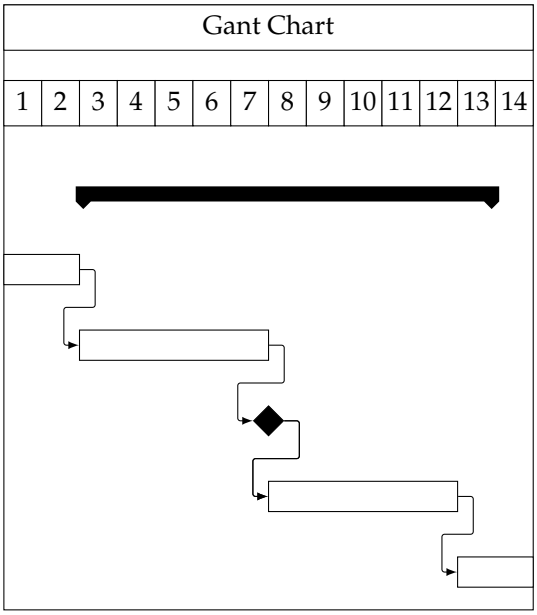
Chapter 5

Updated Time Management

5.1 Time Schedule

Activity	Duration

5.2 Gantt Chart



Chapter 6

Skills

Skills	Related Methodologies	Examples	Summary
Monday	11C	22C	A clear day with lots of sunshine. However, the strong breeze will bring down the temperatures.
Tuesday	9C	19C	Cloudy with rain, across many northern regions. Clear spells across most of Scotland and Northern Ireland, but rain reaching the far northwest.
Wednesday	10C	21C	Rain will still linger for the morning. Conditions will improve by early afternoon and continue throughout the evening.

Part II

Thesis

Chapter 1

Introduction

1.1 Definition

1.2 Research Goal

1.3 Thesis's Structure

Chapter 2

Background

Web applications have made a rapid progress over the last years in the field of both technologies used and architectural approach. A web application is consisted of a client and a web server. Client is considered to be, for example, a web browser in a mobile phone or in a desktop computer. Client sends a request to the server, where processes are performed depending on the request, and a response is sent back to the client. (Voutilainen, 2017) As picture bellow reveals, client is making a request and server attempts to fulfill it by referring to a data base, performing calculations, controlling or sending another request to other servers.

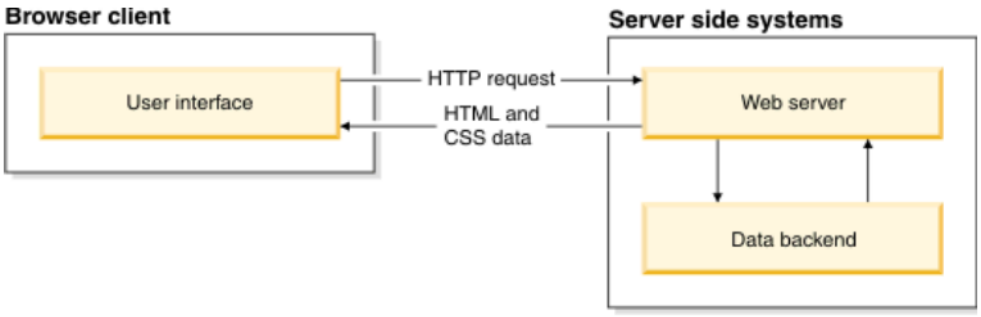


FIGURE 2.1: Web application data transfer model

Functionalities can be spotted in the client side as well. Client can customize HTML DOM, Document Object Model structure used for accessing different elements, display interactive visualizations or alerts through the utilization of Javascript programming language. (Voutilainen, 2017)

Architecture, which is a set of defined terms and rules used as instructions to build a web service, influence both software design and engineering. The choice of a web application's architectural design impacts on development time and maintenance costs, every-day's transactional performance, response times, continual application's flexibility and scalability. The architecture is selected based on the app's complexity, integration level, number of users and their geographical distribution, network's nature and long-term transactional needs. (Cemus et al., 2015)

2.0.1 Architectural Designs

In the late 1950s, mainframe architecture was introduced. This architecture was designed for mainframe computers that are used to large-scale computing applications, such as data storage or customer statistics. Every kind of program and data was stored in a single machine and users could only reach this centralized computer only through the terminals' usage.

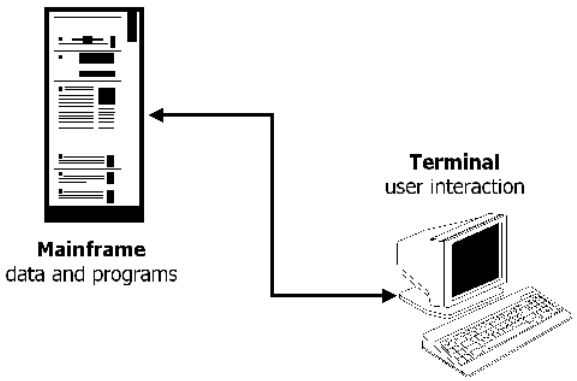


FIGURE 2.2: Mainframe Architecture

In the 1980s, two-tier architecture was introduced due to the entry of network connected computers. In more details, this architectural approach consists of an application running in the client and interacting with the server as a database management system. In that perspective, client contains the presentation logic, navigation of the application, business rules and the database access. By changing the business rules in two-tier architecture, the client had to be modified and tested all over again, even in case the user interface is the same. For minimizing the costs of conversions, presentation logic and business rules had to be separated, fact that gained the principle of three-layer architecture.

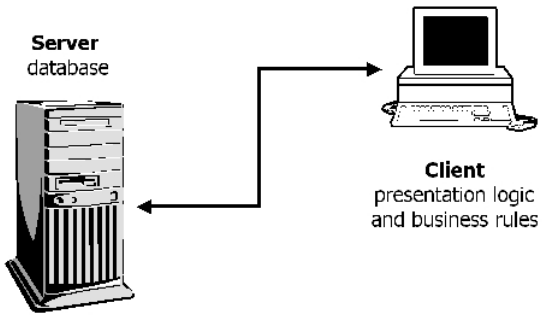


FIGURE 2.3: Two-Tier Architecture

In a three-tier architecture, also referred as multi-tier, there are up to three interacting layers. System functionality is thereby distributed with each own of these tiers having a subset of responsibilities.

As the Figure 2.4 shows, first tier refers to the presentation logic, known as client, and includes user interface and input validation. Second tier or, in other words, middle tier or application server, provides data access and the business logic. Finally, third tier is the data server and provides business data and resources. The pros

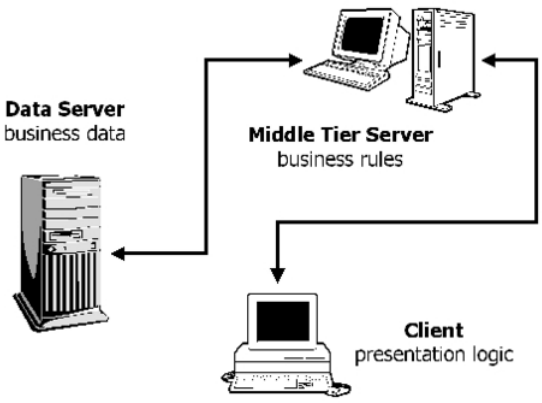


FIGURE 2.4: Three-Tier Architecture

of three-layer architectural design is the ease replace or modification of any layer without influencing or changing the others. Another advantage is the load balancing that this separation of layers and the database functionality provides. (Ramirez, 2000)

2.1 Three-layer Architecture

Three-layer Architecture is a software architectural pattern in which the application is separated into three logical layers known as presentation, business logic and data storage layer. This architecture is adopted by client-server applications that have frontend, backend and database.(Chen and Zhang, 2013) Data access and calculations required by the presentation layer, are part of the business logic layer and, for this purpose, calls to middle-tier servers are made. Middle-layer servers can be approached by various clients, which are from different applications as well. Each one of these tiers has specific responsibilities and can be handled independently. (Gallaugher and Rarnanathan, 1996)

Interaction between client and server is succeeded mostly through the Remote Procedure Call, which is a way to describe calling mechanism among procedures and to exchange data via messages. In RPC, clients request data by passing parameters needed and specify data structure to received values in order the request to be fulfilled.
HTTP is the protocol used for messages' passing. HTTP stands for Hypertext Transfer Protocol through which resources are exposed across distributed systems. An HTTP request includes a body with the representation of resources required by the client. An architectural style that is based on RPC implementation is called Representational State Transfer. REST is implemented in client/server models where the client is gaining data or interacting with resources managed by server.

There are a lot of advantages adapting three-architecture layering design. First and foremost, modularity, having separate software entities allows each layer to be managed independently of the others.(Chen and Zhang, 2013) This has as a result different groups of people to focus on different tiers, so as parallel development to be succeeded and people to become specialists. It has to be mentioned that skills needed for application development varies, and having some experts responsible for each tier can improve the general quality of the application.(Gallaugher and Rarnanathan, 1996)

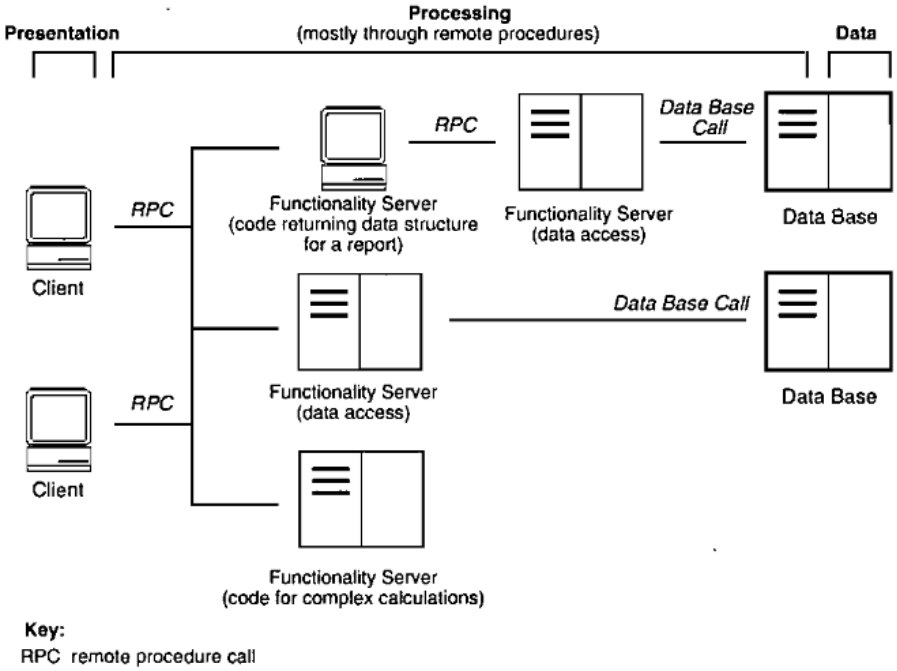


FIGURE 2.5: Three-Tier Architecture

Scalability of three-tier architectural pattern is another benefit. This architecture provides flexibility in resource distribution. In more details, servers are portable, and dynamically distributed and changed based on the application's requirements. (Gallaugher and Rarnanathan, 1996) Each of the tiers scales horizontally in order trafficking and request demand to be supported. For example, scalability can be done by adding more Elastic Compute Cloud instances, which is a cloud service providing security and compute capacity, and load balancing to each layer. (Chen and Zhang, 2013)

Another core profit of this distribution is that code units can be reusable. This logic minimize the maintenance costs, development efforts and the ability to easily switch technologies used. Moreover, there are various additional features that support modularized applications, which means that integrated security, server control and dynamic fault-tolerance are supported. (Gallaugher and Rarnanathan, 1996)

Security is easier to be performed in three-layer architecture. All of the interactions within the application are made through private Internet protocol addresses. Users access client/server systems via the presentation tier. The other two layers, server and database, are not exposed to network which offers protection, security and barriers against malicious users. Fault tolerant is also provided for adaption in any unexpected change. (Chen and Zhang, 2013)

In conclusion, this layering model is the most frequent architectural design and is defined as components' separation into different tiers. Each layer's components are abstract with limited dependences between them, reusable and easy maintained. (Chen and Zhang, 2013)

Presentation Layer

Presentation layer or client is the user interface part of the application. In other words, this layer controls the interaction between user and system, and is also responsible for input validation. Presentation tier's infrastructure is exclusively related to interface elements. (Chen and Zhang, 2013)

Business Logic Layer

Business logic layer or server is the body of an application. This is related to how the service works and it is responsible for computations and connection between client and database. (Chen and Zhang, 2013) Several server requests and data access is made through the middle tier instead of client, thus traffic, memory and disk storage requirements are minimized. (Gallaugher and Rarnanathan, 1996)

Data Layer

Data access layer or database is responsible for providing business data and resources. Data are stored in this layer and are accessed from other layers when it is needed. (Chen and Zhang, 2013)

2.2 Rest

Representative State Transfer is an architectural style for building networked hypermedia applications that are easy to implement, lightweight, maintainable and scalable. A service based on Rest architectural approach is called Restful. The main purpose of a Restful service is providing data access to the client through a window. By the term of data or resources, we mean everything that can be captured in a computer-based informational system, such as pictures, videos, Web pages or any other business information. (Vaqqas, 2014)

Rest architectural style is based on four main principles. The first one is that resources are identified by URIs, which is a universal addressing space for resources and service exploration. Furthermore, the principle of uniform interface is the way resources are by using a set of four operations. More specifically, resources can be controlled by PUT, POST, GET, DELETE, which are for update, add, retrieve and remove actions. The next principle stands for self-descriptive messages. In other words, resources can be represented in a variety of formats depending on the requirements, such as JSON, XML, HTML or even plain text, and meta-data are also available in order caching to be controlled, transmitting errors to be detected and authentication to be performed. Last but not least, every interaction with a resource is stateless. This means that each request message is self-contained and there is no need of state transfer. (Pautasso, Zimmermann, and Leymann, 2008)

HTTP is the protocol that is used in almost every Restful Web service and it is implementing the service with features of a uniform interface and caching. This protocol is giving the ability of communication between client and server through messages. Client sends a request to the server, and server returns a response to that request. (Vaqqas, 2014) Rest APIs are the bridge between this communication, so as the client to get the resources needed from the server without knowing how the structure of Restful API works and vice versa. (Padmanaban et al., 2018)

In conclusion, Rest architectural approach is a lightweight infrastructure, where services can be built with minimum tooling and effort that leads to inexpensive and

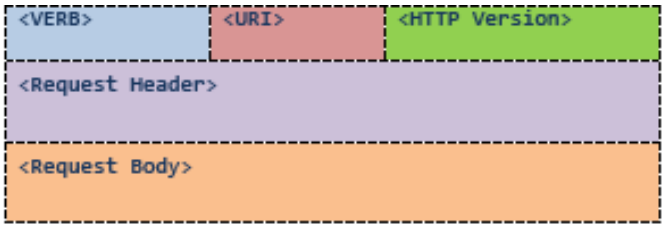


FIGURE 2.6: HTTP request format

low barrier adoption. Restful Web services serve a large number of clients because of the caching and load balancing build of Rest, and have the ability to access resources without registration, and the advantage to optimize data in different formats. (Pautasso, Zimmermann, and Leymann, 2008)

2.3 Dynamic Pages

Web application systems are using Web browsers for representing client. Web browsers interprets HTML, CSS and Javascript code, and communicate with server side through the usage of urls and HTTP protocol. In first place, static web pages were send to browsers and server's responsibility was to locate and send files, based on client's requests. Afterwards, dynamic pages were generated by servers via running software, and by clients via executable code. Thus, a lot different software development, such as languages, APIS, libraries or frameworks, were build to support dynamic pages' approach. Ajax, Javascript, Python, and much more other such development tools, are a good example. (Kulesza et al., 2018)

Ajax stands for "Asynchronous JavaScript And XML" and provides asynchronous requests for data transfer. By using Ajax, an application can dynamically update its page's content without the need of reloading the entire DOM all over again. In general, Ajax is a way to get a certain functionality by using web technologies on the client side, in order to create asynchronous applications. Ajax is different than JS frameworks or libraries which include a lot capabilities and functionalities along with Ajax. (*Redux Official Website*)

JavaScript is the language created to fulfill the need of client-based dynamic pages. JavaScript is being developed really quick and new versions of the language are often released, like the so called ECMAScript 2015, or namely ES6, and other more recent ones, like ES7. Generally, ECMAScript or ES is a standard formation body of JS scripting language with ES5, named also as ECMAScript 2014, to be the version all browsers understand. (Accomazzo et al., 2016) As regards coding with JavaScript, developers prefer to use ES6 and its upgrades for coding. This is because these new versions mark a new generation of the referring language with a dozen of additional features compared to ES5, the previous version. For using new features implemented in ES6, there are programs like Babel that convert the newer syntax to ES5, that is browser-compatible. (Masiello and Friedmann, 2017)

Moreover, new technologies based on JavaScript are regularly released. So, libraries and frameworks are inclined to make easier JS development and improve its capabilities. JavaScript's libraries exist for a long period of time and in 2006, they got popular for first time with jQuary. AngularJS and Ember, which are other JS frameworks, became known between 2010 and 2011. AngularJS was the first framework that composed routing and data binding in one. Ember followed and provided some

improvements on AngularJS, such as better use of routing. Other frameworks and libraries, such as React, Angular, Vue, were announced until 2015. Javascript and its frameworks, CSS and native HTML are more and more powerful today. (Voutilainen, 2017)

FIGURE 2.7: Historical overview of JS frameworks and libraries

A framework is defined as a large reusable collection of libraries, functions and tools in order application's main structure to be implemented. Thus, JavaScript frameworks are implementing the whole structure of an application, and make development of JS painless and faster by offering ready, optimized functions in comparison with native JS. Dependency management, file system structure and routing possibilities are also included. The term framework is used to declare that the execution flow of an application is handled by the framework and not the developer. This is the main difference between JS frameworks and libraries, since a library provides only a set of functionalities, while a framework conducts processing and data flow. (Voutilainen, 2017)

Angular and ReactJS are nowadays widely scoped, full and continually improved JS frameworks or libraries, and their popularity have been significantly increased over time in front-end development. However, there is no framework or library considered to be as the best, a group of great choices exist that do have different functionalities and are selected based on some parameters that will be investigated in this thesis. (Voutilainen, 2017)

2.3.1 Data Architecture

By developing dynamic pages, the need of application's data management was increased. For this reason, several data architectural patterns have been developed over time. At first, MVC pattern was used for a long period. MVC stands for Model-View-Controller, where model contains the business logic, view presents data through the user interface and controller connects the other two. However, MVC is not compiled into client side in the best way, fact that leads to the development of other data architectural approaches based on MVC for front-end. More specifically, there is MVW, or in other words two-way data binding, which means Model-View-Whatever. This pattern is used to describe Angular JS's architecture. MVW provide a common data structure in the application, and changes made in any area reflect the whole app. Another architectural approach is **Flux72**, which is an one-way data flow pattern. In this case, there are states that keep data and actions that change these data if needed, while views render what have been stored. Last but not least, there is the so called Observable pattern which is implemented from RxJs73 library. This is a publisher-subscriber architecture that provides streams of data. It includes

functions for publishing values which are only executed in case subscribers exist. (Murray et al., 2018)

Redux

Redux is a library for data management in client side and was based on Facebook's Flux architectural approach, which was mentioned in previously as Flux72 pattern. (Masiello and Friedmann, 2017) Managing data can be complicated when it comes to large apps. Intermediate passing of component state, the coupling between parent and child components that makes refactoring inflexible and the mismatching of state and DOM tree, are the reasons Redux was designed. ((2018))

More specifically, Redux is a Model-View-Controller library that handles data and interactions between layers inside an application. For this purpose, it is using reducers which are functions for computing application's state (Geary, 2016) and a global store that wraps all states of the application. In that way, data can be accessed and handled from any component, fact that unbinds UI from state changes, and reduces errors raised from state mismanagement. (Accomazzo et al., 2016)

Redux is better described via three main principles. First of all, there is a single store, which mostly has the form of a JS object, and uses reducer functions for managing the small parts of the store. (Masiello and Friedmann, 2017) In this way, it is easier to design and parse data through the application, and quick the process of debugging and testing. (*Redux Official Website*) The next principle is that state must not be modified by any component. For this purpose, reducer functions are used to build a new state when an action is provided without affecting the original state. Finally, the last principle is that reducers have to be functions that do not include API calls and do have deterministic results. (Masiello and Friedmann, 2017)

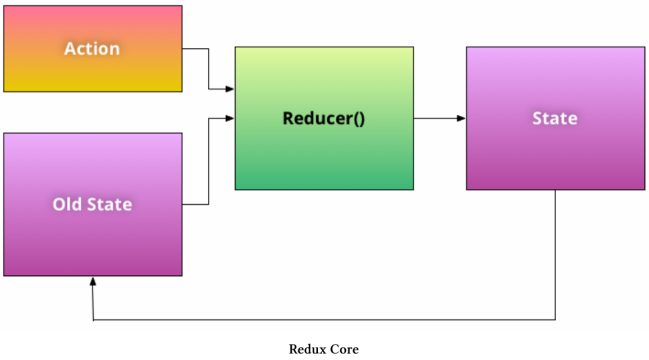


FIGURE 2.8: Redux Structure

In conclusion, Redux is based on an architectural approach that provides scalability and tools for better data management. This library can be used in combination with other libraries or frameworks, like React and Angular, as it will be mentioned in the next Chapters.

Chapter 3

ReactJS

3.1 Definition

ReactJS is a JavaScript library for building web interfaces. The library was created by Jordan Walke, software engineer on Facebook, and is maintained by Facebook, Instagram and a community of individual developers and organisations. React became open source on March 2013, while it is used by Facebook since 2011, Instagram since 2012. PayPal, Uber, Sberbank, Asana, Khan Academy, HipChat, Flipboard and Atom are a few more applications using React. (Mardan, 2017)

As mentioned in Chapter 2, library is just a set of functionalities that developers use. It doesn't aim to cover all fields of an application or to provide a complete solution for developing an app unlike frameworks. React is a UI component library which creates interactive user interfaces. It was developed for complex and large scale web based applications in order to manage how views change in response to data modifications. In that way, better user experience is provided with fast and robust development. (Mardan, 2017)

In more details, React is mostly a view-layer solution, but it includes mechanisms for managing state without providing a specific way for data flow management, server or API interaction, or routing. For this reason, additional libraries will be needed. Its main concern is simplicity and scalability. Most popular features of React library are Virtual Document Object Model, Lifecycle Methods, Stateful components, JSX and One-way data binding that will be analyzed later on this chapter. (Masiello and Friedmann, 2017)

3.2 React Virtual DOM

DOM stands for Document Object Model, and represents an XML or HTML document as a tree structure where each node is a different part of the document. The HTML DOM was designed for static pages and not for creating dynamic pages. So, when DOM is updated, every node and page has to be updated as well, fact that reduces application performance. For this reason, Virtual DOM was invented. Virtual DOM is basically an abstraction of HTML DOM and has analogous properties with a real DOM, with the difference that it cannot make any direct change to the screen. It is also lightweight and detached from browser and can be updated without affecting real DOM which means faster manipulation and updates. (Naim, 2017)

React differs from other front-end JavaScript frameworks, since it is not working with the browser's DOM. Alternatively, React keeps a JavaScript representation of the DOM in memory, the Virtual DOM which is a tree of JS objects, and makes all modifications in there. In that way, actual DOM is not directly manipulated and the minimum number of changes required are eventually applied to real DOM. More

specifically, React compares virtual DOM with the actual one, determines which parts have been updated and then updates only those in browser's DOM. Moreover, Solutions for browser differences, server-side rendering and implementation of target rendering are provided in this way. (Accomazzo et al., 2016) This approach brings greater performance which can be noticed by end users. (Masiello and Friedmann, 2017)

By updating actual DOM, there are some obstacles. It is difficult to keep track of changes, the current and previous state of DOM, so as to manipulate it based on needs. Furthermore, changing the real DOM is causing low performance and high costs. For these reasons, virtual DOM was introduced which provides an API for DOM' s transformation. Developers code as if they are re-creating the whole DOM on each update. This leads to easier development model which does not require tracking changes of DOM. This implementation uses effective algorithms for rendering a JSX element so as to be aware of what has been changed and update only those elements that are modified, updates at the same time subtrees of DOM and batch the updates. (Accomazzo et al., 2016)

In conclusion, React's Virtual DOM results to an easy-manipulated and improved way of building web applications. Virtual DOM is actually an intermediate area in which data are firstly changed due to faster processing. In fact, if changes in DOM are not frequent, Virtual DOM maybe is not suited, but in complex and dynamically modified ones, re-rendering whenever needed is a great feature. (Masiello and Friedmann, 2017)

3.3 Stateful Components

React split the user interface, which is what screen shows, into smaller parts in order to be reusable and easy-maintainable. These parts are called React components and provide both data to the view and changes to it. More specifically, React is a set of components that are nested inside one another and there is one rooting component that composes all of them. Components are basically JavaScript functions that take inputs named properties and return as output React UI elements that are what is shown to the user. (Stefanov, 2016) React components include a render method that returns what has to be displayed as well as other lifecycle methods, in order code to be executed in certain times during component's life. All these methods will be described in details during next section. (*React Official Website*)

3.3.1 State

Components receive as inputs the so called "properties" that are passed externally through their parent. Except from properties, each component also have its internal state that can keep track of. (Masiello and Friedmann, 2017)

State is a plain JavaScript object that is used to track user events and other variables inside component.Moreover, it can be passed as properties to its child components. Furthermore, state is owned by the component, is private to it, and can be updated any time needed. Whenever component's state or its passed props are changed, the component, and all of its child components, are re-rendered. (Accomazzo et al., 2016)

3.4 Lifecycle Methods

Each React component rendered into the DOM follows a series of steps. Developers can access each step through component's life-cycle methods, so tasks and specific check conditions to a stage can be performed. Lifecycle methods are used to listen changes in components. Thus, component is constant until its parent pass new props or some event causes any change in its state. (Masiello and Friedmann, 2017) There are four main stages for each component's life, the so called "Mounting" stage which is the phase where an instance of a component is being created and inserted into DOM, the "Updating" which is the phase where component is being re-rendered, the "Unmounting" where component is being deleted from the DOM, and another not that critical, the "Error Handling" for any errors occurred during rendering. Each of first three previously mentioned stages of component's life include their own methods that will be described in details. (*React Official Website*)

Before a component has been placed into DOM for first time, a method named **componentWillMount** is applied so as component to receive timers and data needed from the server. Method **constructor** belongs to "Mounting" stage and is called when initializing the component. In this stage **render** method is also called and converts JSX elements to HTML which place them into DOM, or in other words mounts component. After mounting is done, method **componentDidMount** is called and used as an integration between non-React and React libraries. (Masiello and Friedmann, 2017)

The first method called when either props or state has been changed, or in other words during the "Updating" stage, is **shouldComponentUpdate**. The method receives two arguments a new set of properties and a new state, and compares those with the old ones. Moreover, this method is returning a boolean value. (Masiello and Friedmann, 2017) If the value returned is false, then the update is aborted which means that the render method won't be invoked, while if it is true, the update is normally happening. This is useful for performance reasons of the application, only in cases that the changes made are not that necessary to be made. Rendering is generally considered as computationally expensive and can slow down the application. This decision is made based on either the comparison of new and old state and properties, or if the component is static and doesn't need to be re-rendered. (Stefanov, 2016) If method is not defined, its default value is true. The next method called, if the previously mentioned method return true, is **render** again. In this case, render gets the new JSX representations, compares it to the old one into the virtual DOM, and creates and apply changed parts to real DOM. Finally, once this process is complete, **componentDidUpdate** which receives the previous state and properties as arguments is executed. This is used to operate on the DOM, like doing network requests, after component has been updated. (*React Official Website*) After that the update lifecycle, the components remains inactive until a change to be occurred. This methods are executed all over again unless the component is unmounted from DOM. (Masiello and Friedmann, 2017)

As regards the "Unmounting" stage, there is only one method called named textbfcomponentWillUnmount which does not receive any arguments. This method is executed right before the component is removed from DOM and is the final stage of component's life. (Stefanov, 2016) In this phase, any necessary cleanup is performed. Anything that has been created over component's lifecycle, such as invalidating timers, canceling network requests, or cleaning up subscriptions made, are removed through this method. (*React Official Website*)

Each of the methods mentioned above might be used inside a component, but their usage is optional and based on component's functionality needs. Furthermore, it is a good practice to use these methods for DOM manipulation and not other kind of libraries alongside React. This is because React uses a virtual representation of DOM in order to apply and manage changes in browser's DOM. So, if other libraries are used, there are possibilities of not being synchronized with React expectations so as errors to happen when React tries to match changes. (Masiello and Friedmann, 2017)

3.5 JSX

JSX, which stands for "JavaScript XML", was created by Facebook community for React library and it is an extension to ESCMAScript syntax. ECMAScript or ES is a standard formation body of JS scripting language, as referred to Chapter 2, and the ES6 version is mostly used among JavaScript developers. More specifically, JSX has a syntax analogous to HTML and is a markup language compiled to ES6 that aims to define component's layout. It is not necessary to be used alongside with React, but is considered as good practice, otherwise React is becoming much more complex and with lower performance. Furthermore, JSX includes tools for converting ES6 to ES5, the browser-compatible syntax. (Masiello and Friedmann, 2017)

JSX describes the way user interface should look like by producing React elements. Events handler, state changes and data represented are closely related to UI logic. For this reason, JSX's components contain both markup and logic-based technologies in the same file, fact that differentiates React from other frameworks or libraries.(*React Official Website*) In that way, a lot useful errors and warnings are being caught because of the debugging made during compilation process.(Accomazzo et al., 2016) Another benefit of JSX is the speed. Even if JSX is compiled to JS, its output is optimized with a better way compared to the same code written directly in JavaScript. In mobile applications has been found that JSX is 12 % faster in IOS and 29 % in Androids than pure JS code. (Stefanov, 2016) To sum up, JSX is a representation of component's HTML in JS and also close to object-oriented languages, like Java. (Masiello and Friedmann, 2017)

3.5.1 Babel

As referred in Chapter 2, nowadays the majority of browsers do not support ES6 or other languages, except ES5. This is happening because it takes time to update JavaScript engines of browsers and much more time for users to upgrade to their latest version. So, any language used in client side needs to be converted to ES5 so as this gap to be closed and code to be executed in any browser.(Accomazzo et al., 2016) For this purpose, there are two main compilers, traceur32 by Google and babel33 by JavaScript community. These two are not used for Typescript transition to browser-compatible code, but for pure ES6 code. (Murray et al., 2018)

As regards Babel, or babel133, is a JavaScript transpiler that changes ES6 to ES5 code as it has been pointed out. However, this tranpiller includes the ability to understand JSX. In this way, JSX can be compiled to conventional ES5 and browser to normally execute code. (Accomazzo et al., 2016)

3.6 One-way data binding

Data binding is the way connection between user interface and business logic is succeeded. When binding of these two layers is properly built, components, that are connected to recently modified data, are re-rendered. (*Microsoft Official Website*) There are three main types of binding, one-way binding, two-way binding and Observables, as it is analyzed in Chapter 2.

React follows one-way data flow which means state can change view, but not vice versa. One-way flow or binding is an one-way direction from state to view that keeps under control state and models, and makes application's architecture less complex and more predictable. Data pass only from parent to child components, so in case changes are made, event handlers need to be emitted. Even if it is needed extra code for setting data through event handlers to state in order view to be rendered, complex user interface and the amount of views and states needed are reduced in a large extend. (Mardan, 2017)

Generally, This way of binding is suitable for applications that do not need to control view's changes. (*Microsoft Official Website*) React combined with Redux so as one-way binding to be provided.

3.6.1 Redux

React is well combined with Redux since one-way data flow pattern is adopted, as figure 3.2 also reveals. Redux is providing data management and a global store to the application which leads to scalability and interactivity. Any data can be updated from any view at anytime and, in this way, debugging is easier. A lot services are using Redux alongside with React for faster responses and a better user experience, such as Facebook, Instagram and Airbnb (Naim, 2017)

The process when using Redux is shown in figure 3.1 bellow. When a user interacts with the application, an action related to this interaction is dispatched. In case an HTTP request is required to server side, the action is returned and awaits for the response. Action and current state are sent to reducer when request to server is fulfilled, and reducer creates the new state and substitutes the old one. Finally, any component, that its state has been changed based on the updates in store, is re-rendered. ((2018))

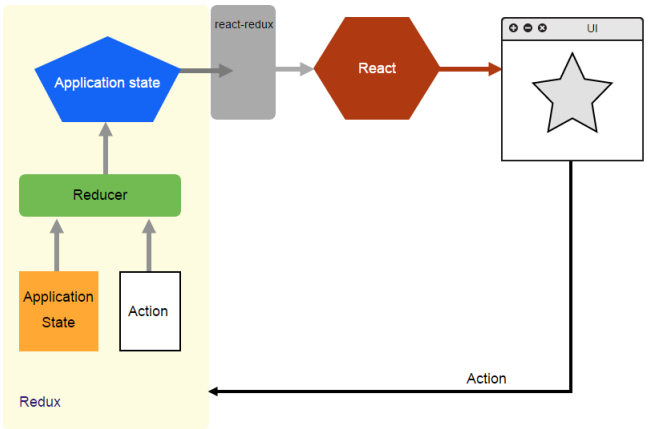


FIGURE 3.1: React with Redux

3.7 Summery

React library has changed the way user interface is developed by building stateful components in JSX syntax. React is one of the most popular libraries between front-end developers and well-known companies for client side layer. In this chapter, was covered the definition and conceptual fundamentals of React, as well as some external libraries used for its better usage.

Chapter 4

Angular

4.1 Definition

Angular is a JavaScript framework for developing client side applications. This framework was created on October 2010 by Google. It is maintained by Google and a community of individual developers since September 2016 that its code became open source. (Voutilainen, 2017) Angular as framework is providing a large set of libraries, functions and tools, and its implementing the entire structure of a client-side application. Moreover, Angular is using templates that extend HTML style syntax for view's representation, and is built in TypeScript, a JavaScript-like language. (*Angular Official Website*)

Angular's advantage is that provides the ability of creating and managing project through terminal. Due to its complicated set up, Google created a command line interface, or CLI, that makes Angular's usage much easier. Angular CLI is responsible for creating and maintaining common pattern inside an app. (Seshadri, 2018) Creating projects, adding new controllers and much more other tasks, are automated and easy implemented with just one command. Last but not least, Angular CLI is based on Webpack, a tool that groups TypeScript, JS, CSS, HTML and any files used in the application, and makes deployment, building app for production, simpler. (Murray et al., 2018)

4.1.1 Angular & AngularJS

AngularJS, or sometimes referred as Angular 1, was firstly released in order to provide quick, scalable and maintainable web applications. As years passed, the way browsers, and generally web, used to work changed dramatically, so AngularJS stopped solving problems relevant with the new updates of web. Thus, Angular was created on 2014 which is basically a totally newly written framework. As "Angular" are referred all the newest version, starting from Angular2 and above.(Seshadri, 2018)

More specifically, Angular and AngularJS are two different frameworks made from the same team. As regards AngularJS, it is using directives, controllers, scopes, services and dependency injections, while Angular is using components, instead of directives, and services. Comparing these two frameworks, modules were replaced by web components and existing features of AngularJS were improved, such as dependency injection and templating. (Seshadri, 2018) Scope, which stands for two-way binding, and directive definition objects, controllers and angular.module were removed from the new versions of Angular. (Murray et al., 2018)

4.1.2 HTTP

Angular is providing an impended HTTP library through which external APIs can be called. The HTTP requests made are asynchronous that enhance pages performance. This means that user can continue interacting without waiting for the HTTP's response. In general, there are three ways of dealing with asynchronous code in Angular, Callbacks, Promises and Observables. (Murray et al., 2018)

4.1.3 Testing

When using Angular CLI for component's creation, its main infrastructure is set up and includes four files. One file is for writing css, one for html, one for TypeScript code and one extra file for testing TypeScript code with a spec skeleton. There are some basic testing when initializing the component that can be improved and contain all test's needed for checking code's validation. (Seshadri, 2018)

4.2 Typescript

Angular is using a JavaScript-based language named TypeScript, which was the result of Microsoft's and Google's collaboration. TypeScript is a superset of ES6 with the additional features of types and annotations, as it is shown in the diagram bellow. It is compiled to ES5 in order code to be compatible with browsers, but it have five major upgrades compared to ES5 code that will be described later on this section. (Murray et al., 2018)

It is not obligatory to write TypeScript in Angular apps. However, it is a good practice due to the features provided, that also make coding easier to be maintained and understood. (Seshadri, 2018)

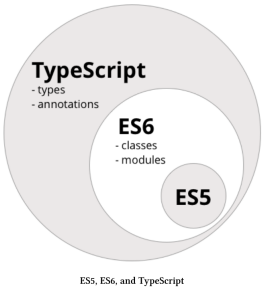


FIGURE 4.1: Typescript

4.2.1 Types

TypeScript's name was inspired by its typing system, its most important addition. Type checking can prevent developers from bugs and make code much readable due to its obligatory clarification. (Murray et al., 2018)

Regarding types provided, they are the same as in JavaScript, booleans (true or false), numbers, strings, arrays, enums (similar to arrays but has numeric values as names), any (any type of value), void (no type or returned value expected). Types are not necessarily used in TypeScript, they can be omitted in case of writing quick code. (Murray et al., 2018)

decorator

4.2.2 classes

ES5 JavaScript is using functions and prototype-based objects, through which an object-oriented approach is succeed. In this version, prototypes are used instead of classes. (Murray et al., 2018) In contrast, ES6 version is using an object-oriented approach based on classes, that inherit functionality and built objects. (*TypeScript Official Website*)

In more details, classes include properties, methods and constructors. Properties are the data passed as arguments to a class's instance and can also refer to a type. A regards methods, they are functions included in an object and are called through the instances of them. Lastly, every object owns at least one constructor, which is a method executed at the creation of class's instance. It can take parameters, but it does not return any values except the instance of the object. As object-oriented, classes inherit their behavior from their parent which can be then modified. (Murray et al., 2018)

4.2.3 Imports

By using import, library modules and other Angular applications are imported in components, services and other parts of the application. In this way, functionalities included in these imports can be used, and extra both code and effort by developer's side can be reduced. (Seshadri, 2018)

4.2.4 Decorators

With the introduction of Classes in TypeScript and ES6, there now exist certain scenarios that require additional features to support annotating or modifying classes and class members. Decorators provide a way to add both annotations and a meta-programming syntax for class declarations and members. Decorators are a stage 2 proposal for JavaScript and are available as an experimental feature of TypeScript. (*TypeScript Official Website*)

A Decorator is a special kind of declaration that can be attached to a class declaration, method, accessor, property, or parameter. Decorators use the form @expression, where expression must evaluate to a function that will be called at runtime with information about the decorated declaration. (*TypeScript Official Website*)

4.2.5 Utilities

Due to TypeScript is a superset of ES6 JavaScript, extended syntax feature of ES6 are also included in TypeScript and make programming easier. First of all, arrow functions is an important addition. Generally, the arrow-syntaxed functions are sharing the same this with the rest of their component or service. In contrast, when a function is applied in traditional JS, it gives its own this, fact that leads to difficulties using global variables and functions. Moreover, new template string were added, thus variables can be included in strings, as long as backticks are used instead of double or single quotes, and multi-line strings are allowed. (Murray et al., 2018)

4.3 Components

Angular components are TypeScript classes decorated with extra attributes and metadata. Classes basically include any data and functionality needed, whereas decorators define the way of translating to HTML. (Seshadri, 2018)

Angular applications are in fact a tree of components, where its root is the application and that's what it will be rendered when any updates exist. As regarding components, they can be built from smaller components that consist of parent-child structure. When a component is rendered in Angular, its dependent components are updated as well. (Murray et al., 2018)

More specifically, components have three main parts, which are component's decorator or @Component, a view and a controller. Each component is responsible for a small part of screen and controls this part through templates. Component's decorator is responsible for defining to other parts of the application how interaction with the component is succeeded. For this purpose, it uses templates, which is the visual part of component or as called the view, and selectors, which indicates how components will be recognized from templates and what parts of HTML match the component. As regards controllers, they accept server's requests and run comprehensive actions based on paths and parameters sent by server. These actions are responsible for rendering components when needed. (Murray et al., 2018)

4.4 Services

In Angular, components are responsible for data representation and user interface's updates. Data are passed from components to the screen and, through events, from screen to component's methods where changes for user interface will be handled. Basically, components is the presentation layer, while servers are the ones responsible for fetching real data and business logic to the application. (Murray et al., 2018)

More specifically, Angular services are a common layer through the application that is used in three cases. Firstly, services are created when data are needed from or sent to the server. Secondly, services can be applied for writing application logic that can be reused across components. Additionally, services are used in case data sharing via components, particularly when components do not have access to one another. (Seshadri, 2018)

Services have their own store and can access all components in the application. Generally, they are the layer that handles how data and application logic works, so as components to be only bound to what will be represented in screen. (Seshadri, 2018)

4.5 Lifecycle Methods

Each component and directive has its life-cycle that is handled by Angular. Angular's lifecycle hooks were created in order developers to write code that acts at specific moments of directive's or component's life. Life-cycle hooks are provided through an interface in each part of the app needed. There are three main stages of life-cycle, creation, update and destruction, that each includes a list of hooks. In order to add these hooks in code, it is needed declaration of interface's implementation inside directive or component and also of hook's methods wanted. Hook methods are formed by the name of hook plus the prefix "ng". In this way, Angular will call the component or directive, and code written in methods at the right time. (Murray et al., 2018)

In figure 4.2, it is shown the process followed in the lifecycle of any Angular-based app.

Let's dive into hook methods represented in the diagram above. Constructor is the first method executed and includes any initializations needed. Afterwards, when values of properties or data are modified, ngOnChanges method is triggered. Method ngOnInit is following and is used to perform complicated initializations that cannot be made in constructor. (*Angular Official Website*) Every time data change all related components or directives are updated, fact that affects performance. So, in case that a change is not important to be executed or an update is needed when a

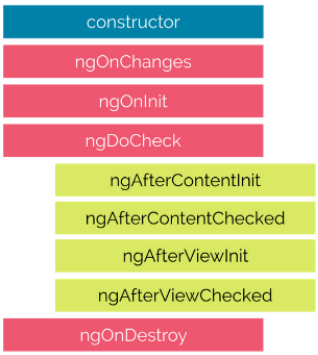


FIGURE 4.2: Life-cycle hooks in Angular

specific property have been modified, onDoCheck method can be used. This method overrides ngOnChanges which is ignored. (Murray et al., 2018) Moving forward, ngAfterContentInit is triggered when content is extended into component's view, while ngAfterContentChecked when this content is checked after its projection. Furthermore, ngAfterViewInit is relevant only to components and called after the initialization of component's and its child's views. The same with ngAfterViewChecked method which is executed after the views are checked by Angular. Finally, ngOnDestroy is the method that clears up any data remained in directives or components before they are removed.(*Angular Official Website*)

It is not obligatory hooks to be implemented in a class, but it is considered as a good practice. Performance can be increased and actions in particular moments can be executed. (Murray et al., 2018)

4.6 Two or one-way data binding

Two-way data binding is an architecture in which information flows from state to view and vice versa. In Angular JS, the default data flow is the two-way binding, or MVW as noticed in 2, which means that when model is modified, view is also changed and the other way around. (Murray et al., 2018) This type of binding is easy to start with and is also suitable for totally interactive user interfaces since data are changed by two different directions. (*Microsoft Official Website*)

On the other hand, two direction data binding is possible to cause a flow of unpredictable updates and a difficulty to follow data flow as application goes bigger. Moreover, another problem with this architectural approach is that it binds data flow with DOM tree. For these reasons, new released Angular is flexible to change between one or two-way data structure if it is needed. As described in Chapter 2, two-direction binding pass data down via components and event handlers needed to reflect state based on view layer's changes. For adapting one-way structure, Angular can use either Observables-based, such as Reactive Extensions Library for JavaScript (RxJS), or Flux-based architecture, such as Redux. When using Observables as main data architecture in Angular, it is named Reacting Programming which is a way to use asynchronous data streams. (Murray et al., 2018)

4.7 Summery

Angular is a framework that includes most of libraries and functionalities needed to built a client-side application. Moreover, it is well combined with TypeScript language and is widely used by both individual developers and companies. In this chapter, was covered the definition and main functionality of Angular.

Chapter 5

Comparison

5.1 Architectural Differences

5.1.1 Framework & Library

5.1.2 Real & Virtual DOM

5.1.3 Templates: HTML & JSX

5.1.4 TypeScript & JS

5.1.5 Components

5.1.6 State Management

5.1.7 Data Binding

5.2 React Native & IONIC

5.3 Testing

5.4 Learning Curve

5.5 Performance

5.6 Popularity

5.7 Popularity and future

My search in google trends
My search in npm trends (https://www.npmtrends.com/react-vs-@angular/cli)

5.7.1 What are companies using?

5.8 Conclusion

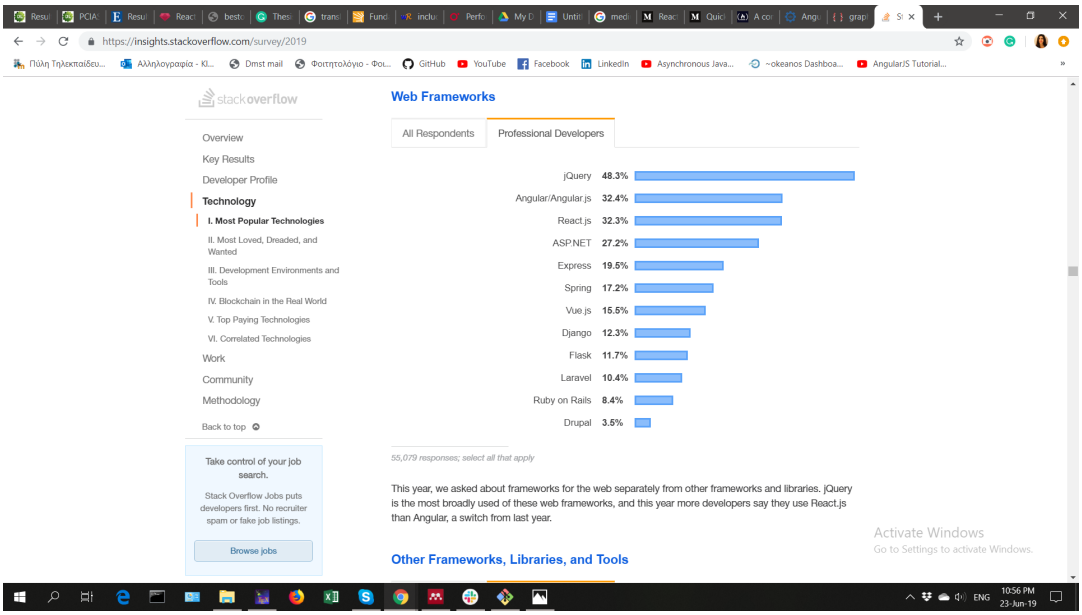
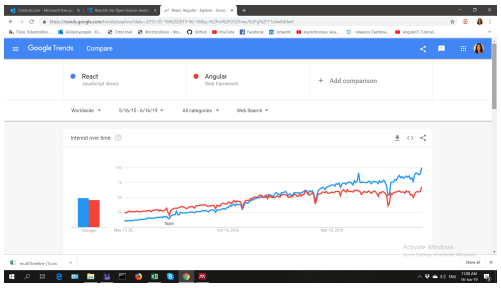
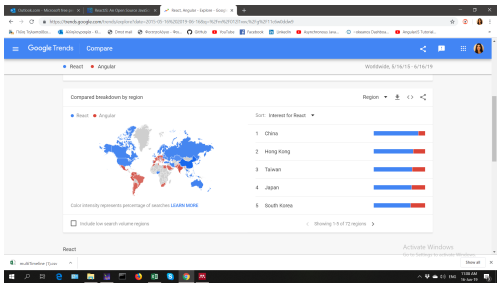


FIGURE 5.1: ReactJS-VS-Angular-Survey-Stackoverflow



(A) Trends during 16/06/2015-2019



(B) Countries' preferences

FIGURE 5.2: ReactJS VS Angular in Google Trends

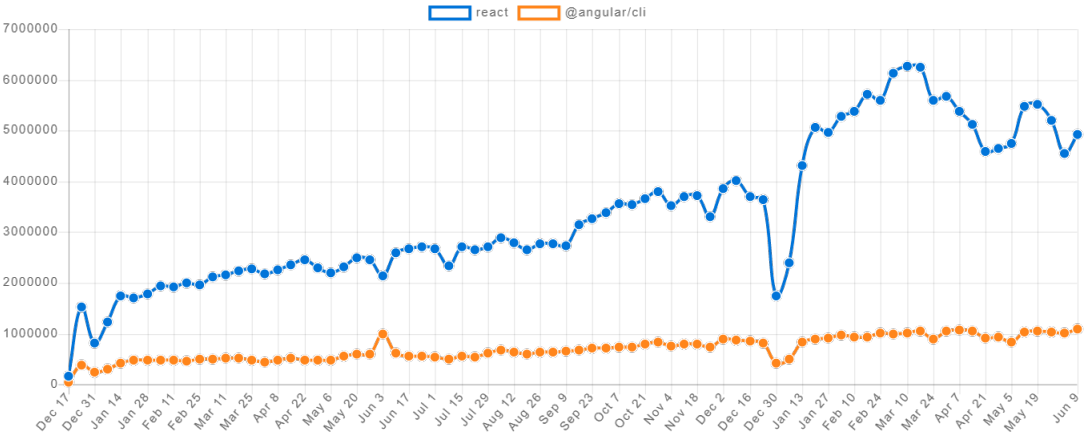


FIGURE 5.3: npm-trends-react-vs-angular

Chapter 6

Conclusion

6.1 Future Work

References

Abramov, Dan and the Redux documentation authors. *Redux Official Website*. URL: https://redux.js.org/.

Accomazzo, Anthony et al. (2016). *Fullstack React*. URL: https://www.fullstackreact.com/.

Cemus, Karel et al. (Oct. 2015). "Enterprise Information Systems : Comparison of Aspect-driven and MVC-like Approaches". In: *Proceedings of the 2015 Conference on research in adaptive and convergent systems (RACS). ACM*, pp. 330–336. URL: https://dl.acm.org/citation.cfm?doid=2811411.2811477.

Chen, Xuebin and Shufen Zhang (Apr. 2013). "Experiment teaching management system based on three-layer architecture". In: *8th International Conference on Computer Science and Education Computer Science and Education (ICCSE)*, pp. 1298–1302. URL: http://eds.a.ebscohost.com/eds/detail/detail?vid=0&sid=1e19995b-4b66-4809-a426-e0a4ac683f32%40sessionmgr4008&bdata=JnNpdGU9ZWRzLWxpdmU%3d#AN=edseee.6554122&db=edseee.

Gallaugher, John M. and Suresh C. Rarnanathan (1996). "Choosing a client/server architecture: A comparison of Two-and Three-Tier systems". In: *Information Systems Management* 13, pp. 7–13. URL: http://eds.a.ebscohost.com/eds/detail/detail?vid=1&sid=64174bb1-2f01-4844-b4a0-8eb1916d5792%40sessionmgr4008&bdata=JnNpdGU9ZWRzLWxpdmU%3d#AN=edselc.2-52.0-0642312740&db=edselc.

Geary, David (July 2016). *Introducing Redux*. URL: https://developer.ibm.com/tutorials/wa-manage-state-with-redux-p1-david-geary/.

Google. *Angular Official Website*. URL: https://angular.io/.

Kulesza, Raoni et al. (Apr. 2018). "Evolution of software architectures: From Web 1.0 to Web 3.0 systems". In: *WebMedia 2018 - Proceedings of the 24th Brazilian Symposium on Multimedia and the Web*, pp. 11–13.

Mardan, Azat (2017). *React Quickly*. Manning. ISBN: 9781617293344. URL: http://reactquickly.co/.

Masiello, Eric and Jacob Friedmann (Jan. 2017). *Mastering React Native*. URL: https://www.packtpub.com/web-development/mastering-react-native.

Microsoft. *Microsoft Official Website*. URL: https://docs.microsoft.com/en-us/dotnet/framework/wpf/data/data-binding-overview.

— *TypeScript Official Website*. URL: https://www.typescriptlang.org/docs/handbook/decorators.html.

Murray, N. et al. (2018). *Ng-Book: The Complete Guide to Angular 5*. Fullstack.io. ISBN: 9780991344642. URL: https://books.google.gr/books?id=6_AqtAEACAAJ.

Naim, Naimul Islam (May 2017). "ReactJS : An Open Source JavaScript Library for Front-end Developement". In: URL: http://www.theseus.fi/handle/10024/130495.

Padmanaban, R. et al. (2018). "Computability evaluation of RESTful API using Primitive Recursive Function". In: *Journal of King Saud University - Computer and Information Sciences*. URL: https://doi.org/10.1016/j.jksuci.2018.11.014.

Pautasso, Cesare, Olaf Zimmermann, and Frank Leymann (2008). "RESTful Web Services vs . " Big " Web Services : Making the Right Architectural Decision Categories and Subject Descriptors". In: *Proceedings of the 17th international conference on World Wide Web*, pp. 805–814. URL: http://wwwconference.org/www2008/papers/pdf/p805-pautassoA.pdf.

Ramirez, Ariel Ortiz (July 2000). "Three-Tier Architecture". In: *Linux Journal*. URL: https://www.linuxjournal.com/article/3508.

Seshadri, Shyam (June 2018). *Angular: Up and Running*. O'Reilly Media. ISBN: 9781491999837. URL: https://learning.oreilly.com/library/view/angular-up-and/9781491999820.

Source, Facebook Open. *React Official Website*. URL: https://reactjs.org/.

Stefanov, Stoyan (July 2016). *React: Up and Running*. O'Reilly Media. URL: http://shop.oreilly.com/product/0636920042266.do.

Vaqqas, M. (Sept. 2014). "RESTful Web Services: A Tutorial". In: *Dr. Dobb's Journal*. URL: http://www.drdobbs.com/web-development/restful-web-services-a-tutorial/240169069.

Voutilainen, Jaakko (Dec. 2017). "Evaluation of Front-end JavaScript Frameworks for Master Data Management Application Development". In: *Metropolia University of Applied Sciences*, pp. 1–50. URL: https://www.theseus.fi/bitstream/handle/10024/138668/Voutilainen_Jaakko.pdf?sequence=1&isAllowed=y.