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Hes·SO GENÈVE
Haute Ecole Spécialisée
de Suisse occidentale

PocketHepia
A student card platform based on NFC

Bachelor Thesis presented by

Mr. Maxime Alexandre LOVINO

for the obtention of the Bachelor of Science HES-SO in

Ingénierie des Technologies de l'Information avec orientation en Logiciels et Systèmes Complexes

September 2018

Professor in charge of Bachelor Thesis
Prof. Mickaël Hoerdt

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printemps 2018
Session de bachelor

INGÉNIERIE DES TECHNOLOGIES DE L'INFORMATION
ORIENTATION – LOGICIEL

Carte d'étudiant virtuelle basée sur la technologie NFC

Descriptif :

Le standard NFC définit un ensemble de protocoles permettant une communication entre deux appareils électroniques à condition que les appareils soient très proches l'un de l'autre (de l'ordre du centimètre).

Le but de ce projet est de réaliser un système logiciel de gestion de de carte d'étudiant virtuelle basée sur la technologie NFC (Near Field Communication). Les usages possibles de cette application, mais non exhaustifs, seraient les suivants : porte-monnaie électronique, badge d'accès électronique aux salles d'un batiment, emprunts de livres à la bibliothèque d'une institution, etc.

Pour les utilisateurs de la carte, une application mobile sera réalisée sous Android. Pour la gestion des utilisateurs et des accès, une application web accessible basée sur l'environnement de développement web MEAN (Mongodb, Express, Angular Js et Nodejs) sera aussi réalisée. La partie matérielle du projet n'est pas prioritaire.

Travail demandé :

1. Etude des protocoles de la pile logicielle NFC
   (a) authentification, modes de fonctionnement, pile protocolaire depuis la couche MAC.
   (b) Implémentation sur la pile de développement Android

2. Architecture de l'application mobile et de l'application web
   (a) Les deux applications devront partager le même backend
   (b) L'application web devra comporter un mode « administrateur » permettant de gérer les différentes cartes NFC enregistrées sur le système.
   (c) On portera une attention particulière sur l'utilisabilité de l'interface (UX design) et la gestion des logs d'administration et d'accès aux bornes NFC gérées par le système.

3. Implémentation et développement
   (a) L'implémentation de l'application web devra utiliser l'environnement MEAN (Mongodb, Express, AngularJS et Node.js)
   (b) L'implémentation de l'application mobile devra utiliser l'environnement Android.
   (c) On portera une attention particulière aux tests et à la modularité du code.

Si le temps disponible le permet, une maquette avec un lecteur NFC connecté au service sera construite dans un but de démonstration du système.

Candidat :
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Filière d'études : ITI

Professeur(s) responsable(s) :
HOERDT Mickaël

En collaboration avec : **-**
Travail de bachelor soumis à une convention de stage en entreprise : **non**
Travail de bachelor soumis à un contrat de confidentialité : **non**

Timbre de la direction

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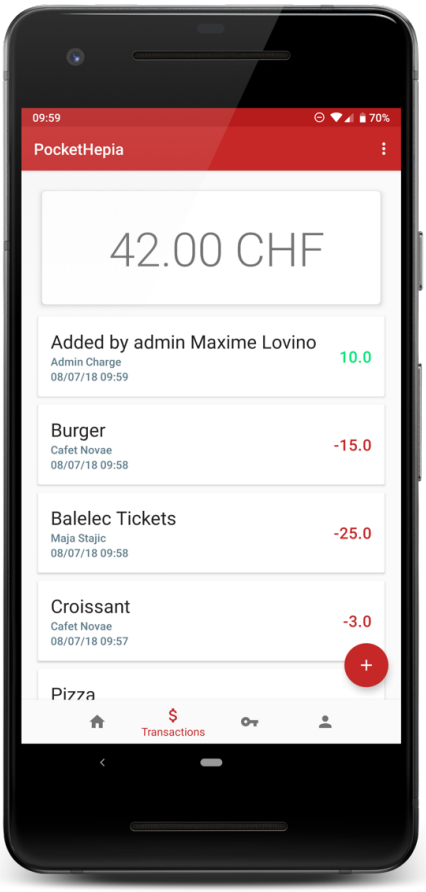
Session de bachelor

Résumé :

PocketHepia est un projet de plateforme de carte d'étudiant NFC pour l'hepia. Cette carte d'étudiant aura deux fonctionnalités initialement : la gestion des accès aux salles de cours et les paiements entre élèves ou à la cafétéria. Cette plateforme est accompagnée de deux clients, un client web et une application mobile, permettant aux étudiants d'avoir un accès en lectures à leurs dernières transactions ou leurs accès et aux administrateurs de gérer ces données.



Cette plateforme se veut extensible et a été spécifiée pour intégrer d'autres fonctionnalités, par exemple avec la bibliothèque, ou même s'intégrer à l'infrastructure d'authentification en place à l'hepia.

Le projet est construit autour d'un environnement de développement MEAN, avec une base de données MongoDB, un backend Node.JS+Express et un frontend web Angular. L'application mobile native a été développée sur Android pour bénéficier de l'accès à la puce NFC et a été construite avec les toutes dernières librairies Android permettant de simplifier et optimiser le développement sur cette plateforme.

Au niveau de l'infrastructure, le déploiement du projet a été mis en place avec des containers Docker et l'utilisation de Docker Compose pour orchestrer le déploiement des différents modules et la communication entre eux.

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et d'architecture de Genève

Spring 2018
Bachelor session

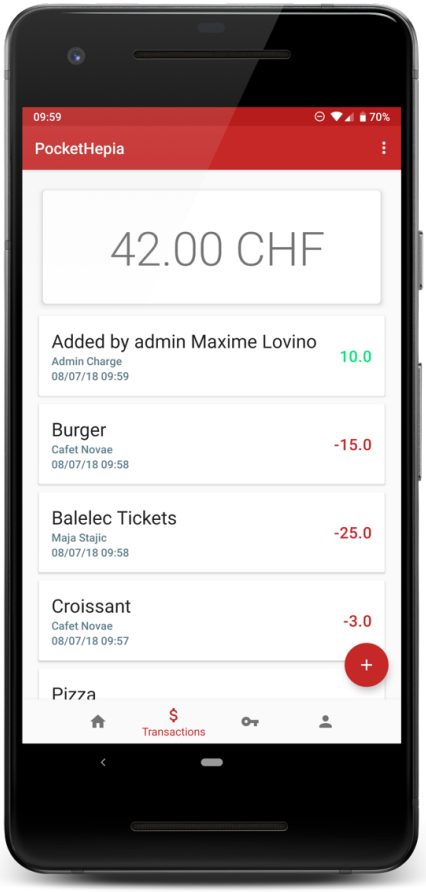
Abstract :

PocketHepia is a NFC student card platform for hepia. This student card will initially integrate two features: handling of accesses to classrooms and payments between students or at the canteen. This platform has two companion clients, a mobile application and a web client, that allow students to have read access to their payments and accesses and administrators to manage the students' data.

This platform is extensible and has been specified to integrate additional features, with the school library for example, or even hooking it to the existing authentication infrastructure at hepia.

The project is built around the MEAN development stack with a MongoDB database, a NodeJS+Express backend and an Angular web frontend. The mobile application has been built natively on Android to take advantage of platform-specific NFC features and takes full profit from the latest and greatest Android libraries designed to improve and simplify app development on Android.

On the infrastructure side of things, deployment is done using Docker containers and we are using Docker Compose to orchestrate the deployment of the individual module containers and handle communication between them.



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In collaboration with: ----------
Bachelor Thesis linked to a company internship: no
Confidential Bachelor Thesis : no

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Terms and Definitions

IDE est un acronyme pour Integrated Development Environment. Il s'agit d'un programme intégrant un éditeur de texte avec coloration syntaxique et autocomplétion du code pour un ou plusieurs langages de programmation ainsi que des fonctions de compilation, débogage et tout autre fonctionnalité permettant de faciliter et fluidifier le travail du développeur.

JVM est un acronyme pour Java Virtual Machine. Il s'agit d'une machine virtuelle permettant d'executer un programme compilé en bytecode Java sur un ordinateur ou un terminal mobile. On parle de langage fonctionnant sur la JVM lorsque la compilation du langage produit du bytecode Java..

NFC est un acronyme pour Near Field Communication qui représente un ensemble de protocoles de communication permettant de communiquer à des distances de quelques centimètres en utilisant l'induction électromagnétique.

Chapter 1

Introduction

Since starting my studies at hepia almost three years ago after two years at EPFL, I've been shocked by the lack of commodities and study spaces for students. Some of this lack is due to the difference in scale between the two schools, one of them being composed of mainly three building in a constrained city environment and the other an almost-autonomous campus outside the city. But, actually, there isn't really a lack of space at hepia, but a lack of space that students can use to study. Most of the classrooms are locked when not in use by a teacher. When asking about why that is the case, I've been told that it was mainly for security concerns because of the equipment present inside the rooms. If the rooms stayed unlocked, there was no way of knowing who stole or broke something. I suggested the idea of giving access to select students to these classrooms to study and work on projects but it wasn't practical because copies of keys had to be made, the students had to make a money deposit to make sure that they didn't run away with the keys etc.

One solution would have been to use our student cards as an electronic door key to access the rooms. We could also enable other uses for the cards, such as using them as electronic wallets to simplify the payments at the canteen during lunch break. When I suggested the idea, people mostly laughed at me and said "[...] they're never going to do it, unless someone actually does it, presents it as a finished product and then they decide to use it." So, here I am, after 3 years studying at hepia and for my Bachelor Project I decided to work on this exact idea. A multi-function student card platform built on NFC technology with accompanying mobile and web application for administrators to manage the platform and for students to monitor their usage statistics.

1.1 NFC and NDEF

1.1.1 Introduction to NFC

NFC (Near Field Communication) technology is a low range wireless communication technology based on electromagnetic induction. Its usages are

widespread, ranging from access control to contactless credit card payments and public transportation tickets. The range of a NFC communication is more or less 4cm. NFC can be implemented in a physical chip on a card, in a discrete reader or in a smartphone. Most Android smartphones and all iPhones after 2016 have a NFC chip.

There are three operating modes for NFC devices. A device is considered a *Full-NFC* device if it can operate in the three modes, but most of the NFC devices we interact with only support some of the modes:

- The "card emulation" model, also called passive mode enables a device to be used as NFC tag containing data similar to the ones present in physical NFC cards. This mode is the only one available on devices with no power, for example credit cards. This mode is called passive because it uses power from the active NFC reader to power it and enable access to its information. It can also be used on a smartphone to emulate a physical card. It is for example the mode used by mobile payments application such as Apple Pay and Google Pay. The NFC reader simply detects a standard NFC card, without knowing that is in fact emulated by a smartphone.
- The reader mode, also called active mode. This mode allows reading NFC tags data with a smartphone or a specific reader, for example in an electronic doorknob or a metro station gate.
- The peer-to-peer mode is used by two smartphones to exchange information between them. This mode is used on Android by the Android Beam service which allows to send pictures or other data between two Android devices by placing them back to back. In this case, the NFC peer-to-peer mode is used to initiate the connection and pair the device and then the data transfer is carried over Bluetooth or Wi-Fi Direct.

Figure 1: A NFC card reader on the London Underground (active mode) and a Oyster Transport Card (passive mode) [1]

1.1.2 NDEF Format

The NDEF (NFC Data Exchange Format) format is a standardised format used to encode data on NFC tags. By using a standard format, it allows for easier exchange of information between NFC devices. A NDEF message is composed of NDEF records. Each of these records contains metadata that provides information to help decode the data payload contained in the message.

The format of a NDEF record is the following[2]:

```
Bit 7     6       5       4       3       2       1       0
------  ------  ------  ------  ------  ------  ------  ------
[ MB ]  [ ME ]  [ CF ]  [ SR ]  [ IL ]  [        TNF          ]

[                         TYPE LENGTH                         ]

[                       PAYLOAD LENGTH                        ]

[                          ID LENGTH                          ]

[                         RECORD TYPE                         ]

[                              ID                             ]

[                           PAYLOAD                           ]
```

The first byte form the header of the NDEF record, the fields composed the header are:

- The `TNF` (Type Name Format) is a 3 bits value used to identify the record type. The most common are "Empty record" and "Well-Known-Record" to define a record for which the data type is defined by a RTD (Record Type Definition) in the NDEF format, for example plain text or URI.
- The `IL` (ID LENGTH field) is a boolean 1 bit value to tell if the `ID LENGTH` field is present or not in the record.
- The `SR` (Short Record Bit) is a boolean 1 bit value to tell if the `PAYLOAD LENGTH` has a size of 1 byte or less.
- The `CF` (Chunk flag) is a boolean 1 bit value to tell if the record is the first part or a chunk of a bigger record. The value will be 0 if it is the only part or the last chunk of a record.
- The `ME` (Message End) is a boolean 1 bit value to indicate that the record is the last of the NDEF message.
- The `MB` (Message Begin) is a boolean 1 bit value to indicate that the record is the first of the NDEF message.

1.1.2.1 Text payload

To give an example of a data payload contained in a NDEF record, we are going to take a closer look at a plain text payload.
The text payload format is defined like this[3] :

```
Bit 7     6       5       4       3       2       1       0
------  ------  ------  ------  ------  ------  ------  ------
[ ENC]  [RFU ]  [                IANA LENGTH                ]

[                        IANA LANGUAGE CODE                 ]

[                            TEXT                           ]
```

The first byte is called `Status Byte` and contains `ENC` which stores the value of the encoding used in the payload (0 for UTF-8, 1 for UTF-16) and `IANA LENGTH` which stores the length of the `IANA LANGUAGE CODE` field found afterwards. The `RFU` bit is always set to 0. In the `IANA LANGUAGE CODE` is stored the ISO/IANA language code specifying the language of the text stored in the payload as defined in RFC 3066[4], for example "en-US" for American English. The encoding of the language code is always ASCII. Finally we have the text whose length is the length of the payload minus 1 byte and the length of the language code field. The text can be decoded using the encoding specified in `ENC`

1.2 Project inspiration - Camipro EPFL

1.2.1 The card and the official core platform

The inspiration for this project mainly comes from my experience studying at EPFL. The EPFL student card, named Camipro[5], contains an RFID chip that allows to perform various tasks that simplify student life on campus. The use cases for the Camipro card are the following:

- Electronic wallet to pay at every canteen on campus as well as select third-party retailers (for example the Migros shop present on campus)
- Access key to unlock doors and buildings
- Card to collect documents sent to the centralised printing pool system at any printer on campus
- Rent public bicycles[1] on campus and in the Lausanne area
- Rent cars by linking a Mobility[2] subscription to the card

[1] All students have access to a free Publibike account on their card `https://www.publibike.ch/en/publibike/`

[2] `https://www.mobility.ch/en/`

- Borrow books at the library
- Use electric car chargers on campus
- Turn on booked electrical barbecues present on campus[3]

An accompanying web platform called MyCamipro was built as part of the Camipro launch to manage and activate the different services on the card as well as see the recent transactions and the rooms we were given access to.

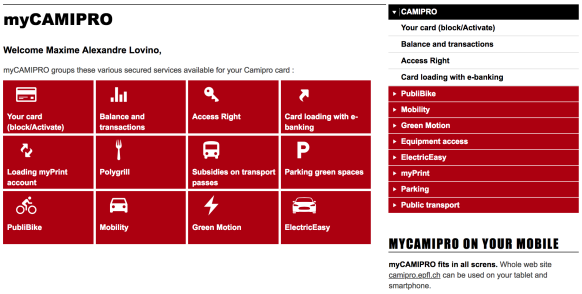

Figure 2: Screenshot of the MyCamipro website

1.2.2 PocketCampus

With the increased usage of smartphones by students, in 2010 a team of 20 computer science students decided to build the PocketCampus application as part of a software engineering class. They continued working on the project after the academic project was finished and it became the official EPFL application in 2013. [6].

Initially you could mainly see the balance of your Camipro card on the app, but version after version, the development team added new integration in the app by collaborating with different services at EPFL. These functions include:

- Accessing the menus of all canteens on campus
- Searching through the whole EPFL directory
- Having access to IS-Academia data to see course schedule and grades
- Printing from your smartphone on the EPFL print system
- Accessing Lausanne public transportation itineraries
- Accessing Moodle documents

[3]The service PolyGrill allows students to book free barbecues on campus and access them with their camipro `https://camipro.epfl.ch/cms/site/camipro/lang/en/polygrill_electric_barbecues`

After having integrated every requested features, the team launched a beta web version of PocketCampus for EPFL in June 2018. They also started diversifying their business by working on PocketCampus as a platform that can be integrated in other companies and stopped working exclusively with EPFL. They announced plans on partnering with Lausanne University (UNIL) to integrate their platform there.

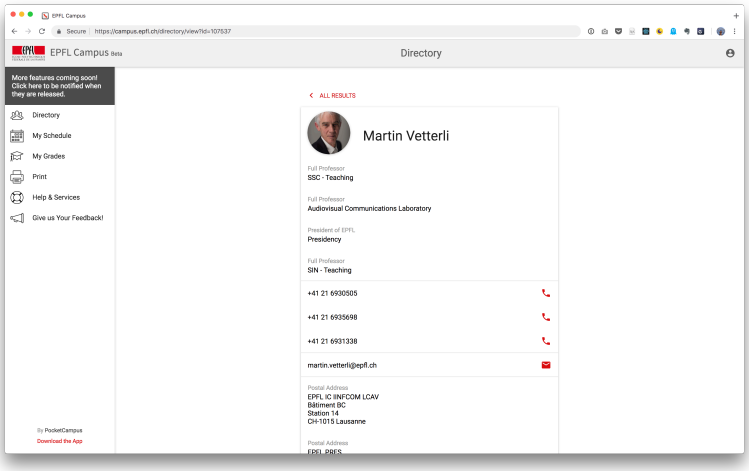

Figure 3: Screenshot of the web version of PocketCampus

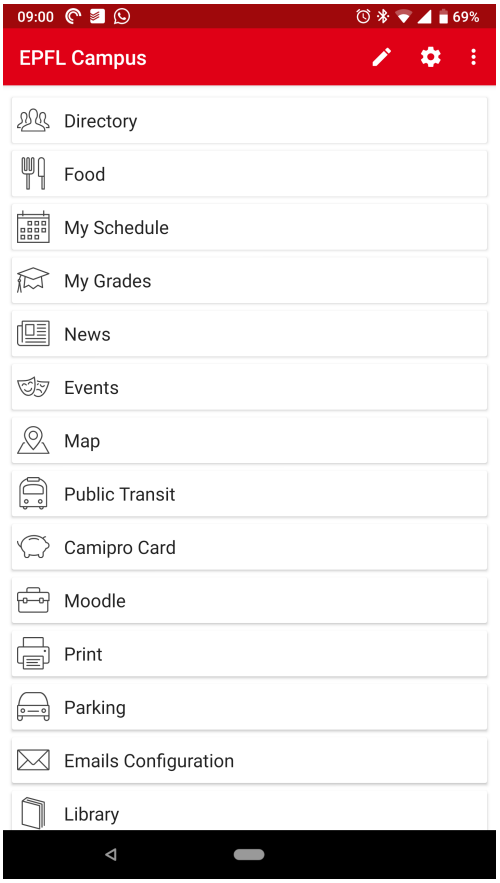

Figure 4: PocketCampus Android application

Chapter 2

The project

The project is called PocketHepia, reminiscent of the name of the project at EPFL and will consist of the two parts of the EPFL project presented earlier: the student card platform, as well as the applicative platform to access information.

The idea of this project is not to build as many features as the EPFL platform due to the time constraints inherent to the Bachelor Project, but rather to focus on some key aspects of the card at first, namely payments, access control and library. We are also building features on the payment side that are not available on the EPFL platform, for example the ability to send money between users. The project of course will be extensible with other features outside the scope of the Bachelor Project.

In this chapter, we will present the main features, roles and user stories for the project as specified at the beginning of this one. All of these are part of the project, but not necessarily part of the Bachelor Project. The idea was to specify the entire project and to start implementing a subset of the functionality for the academic project and continue working on the rest as well as new features outside this scope. Mainly we wanted to remain independent of other school services and infrastructure because of the associated time it would take to get permissions and setup integrations, as well as restrictions to development environments to secure access to these services. For each element of this chapter, we will specify whether it is going to be implemented as part of the Bachelor Project.

The project is composed of three main components:

- The physical student card
- An administration component
- An user facing component

A mobile application and a web application will be developed and both will offer the same user facing features as well as specific administrative features relevant to each application.

2.1 Features of the app

As stated before, we decided to limit the project to the three most important features in our opinion and, out of these, two are going to be implemented as part of the bachelor project.

2.1.1 Payments

The first feature is the electronic wallet functionality. We decided to start with this one because it would be bring the most benefits to the students and would not need specific hardware or collaboration with any school service. Every user has an electronic wallet linked to its account on the platform and can then send money to any other user by choosing the amount to send and tapping the user's card on his phone. Users can be assigned a specific role (see section 2.2) to allow them to receive money directly from a card.

There will be two main ways to add money to an user wallet. Either the user can give cash money to a person with administrative role that will then add money to the user's balance. Or the user will be able to add money to its account by using its credit card on the web application.[1]

2.1.2 Accesses

To continue, the second element of the project is the handling of access control through the platform. This was the original pain point we noticed at hepia with the lack of an easy way to handle accesses to the available classrooms. We will be able to create different areas to group rooms inside them. For example, an area could be an entire floor or labs for a specific section of hepia.

As far as giving access to users, we can give access to a room from a given date and specify if needed an end date for the access. For example, we can setup access for a user until the end of the current semester. We also decided to introduce an optional time range during the day during which the given access is active, so we can for example allow a student to enter a room only between 8am and 7pm.

We also specified the ability to delegate the administration of an area to a user, so that access to rooms can be handled at a department or section level

[1] At the moment, the project is still in the development phase so no bank accounts have been linked to this project and you will be able to recharge your account only using a specific test credit card generated for development purposes

in the school for example (see section 2.2). This feature is planned but will not be implemented as part of the Bachelor Project.

2.1.3 Library books

Finally, the last feature of the project would be an integration with the library to be able to use the card as a library card. Our approach at first was to think about creating the book loans on our platform with the ISBN to identify the book and integrate with the REST API built for BibApp but it wouldn't have been very effective because the library already handles the loans through the NEBIS platform.

The correct way to handle this would be to link the library NEBIS identifier for every user with their account on our platform and then ask NEBIS for API Access to their platform to retrieve book loans for all users and display them on the mobile and web application. This would also benefit people working at the library as they would not need to change their current workflow to accommodate.

We don't have the time during the bachelor project to start a discussion with NEBIS to get access to the required information so this feature will have to be implemented later on.

2.2 Roles

We defined a set of roles for the users on the platform. First, every member of the platform is a simple user. This means that the person has an account on the platform, can login to the web and android application and has read access to its payments, its accesses and its other information and can send money to other users.

Then, there is the admin role that can be added to an user. This role enables the creation of users, attribution of roles, the consultation of administrative logs as well as the creation of access components (rooms, readers) and the attribution of accesses to users.

While these two roles would have been enough to handle all our features. We decided to specify roles specific to different components of the platform.

One of these roles is the "Accept payments" role. This is specific to a canteen or a shop that wants to handle payments using the student card. While every user can send money to another user from the mobile app by tapping the other user's card, this isn't very practical for a canteen or a shop where the transactions should go the other way around. So the shop creates the payment and taps the user's card to take money from it. At first, we wanted this feature

to be available to everyone but we thought about security concerns with this solution because a student could create a payment from the app and start tapping his phone on lost cards or even on people's pocket and if the card was detected it would "steal" their money. So by enabling this feature as a role, we could only allow trusted people, such as canteen's owners to receive payments in that way.

Furthermore, due to the introduction of GDPR recently, we created a specific role called "Auditor" to access sensitive logs concerning all users, mainly access logs and transaction history. Only a user with this role can view all transactions between users and access logs for every room.

Then, there are two roles that will not be implemented as part of the Bachelor project, the "Can invite" and "Area admin" role. The first is to allow specific users to create temporary accounts without needing to contact an administrator. A use case for this would be a teacher creating a temporary account for a visiting colleague from another school. The "Area admin" role consists of delegating the administration of the accesses for an area to an user. Similar to the concept of DNS zones delegation, an administrator could for example give this role to the ITI section dean to allow him to give access to the rooms present on his floor.

Finally, the last role is the "Librarian" role that as its name implies is attributed to users working for the library. This role enables the creation of books loans at the library for users. As stated in section 2.1.3, this role will certainly be removed completely because there is already a system in place to handle book loans at the library.

2.3 The models

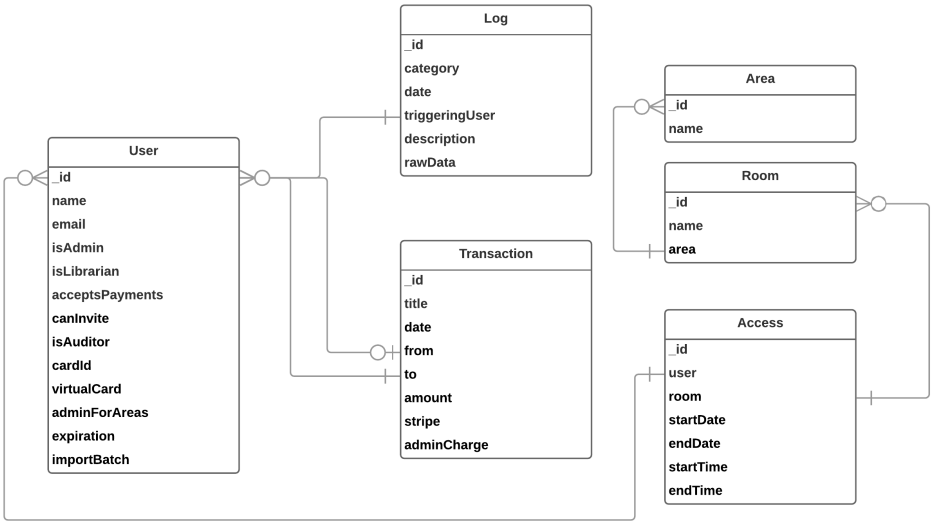

Figure 5: Entity Relationship Diagram of the models

2.3.1 User Accounts

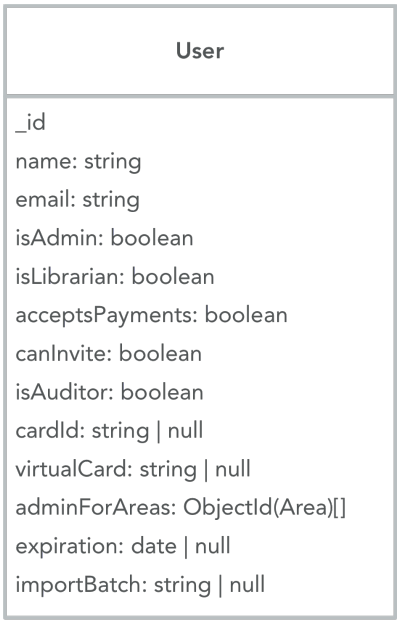

Figure 6: User Model

The first of our models is the User. A user collection is created to store all users on the platform. Users are identified by their email address and will login with their email and password, their full name is also stored. The authentication specific fields will be added to the model by Passport.JS (see section 2.5). A boolean field is also stored for each permission.

The expiration date, the virtual card and the delegation of admin zones are not implemented as part of this bachelor project.

Finally, the `importBatch` is set if the user is imported with a CSV file so that we can group all users imported together and undo the import if necessary.

2.3.1.1 Integration with existing AAI user accounts

If this project is put in production at hepia, we will have to only change this model to integrate it with an existing authentication service, such as AAI or with a directory LDAP service.

In that case, we would remove information already present in the authentication service such as name and email and just store the unique identifier from the authentication service in our model. This model would act as an augmented database on top of the existing service. We would then forward all login/password authentication request to the authentication service and would create the entry for the user in our database after the first login.

This is inspired by the way Nextcloud[2] for example stores user accounts that are linked to a directory service, for example an Active Directory. It stores the full Distinguished Name from the directory service as the unique identifier for the account to link the local account to the directory account.

While we could have asked Switch-AAI to integrate AAI authentication in our application, the time constraints of the project were too tight to launch a discussion and we wanted to stay independent of other services in this phase to avoid being slowed down by for example needing to run our servers on the hepia network exclusively to access the directory.

[2] `https://nextcloud.com/`

2.3.2 Payments

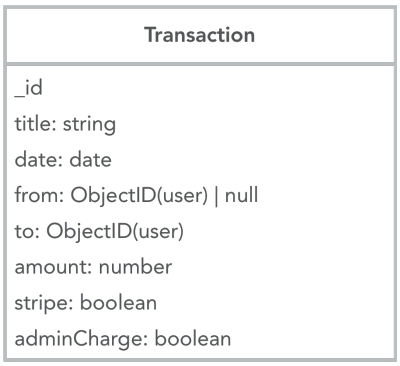

Figure 7: Transaction Model

To handle payments, we defined a Transaction model that represents a money transaction. We store the id of the `to` and `from` users instead of embedding the users document inside the transaction in order to avoid using too much space in the database. The number of transactions can grow very high and it is a waste of space to store two full user documents in each transaction[3]. Finally, we handle the two type of recharges for the user account by setting the `from` user to `null` because the money does not come from any user account and set the corresponding `stripe` or `adminCharge` field to true.

The balance of a user is calculated from the list of transactions in which the user takes part. It is calculated as the sum of the transactions in which the user is the beneficiary minus the sum of transactions in which he makes the payment.

2.3.3 Accesses

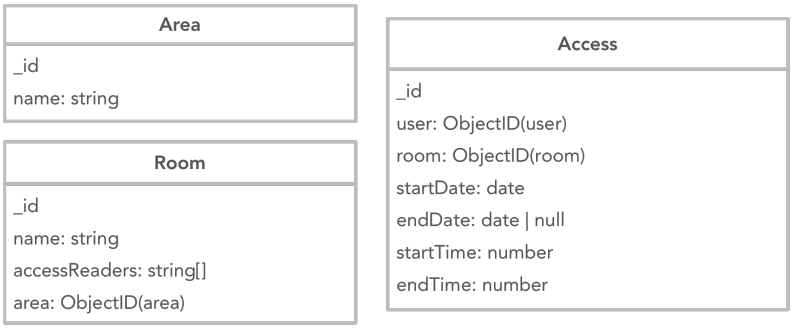

Figure 8: The three models handling accesses

[3]For more on that, see section 3.3.1.1 on Mongo References

The access part of PocketHepia is composed of three models. We defined Areas, Rooms and Accesses. An area contains multiple rooms and each room has a specific set of accesses. Similarly to the payments model, we reference from the child to the parent with the ID of the parent. The room has the id of the area it is part of, and the access stores the id of the user and the room.

When deleting an area, we delete all rooms contained in that area. When deleting a room, we delete all accesses associated with the room. This is done using Mongoose hooks (see section 3.3.2.3) to ensure that on every removal, we cascade it through the children.

2.3.3.1 Access requests

2.3.3.2 Access logs

2.3.4 Logs

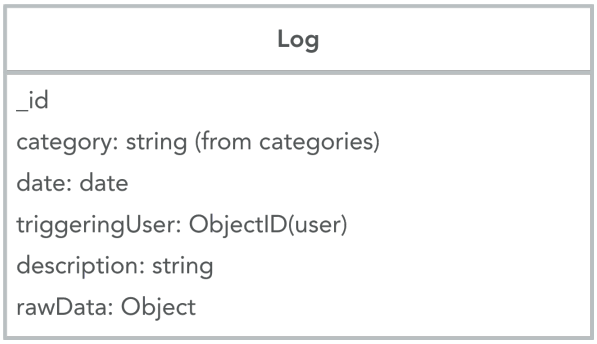

Figure 9: Log Model

Finally, we decided to log all administrative actions and make the logs visible to all admins on the website. Giving access to a room or creating a new account can be sensitive, so we have to keep an historic of those actions.

We defined a Log model to store the logs in the DB and several log categories to distinguish the different logs and filter them.
The log categories are:

- User creation
- User changes its password
- User deleted
- Admin imports users
- Admin cancels an import

- Admin assigns a NFC Tag
- Admin removes a NFC Tag
- Admin adds money to a user balance
- Admin resets a user password
- Admin changes a user permissions
- Admin creates an area
- Admin deletes an area
- Admin creates a room
- Admin deletes a room
- Admin gives an access
- Admin removes an access

As well as categories for features we will not implement yet:

- Admin delegates an area
- Admin removes an area delegation
- Admin completes an access request
- Admin deletes an access request

The category for a log entry is stored as a `string` and we setup validation on the model to ensure the `string` used corresponds to a category.

We also store an embedded object we call `rawData`, this allows us to store additional information specific to each category. For example for a permission change, we store the user before and after the changes.

Finally, the field `triggeringUser` stores the id of the user that did the action, we can then filter the logs to find out everything a specific person did.

2.4 User stories

From the beginning, we wrote simple user stories as a roadmap for the project features we wanted to implement. All of these features are not part of this academic project but are part of the broader student card project.

User story name	**Priority**	**Status as of July 11th 2018**
User must be able to login using username and password (then using JWT to communicate with backend)	1 - Essential	Done
Admin can create users from the website	1 - Essential	Done
User can view its total balance and a summary of its information on the homepage (web and application)	2 - Important	Done
User can view all its transactions on the transactions page (web and application)	2 - Important	Done
User can view its total balance on the transactions page (web and application)	2 - Important	Done
User can view all its accesses to rooms on the access page (web and application)	2 - Important	Done
Admin can delete users from the website	2 - Important	Done
Admin can reset password for all users from the website	2 - Important	Done
Admin can create users in batch by importing a CSV file	2 - Important	Done
Admin can create areas from the website	2 - Important	Done
Admin can create rooms from the website	2 - Important	Done

User story name	**Priority**	**Status as of July 11th 2018**
Admin can give access to a room for a user from the website (start/end date and timerange)	2 - Important	Done
Admin can remove an access from the website	2 - Important	Done
Admin can view all accesses for a user	2 - Important	Done
Admin can view all accesses for a room	2 - Important	Done
Admin can assign a physical card to a user from the Android app	2 - Important	Done
Admin can remove a physical card for a user from the Android app	2 - Important	Done
Admin can view all administrative logs from the website and filter them	2 - Important	Done
All administrative actions should be logged	2 - Important	In progress (all implemented actions are logged)
User having the "Accept Payment" permission can create a payment from the Android app and scan a user card to validate the payment	2 - Important	Done
User can change its password	3 - Normal	Done
User can send money to another user from the Android app	3 - Normal	Done
Admin can undo a user batch import	3 - Normal	Done

User story name	**Priority**	**Status as of July 11th 2018**
Admin can delete areas from the website	3 - Normal	Done
Admin can delete rooms from the website	3 - Normal	Done
Admin can change permissions of users from the website	3 - Normal	Done
Admin can add money to a user account	3 - Normal	Done
User can view all its borrowed books on the books page	4- Nice to have	Not started
All accesses should be logged	4- Nice to have	Not started
User can add money to its account using its credit card (using Stripe)	4- Nice to have	Frontend in progress
User can create a virtual card from the application and use it	4- Nice to have	Placeholder and navigation on Android only
User can request access to a room from the website	4- Nice to have	Not started
Admin can delegate admin rights for an area to a user	4- Nice to have	Not started
Admin can view and mark as done room access requests	4- Nice to have	Not started
Auditor should be able to view access logs	4- Nice to have	Not started
Auditor should be able to view all payments logs	4- Nice to have	Not started

User story name	**Priority**	**Status as of July 11th 2018**
User having the "can invite" permission can create a temporary user from the Android app and the website	4- Nice to have	Not started
User having admin rights for an area can give access to an user to a room in that area (start/end date and start/end hour)	4- Nice to have	Not started
User having admin rights for an area can view and mark as done room access requests for that area	4- Nice to have	Not started
Onboarding setup process in web frontend to create first user when no users exists in the DB	4- Nice to have	Not started
Ability to connect to LDAP (Active Directory for example) for users and authentication	4- Nice to have	Not started
Librarian can create a loan for a book for a user from the Android app	5 - Not relevant	Removed
Librarian can view current bookings for all users from the website and Android app and mark the borrowing as Complete (all history on website)	5 - Not relevant	Removed

Table 2.1: User stories

2.5 Technological choices

2.5.1 The data and backend

For the data and backend part of the project, we decided to build a unique backend for both the web and mobile clients. We would need a database to store the data of our models and a service to access to access that data. The easier solution would be to build a REST API in front of a database. To do this, we saw two main possibilities: a PHP REST API coupled with a SQL Database or a Node.JS Express REST API coupled with a Mongo DB. While we could mix these and use a SQL Database with Node.JS, we wanted to use the better affinity possible between the two. With the increase in popularity in Javascript based backends, we decided to rule out the PHP option and keep the Express/Mongo option. This is also due to the fact that PHP feels dated and does not provide a clear structure unless you use a PHP Framework to complement it.

The second solution that was suggested was to use an object syncing platform to directly synchronise data with all of our clients. One of these platforms is *Realm Platform*[4] and we decided to study the advantages of it for our project and decide if we should use it over the Express/Mongo option.

2.5.1.1 Realm vs. Express-MongoDB

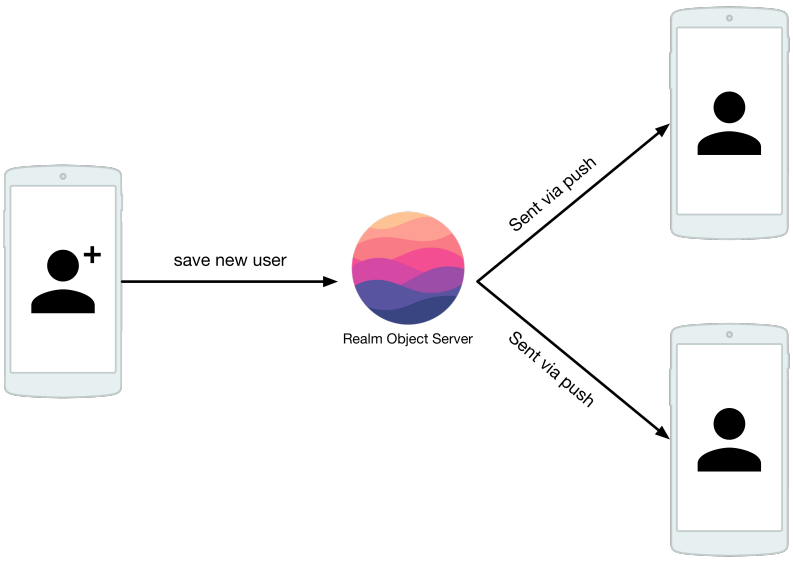

Figure 10: Saving an object in Realm

[4] `https://realm.io/products/realm-platform`

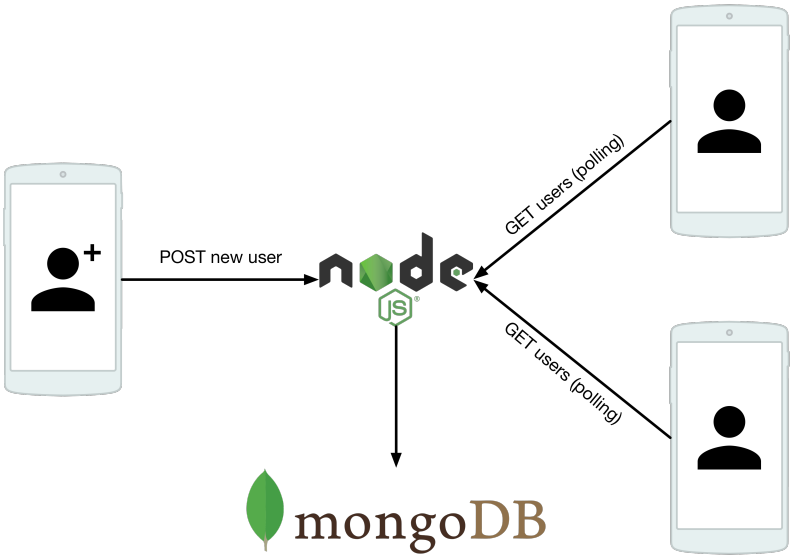

Figure 11: Saving an object in Express/Mongo

The Realm platform integrates the database directly within an object server that takes care of providing access and sending data to all the clients connected to it. This is possible thanks to the Realm runtime that you need to integrate in your client-side application and will replicate the database server on your local client.

On the contrary, using the Express/Mongo approach, we have the Mongo database and we built a REST API in front of it to provide access to the data. We do not need any particular runtime on the client-side and we can just handle data how we want.

As we can see in figures 10 and 11, when we create a new object on a client in Realm and save it locally, it is directly sent to the server and then pushed to other devices without needing any action. On the Express/Mongo side, you save the new object to the server and then other clients can retrieve it.

2.5.1.1.1 Advantages of Realm The advantages of Realm apply mainly on the mobile front. Realm is built to the ground up for the constrained resources and connectivity of mobile devices. It is offline first and will cache changes to be sent to the Realm server when the connection is back. Moreover, the push synchronisation of data back to the clients is the most efficient way to retrieve new data as opposed to polling data from a server at a regular interval.

2.5.1.1.2 Only for specific use cases The problem with Realm is that, beyond mobile, it is not very appropriate for our project. There are many pain points and small decisions that were taken by the Realm team that impose a way of doing things that may not be compatible with every project.

For example, one of these problems is the user authentication part and the user collection. In Realm, a user is not an object like others. It is a special object that is also used to connect to the Realm engine to handle sync. So you are limited to using Realm authentication to use the platform. Moreover, there is no way for a user with admin rights to retrieve a list of users on the client-side. This data is not accessible, unless you use the Realm Studio GUI client.

Another point is that, since you directly interact with the database/object server on the client-side, the code can easily be changed to access other people's information unlike a REST API where access to the database is regulated by the API. To avoid this, Realm has a system of permissions that are assigned to saved objects, but you need to assign the permissions every time you create a new object. Admins do not have direct access to everything, so you also have to add a permission for every admin every time. We wouldn't even imagine trying to add multiple set of roles here, it would be too cumbersome to handle.

Finally, the final point that made us abandon Realm for this project is the lack of clear solution to use it on the web. You have two ways to access the data from a web client. Either activate the GraphQL integration and write GraphQL queries to interact with the data from the web frontend. Or use the Node.JS Realm runtime to connect to the object server and serve as an API to access the data. So, even if we used Realm, we would still need to write an API. We're better off just going with the Express/Mongo option in that case.

It is a shame because the product provide real advantages on mobile that would take time to implement with a custom data solution, but it just isn't flexible enough and is really mobile-first while the web seems a bit like an after-thought for them. Even in their marketing material, they only present mobile-only applications such as chat or photo-sharing applications.

2.5.2 Mobile application

We needed to create a mobile client to access the information and status of a users' data from a smartphone as well as complete some administrative tasks.

We decided to build an Android application as well as coding the website to be responsive so it can be used on any smartphone. For the standard user, the mobile application is the one to use as it will provide access to all information, sync data offline and enable payments to other users. For the

administrators, the mobile application will allow them to manage physical cards for users and for the rest of the administration, they can use the website on their smartphone.

2.5.2.1 Why the need for an application?

While we could have achieved most of the functionality with a web application, there are still some elements that require building a full mobile application. Mainly, access to device features such as NFC. With a mobile web app, we cannot have access to the NFC chip on the smartphone and thus we cannot manage physical cards or make payments through the app. This is also the reason why we only built an Android app and not an iOS one. The API for NFC on iOS[7] is basic and was released in 2017, it does not allow writing on NFC tags[5] and only supported a subset of the formats of the Android API.

Apart from this limitation, all the other functionality could have been incorporated in a web application, for example by making a Progressive Web App (PWA). PWA are an hybrid between a mobile application and a web application and they run on desktop and mobile operating systems. Their main advantages compared to traditional web app is that they can be "installed" on the device and act like a normal application and that they generally store data offline and can sync data in the background through the user of Service Workers.

2.5.2.2 Why go native?

We could have also found a middle ground between the mobile web application and the native web application by using a mobile application framework such as Ionic or React Native to build our mobile application using web technologies. This would have allowed us to reuse some components built for the web in our mobile application.

We decided to opt out of that route and build our application using native Android technologies to better take advantages of the cutting-edge features announced during Google I/O 2018 [6] aiming to modernise and improve the Android development workflow (see section 3.1).

2.5.3 Web Frontend

Finally, we opted to use a frontend framework to provide a good structure to our client-side web application instead of relying on static custom HTML/CSS/JS.

[5] Unless you are a big company partnering directly with Apple

[6] Google I/O is the annual Google developer conference held in June for developers using Google technologies (Chrome, web, Android, iOS,...), `https://events.google.com/io/`

The three main frameworks available at the moment are Angular[7], React and Vue.

Vue is the youngest of the three and, while it is already growing a big community, its documentation is not as complete as the two others and its also growing rapidly which means that some of our code might become obsolete rapidly.

React and Angular are more mature, with Angular being the oldest of the three and are both baked by big companies: Facebook for React and Google for Angular. The biggest difference between the two is that React is Javascript-based and Angular is Typescript-based. We decided then to use Angular to take advantage of the typed nature of Typescript as well as to use Typescript for the first time in a project.

2.5.4 MEAN Stack

By using MongoDB with Express/Node.js and Angular, we are effectively using the *MEAN*[8][8] development stack which is regarded as the more modern equivalent to the *LAMP*[9][9] stack. The *MEAN* stack also has several variants where Angular is replaced by another frontend framework like React or Vue.

[7]There is a distinction to be made between AngularJS (Javascript) and Angular.io (Typescript). While both coexist, you should use Angular.io as it is the version that is developed going forward. In this document, we will be talking about Angular.io when mentioning Angular

[8]Stands for Mongo-Express-Angular-Node

[9]Stands for Linux-Apache-MySQL-PHP

Chapter 3

Technologies

3.1 Developing for Android

Android is a mobile operating system developed by Google and launched in September 2008. The core of Android is open source and is known as the *Android Open Source Program (AOSP)*. But nobody really knows or uses the AOSP version of Android, every phone manufacturer, even Google, forks the AOSP version to build its own for their devices. What is often referred as "pure Android" is the Google implementation of Android on their Nexus and Pixel lines of smartphones. Android runs on all kinds of platforms, from mobile phone to watches, as well as tablets and laptops.

A SDK and an IDE are provided for developing Android applications. Those applications are written mainly in Java, with the ability to write native code in C++ using the Android NDK[1] and interact with the Java code using JNI. The support for a second language named Kotlin was announced at Google I/O 2017 (see section 3.1.2). Applications run in a virtual environment on Android called ART. You can think of ART as the equivalent of the JVM for desktop Java development.

3.1.1 Android Fragmentation

One of the biggest problems for developers is the fragmentation of OS versions running on Android devices. As of May 2018, only 62.3% of devices were running Android Marshmallow (version 6) or later. Android Marshmallow was released in 2015, meaning that 37.7% of devices were running software that was more than 3 years old without security updates or new features (see table **??**).

[1] This is used for example to use some C++ libraries, like OpenCV.

Year	Version Name	Usage of this version	Usage of this version or later
2010	Gingerbread	0.3%	100.0%
2011	Ice Cream Sandwich	0.4%	99.7%
2012	Jelly Bean	4.3%	99.3%
2013	Kit Kat	10.3%	95.0%
2014	Lollipop	22.4%	84.7%
2015	Marshmallow	25.5%	62.3%
2016	Nougat	31.1%	36.8%
2017	Oreo	5.7%	5.7%

Table 3.1: Android OS Fragmentation (May 2018)[10]

3.1.1.1 The problem with updates

This problem is inherent to the very nature of the Android operating system. Each phone manufacturer, or OEM, can fork its own version of Android and integrate its own skin and set of apps on top of it. When a new version of the operating system is released by Google, they can't just start using it. They have to first adapt and test all their apps and customisation with the new version before it can ship to the devices. This is a time (and by extension money) consuming process and many OEMs just don't care about maintaining their devices for more than one or two years. To make matters worse, in certain countries, such as the United States, mobile carriers have to validate and apply their own custom apps and settings on top of the OS, adding to the time needed to validate an update and causing a supplementary potential roadblock to the release of an update.

3.1.1.2 What Google is doing about this?

Google has in the recent years taken different actions to ensure that most of the devices run safe and up-to-date software on them without depending on the OEMs willingness to maintain their products.

3.1.1.2.1 Updating core apps through the Play Store One of the most successful changes to Android in recent years has been to slowly move all Android core applications that are present on every Android device[2] to the Google Play Store. These apps include for example Gmail, Google Calendar, the browser (AOSP browser and Google Chrome) and even apps like the

[2]Actually, not every Android device. Some Asian markets, mainly China don't have access to these apps because they don't have access to any Google services. This is an edge case that won't be discussed in this document.

Phone Dialer and Contacts apps. This move to the Play Store allows Google to update these applications more frequently without needing a full operating system update. While it may be seen as a necessary evil at first, because it is the only way for them to update these apps if the OEM don't apply operating system updates, it is actually a very useful move because it allows for faster iteration on these applications and quicker response for bug fixes.

If we compare this to the other major mobile operating system, iOS, all main applications on the platform are bundled with the OS. So, if Apple needs to update the Safari browser to support a new web API they have to release a full OS version and push it to all their devices instead of just updating the application that needs an update as Google would do on Android.

3.1.1.2.2 Android Support Library

3.1.1.2.3 Project Treble

3.1.1.2.4 Security updates

3.1.2 Kotlin

As discussed in section 3.1, Kotlin has become a primary Android language in 2017. After having used this language for a first Android project last year, I decided to build all my subsequent Android application in Kotlin. The simplifications and reductions in code length provided by this language compared to Java make developing Android applications more enjoyable. It also helps avoid many runtime errors by catching many error-prone scenarios at compile time. In this section, we will go in further details in some of the advantages provided by Kotlin and how Google is encouraging developers to use Kotlin by introducing new Kotlin-specific features in the Android SDK.

3.1.2.1 Full interoperability with Java

First of all, the fact that Kotlin is fully compatible with Java and runs on the Java Virtual Machine (JVM) allows it to be easily integrated in an existing project or interact with existing Java libraries. You can just start writing classes in Kotlin and call existing Java classes from it and vice-versa. Then, when you want to convert Java code to Kotlin, Android Studio integrates a tool to convert a file to Kotlin almost perfectly. There are just some small changes to write afterwards, for example concerning the conversions of variables to constants. The IDE will even suggest converting Java code pasted inside a Kotlin file to the Kotlin version of the code.

3.1.2.2 Data classes

Java is often defined by its detractors as a very verbose language, requiring to write a lot of repetitive boilerplate code[3] for simple tasks. One of these tasks is the creation of classes with accessors and mutators for some of the class fields and overriding `equals` and `toString` methods. In Object Oriented Programming, we often have to write a lot of small classes just to match the Models in our applications. These are often referred as Beans or POJOs[4]. Kotlin introduces the concept of data classes[12] to simplify the implementation of these type of classes. By using a data class, you get "for free" an accessor (and mutator) for each field of the class, a correct overriding of the `equals` method, an overriding of the `toString` method listing the values of all fields in the instance and a `copy` method corresponding to a copy constructor in Java. For example, if we take a simple person class in Java:

```
1  class Person {
2    private String firstName;
3    private String lastName;
4    private int age;
5
6    public Person (String firstName, String lastName, int age) {
7      this.firstName = firstName;
8      this.lastName = lastName;
9      this.age = age;
10   }
11
12   public Person (Person other) {
13     this.firstName = other.firstName;
14     this.lastName = other.lastName;
15     this.age = other.age;
16   }
17
18
19   public String getFirstName () {
20     return this.firstName;
21   }
22
23   public String getLastName () {
24     return this.lastName;
25   }
26
27   public int getAge () {
```

[3] Boilerplate code or boilerplate refers to sections of code that have to be included in many places with little or no alteration[11]

[4] Plain Old Java Object

```
28      return this.age;
29    }
30
31    @Override
32    public boolean equals (Object o) {
33      if (this == o) return true;
34      if (o == null || getClass() != o.getClass()) return false;
35      Person person = (Person) o;
36      return age == person.age &&
        ↪  firstName.equals(person.firstName) &&
        ↪  lastName.equals(person.lastName);
37    }
38
39    @Override
40    public String toString () {
41      return "Person{" +
42          "firstName='" + firstName + '\'' +
43          ", lastName='" + lastName + '\'' +
44          ", age=" + age +
45          '}';
46    }
47  }
```

Listing 1: Person class implementation in Java

And then the same class written using data classes in Kotlin:

```
1  data class Person(val firstName: String, val lastName: String,
   ↪  val age: Int)
```

Listing 2: Person class implementation in Kotlin using Data Classes

3.1.2.3 Constants first

As in Java, you can define variables and constants in Kotlin but, in the later you will be more inclined to use constants because you can use them in more cases and the compiler suggests using constants when it detects that a variable is never assigned a new value. To use a constant, you use the keyword `val` instead of `var`.

One example of a case where you can use a constant in Kotlin but not in Java is when using blocks such as try/catch or control flow blocks. In Kotlin, these blocks return a value so you can assign the value returned by the block to a

constant. The value returned by a block is the last line of the block or the last line of the taken branch of a control flow block[13].

For example, let's say that we are parsing a `String` as an `Integer` and we want to check if the value is between a given range. When parsing, an Exception can be returned if the value is not a number, so we have to be aware of that.

In Kotlin, we can directly assign the value of the whole try/catch block to the constant:

```kotlin
fun main(args: Array<String>) {
    val ageInput = "Not a number string"

    // isAdult can be a constant,
    // without needing a initial temporary assignment
    val isAdult = try {
        val age = ageInput.toInt()
        when(age){
            in 18..99 -> true
            else -> false
        }
    }catch (exception: NumberFormatException){
        false
    }

    println(isAdult)
}
```

Listing 3: Assigning values returned by control blocks in Kotlin

However, in Java, we have to define a variable first and then we have to reassign it according to the branch we are in:

```java
public class ConstantsDemo {
  public static void main (String[] args) {
    String ageInput = "Not a number string";

    //isAdult can't be final
    boolean isAdult = false;

    try{
      final int age = Integer.valueOf(ageInput);
      if (age > 18 && age < 99){
        isAdult = true;
```

```
12        }
13      }catch (NumberFormatException e){
14        isAdult = false;
15      }
16
17      System.out.println(isAdult);
18    }
19  }
```

Listing 4: Assigning values with control blocks in Java

3.1.2.4 Class extensions

Another advantage of Kotlin is the ability to write class extensions[14]. This is useful to add methods to classes present in libraries for example and is used extensively as part of the Android KTX project (see section 3.1.4.1).

For example, if we are using the `ByteArray` class and we want to convert the value to a hexadecimal `String`, we can write a class extension method or property for the `ByteArray` class that we can then call on any instance of the class.
This is done in this way:

```
1  // This creates an extension method
2  fun ByteArray.toHex(): String {
3      val sb = StringBuilder()
4      this.forEach {
5          sb.append(String.format("%02x", it))
6      }
7      return sb.toString()
8  }
9
10 // This creates an extension method that we can read
11 val ByteArray.hexString: String
12     get() {
13         val sb = StringBuilder()
14         this.forEach {
15             sb.append(String.format("%02x", it))
16         }
17         return sb.toString()
18     }
```

And can then be called like any methods or properties:

```
fun main(args: Array<String>) {
    val bytes = byteArrayOf(202.toByte(), 254.toByte()) //This
    ↪ is 0xCAFE

    println(bytes.hexString) //Displays "cafe"
    println(bytes.toHex()) //Displays "cafe"
}
```

3.1.2.5 Null safety

In terms of safety, Kotlin introduces concepts already seen in other languages such as Scala or Swift but not present in Java, mainly around the handling of `null` values[15].

In Java, if a function returns a `String` or another `Object`, it can also return a `null` value and if we forget to check if the value is not `null` and try to access it, the program will throw a `NullPointerException` at runtime and it will certainly crash. Runtime errors are unexpected and can happen at anytime so they should be avoided at any cost.

In Kotlin, they introduce the concept of optional types, denoted by a `?`. This allows for compile time check of `null` values risks. First of all, a function that returns a `String` can't return a `null` value. To return a `null` value you specifically have to return an optional type, in this case a `String?`. This optional type can only be accessed after checking if it contains a non `null` value. After the check, it will be *smart-casted* as `String` in the corresponding code block. The program will not compile if an optional type is used without checking if it contains a value first which avoids the possibility of having `NullPointerException` at runtime[5]

For example, an usage of the optional types is a function that finds an element in a list and returns the index of the element in the list. If the element is not contained in the list, it will return a `null` value. The function should then return a `Int?` and this value can only be used after specifically checking that the value is not `null`:

```
fun findInList(list: List<String>, element: String): Int? {
    for ((index, value) in list.withIndex()) {
```

[5]This is valid for Kotlin code. When interacting with existing Java code, the Java code can use annotations `@Nullable` and `@NotNull` to mimic optional types but they are not required annotations so you can still run into problems depending on the Java library. An error could also happen if we bypass the `null` safety check by using the *not-null assertion operator*, see paragraph 3.1.2.5.1

```
3           if (value == element) {
4               return index
5           }
6       }
7       return null
8   }
9
10
11  fun main(args: Array<String>) {
12      val list = listOf("never", "gonna", "give", "you", "up")
13
14      val index = findInList(list, "never") //index is an Int?
15
16      //println(list[index]) //This wouldn't compile because no
        ↪  check
17
18      if (index != null){
19          println(list[index]) // We have checked so here index
            ↪  is an Int
20      }else{
21          println("Not found")
22      }
23  }
```

3.1.2.5.1 Optionals-related operators Kotlin also introduces a number of specific operators to handle optional types:

- The *not-null assertion operator*: This operator is `!!` and is used to tell the compiler that we unwrap the value from an optional without checking if it contains a value first. This is the *living dangerously* operator.
- The *safe call operator*: This operator is `?` and can be used when trying to access members and methods for optional types instances. It will return an optional type as well, for example if we have a `user: User?` and we want to get its name, we can use `val name = user?.name` and this will return the name of the user if the user is not `null` and otherwise will return `null`.
- The *Elvis operator*: This operator is `?:` and is used to indicate a value to use if the value is `null`. For example, with the user's name before, `val name = user?.name ?: "Paul"`. The "Paul" name will be used if the expression returns a `null` value

3.1.3 NFC on Android

If an Android device contains a NFC chip, you can use the chip capabilities in an application. To do so, first of all, you have to add the request for permission to access it in the Android Manifest. The Manifest is the configuration file for the application from the OS point of view. It contains the listing of permissions, activities and other configuration. To use NFC, you have to add the line `<uses-permission android:name="android.permission.NFC" />`.

From there, you have two different possibilities that can also be combined. You can either register yourself to the OS to listen for any incoming NFC actions (touching a tag for example) no matter if your app is running or not. You can also intercept NFC actions when your app is in the foreground. In most cases, the latter solution is the one needed, unless you want your app to be launched when a specific NFC accessory is detected. The foreground method is called *Foreground dispatch*, it means we are filtering the intent that are received by our foreground Activity to include NFC related intents and passing them to the Activity.

3.1.3.1 Setting up *Foreground Dispatch*

You have to setup *Foreground Dispatch*[16] at the Activity level, preferably in the `fun onCreate(savedState: Bundle?)` method and then enable it and disable on resume and pause of the Activity respectively. If you need to use it in multiple activities, it is easier to setup a superclass Activity and extends all other Activities from it. We can then just override the `fun onNewIntent(intent: Intent)` in the specific Activity for which we need to handle NFC specifically. In the superclass Activity, we can just discard the received NFC intent.

As we can see in source code 5, we have to register all technologies and intent types that we need to filter and create a pendingIntent to be sent by it. We activate the filter when the Activity is resumed and disable it when it is destroyed. This is to avoid blocking all other apps after our application quits and avoid crashes as well because if a NFC action happens and our app gets it in the background, it will crash. When we get the NFC intent, we just log a message by default and discard the intent.

```
1 open class ForegroundDispatchedActivity : AppCompatActivity()
  ↪ {
2     private var nfcAdapter: NfcAdapter? = null
3     private var pendingIntent: PendingIntent? = null
4     private var intentFilters: Array<IntentFilter>? = null
5     private var techLists: Array<Array<String>>? = null
6
7     override fun onCreate(savedState: Bundle?) {
8         super.onCreate(savedState)
```

```
9           nfcAdapter = NfcAdapter.getDefaultAdapter(this)
10          /*
11          Create a generic PendingIntent that will be delivered
    ↪   to this activity. The NFC stack
12          will fill in the intent with the details of the
    ↪   discovered tag before delivering to
13          this activity.
14           */
15          pendingIntent = PendingIntent.getActivity(this, 0,
            ↪   Intent(this,
            ↪   this.javaClass).addFlags(Intent.FLAG_ACTIVITY_SINGLE_TOP),
            ↪   0)
16          // Setup an intent filter for all MIME based
            ↪   dispatches
17
18          val intentFilterNDEF =
            ↪   IntentFilter(NfcAdapter.ACTION_NDEF_DISCOVERED)
19          try {
20              intentFilterNDEF.addDataType("text/plain")
21          } catch (e: IntentFilter.MalformedMimeTypeException) {
22              Log.w(this::class.java.name, "Failed to build
                ↪   intent filter")
23          }
24
25          val intentFilterTech =
            ↪   IntentFilter(NfcAdapter.ACTION_TECH_DISCOVERED)
26          intentFilters = arrayOf(intentFilterNDEF,
            ↪   intentFilterTech,
            ↪   IntentFilter(NfcAdapter.ACTION_TAG_DISCOVERED))
27          /*
28          Here we put each one in its own subarray, because:
29          "Each of the tech-list sets is considered
    ↪   independently, and your activity is considered a match if
    ↪   any single tech-list set is a subset of the technologies
    ↪   that are returned by getTechList()."
30           */
31          //In our case, we're writing NDEF, so we need
            ↪   compatible tags
32          techLists = arrayOf(arrayOf(Ndef::class.java.name),
            ↪   arrayOf(NdefFormatable::class.java.name),
            ↪   arrayOf(NfcA::class.java.name))
33      }
34
35      override fun onResume() {
```

```
36          super.onResume()
37          nfcAdapter?.enableForegroundDispatch(this,
            ↪  pendingIntent, intentFilters, techLists)
38      }
39
40      override fun onNewIntent(intent: Intent) {
41          Log.i(this::class.java.name, "Tag discovered, ignoring
            ↪  because not NFC activity")
42      }
43
44      override fun onPause() {
45          super.onPause()
46          nfcAdapter?.disableForegroundDispatch(this)
47      }
48  }
```

Listing 5: Foreground Dispatched superclass Activity

3.1.3.2 Getting a Tag ID

Now, if we want to read a NFC Tag inside an Activity, we just need to override the `fun onNewIntent(intent: Intent)` method. For example, when assigning a Tag to a new `User`, we have to get the NFC Tag unique identifier and send it to our backend. To do that, we can use the following code:

```
1  override fun onNewIntent(intent: Intent) {
2    val tagID = intent.getByteArrayExtra(NfcAdapter.EXTRA_ID)
     ↪  //ByteArray
3    val hexTagID = tagID.toHex() //this converts ByteArray to
     ↪  hexa String
4    //send Hexadecimal tag ID to backend
5  }
```

Listing 6: Reading ID from NFC Tag

3.1.4 Android Jetpack

Android Jetpack is a set of tools and libraries designed to improve the quality of Android applications by providing guidelines and code to implement common behaviours. Initially launched as *Android Architecture Components* at Google I/O 2017, it has been renamed in 2018 and gained new features. The main goals of Android Jetpack are to accelerate development by providing adaptable common features, to help with tedious activities such as background work and

lifecycle management that require a lot of boilerplate code[11] and to improve the quality of applications by providing modern and robust core libraries.[17]. You do not have to use Android Jetpack libraries but they can be seen as a set of good practices and tools to help development.

3.1.4.1 Android KTX

Android KTX is a Kotlin-specific part of Android Jetpack. It provides Kotlin extensions for Android and Jetpack libraries to take advantage of Kotlin features and make code more concise[18]. It is composed of different modules, each related to a library or use case on Android. KTX is also open source and actively developed on GitHub[19]. You can contribute to it by creating new extensions or just suggesting them to the development team.

An example of Kotlin features used in KTX is the improvement to the usage of Lambdas and anonymous functions as well as the usage of these functions to avoid chaining calls.

For example, when replacing a fragment in a view, you can use a block with KTX in which you write the replacement operation and the block will begin and commit the transaction automatically:

```
1  //Without Android KTX
2  supportFragmentManager
3      .beginTransaction()
4      .replace(R.id.my_fragment_container, myFragment,
       ↪  FRAGMENT_TAG)
5      .commitAllowingStateLoss()
6
7  //With Android KTX
8  supportFragmentManager.transaction(allowStateLoss = true) {
9      replace(R.id.my_fragment_container, myFragment,
       ↪  FRAGMENT_TAG)
10 }
```

Similarly when working with a SQLite Database and writing a transaction, the KTX version will take care of catching the exception and cancelling the commit if an exception is raised:

```
1  //Without Android KTX
2  db.beginTransaction()
3  try {
4      // insert data
5      db.setTransactionSuccessful()
```

```
6  } finally {
7      db.endTransaction()
8  }
9
10 //With Android KTX
11 db.transaction {
12     // insert data
13 }
```

3.1.4.2 Room - Data persistence

There are three main ways to store persistent data in an Android application. First, you can use files, either user accessible files or files only available from the app code. Secondly, you can use `SharedPreferences` to store key/value pairs. And finally, you can use a database. Databases on Android are built on SQLite and have always been the best way to store data on Android. The problem though was that the code to write to use databases was too long and complex and you could easily run into errors due to the usage of bad practices or wrong SQL syntax for example. Moreover, you always had to parse the data returned from the database into models and vice-versa so it always felt like you had to do the work twice.

With Room[20], part of the Architecture section of Android Jetpack, the goal is to simplify the usage of SQLite databases by providing an abstraction layer on top of it. Used in conjunction with ViewModel and LiveData, it simplifies the handling and presentation of data on Android.

As seen in figure 12, the application interacts with the Room Database to get an instance of Data Access Objects (DAO) and retrieve Entities. All of these are generated by the library, we just have to provide simple ”configuration” classes and interfaces.

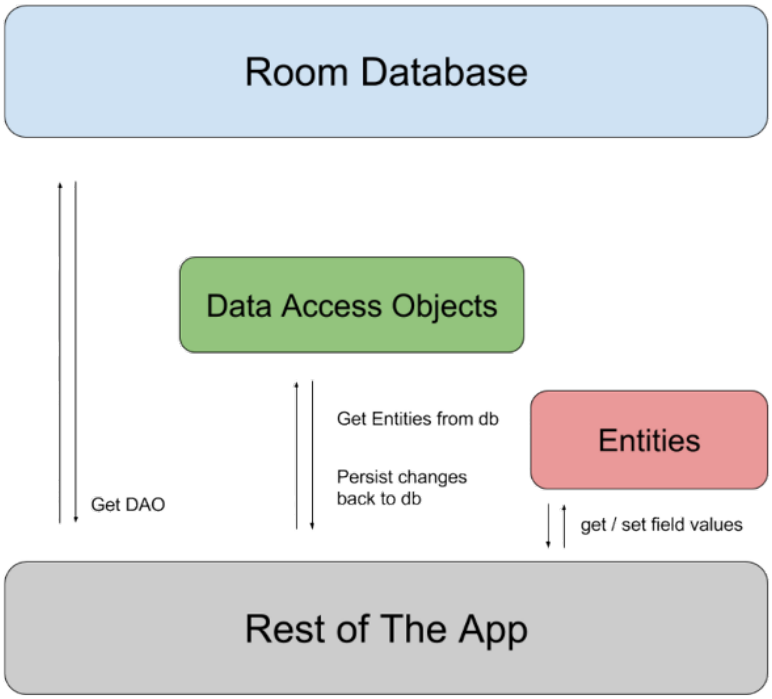

Figure 12: Room architecture[21]

The Entity[22] is the model that we are saving in the database. The advantage here is that we do not need to build a model and a separate table, we can just annotate our model with `@Entity` and other annotations to define the database table automatically.
For example, a `User` entity is just a data class in Kotlin:

```
1  import android.arch.persistence.room.Entity
2  import android.arch.persistence.room.PrimaryKey
3
4  @Entity
5  data class User(
6          @PrimaryKey val id: String,
7          val name: String,
8          val email: String,
9          val isAdmin: Boolean,
10         val cardId: String?,
11         val virtualCard: String?,
12         var balance: Double?,
13         val isLibrarian: Boolean,
14         val acceptsPayments: Boolean,
15         val canInvite: Boolean,
16         val isAuditor: Boolean
```

```
)
```

Then, we have to write a DAO[23] interface for the entity to create methods to interact with the entity in the database. There are methods automatically created for us, such as insertion and deletion of single entries. Queries returning elements from the database have to be written in SQL, but the IDE provides completion and there is compile time check of SQL syntax with table and column names. Finally, we can easily ask for returning LiveData for a query simply by specifying in the signature function.
For example, for the `User` DAO, we can just wrap all the return values from `SELECT` queries in `LiveData` and we will get them in that format:

```
import android.arch.lifecycle.LiveData
import android.arch.persistence.room.*
import ch.maximelovino.pockethepia.data.models.User


@Dao
interface UserDao {
    @Query("SELECT * FROM user")
    fun getAll(): LiveData<List<User>>

    @Query("SELECT * FROM user WHERE id LIKE :id")
    fun findById(id: String): LiveData<User>

    @Insert(onConflict = OnConflictStrategy.REPLACE)
    fun insert(vararg users: User)

    @Delete
    fun delete(user: User)

    @Query("DELETE FROM user")
    fun deleteAll()
}
```

Finally, you can then write the Database[24] class by providing an array of the entities and creating an abstract fun to retrieve each DAO. It is also suggested to make the Database class a Singleton[21]:

```
import android.arch.persistence.room.Database
import android.arch.persistence.room.Room
import android.arch.persistence.room.RoomDatabase
import android.content.Context
```

```
import ch.maximelovino.pockethepia.data.dao.UserDao
import ch.maximelovino.pockethepia.data.models.User


@Database(entities = arrayOf(User::class), version = 1)
abstract class AppDatabase : RoomDatabase() {
    abstract fun userDao(): UserDao

    companion object {
        private var db: AppDatabase? = null

        fun getInstance(context: Context): AppDatabase {
            return if (db != null) {
                db!!
            } else {
                db = Room.databaseBuilder(context,
                ↪  AppDatabase::class.java, "db").build()
                db!!
            }
        }
    }
}
```

3.1.4.2.1 ViewModel The ViewModel[25] bridges the gap between the data and the UI data in a lifecycle aware way. As opposed to storing data in variables in an Activity, data in a ViewModel will remain persistent when configuration changes, for example when rotating the screen.
It is suggested to also implement a Repository behind the ViewModel to abstract the source of the data, database or network for example. In the Repository, we can also write wrapper around insertion tasks to run them on separate threads because you can't run database operations on the main thread[6].
The user Repository and ViewModel look like this:

```
import android.arch.lifecycle.AndroidViewModel
import android.annotation.SuppressLint
import android.app.Application
import android.os.AsyncTask
import ch.maximelovino.pockethepia.data.AppDatabase
import ch.maximelovino.pockethepia.data.dao.UserDao
import ch.maximelovino.pockethepia.data.models.User
```

[6]Queries returning LiveData already run on a background thread, due to the LiveData returning value asynchronously

```
8
9  class UserRepository(application: Application) {
10     private val db: AppDatabase =
       ↪ AppDatabase.getInstance(application.applicationContext)
11     private val userDao = db.userDao()
12     val allUsers = userDao.getAll()
13
14     fun insert(user: User) {
15         InsertAsyncTask(userDao).execute(user)
16     }
17
18     inner class InsertAsyncTask(val dao: UserDao) :
       ↪ AsyncTask<User, Void, Unit>() {
19         override fun doInBackground(vararg users: User?) {
20             val user = users[0] ?: return
21             dao.insert(user)
22         }
23     }
24 }
25
26 class UserViewModel(application: Application) :
   ↪ AndroidViewModel(application) {
27     private val repository: UserRepository =
       ↪ UserRepository(application)
28     val users = this.repository.allUsers
29 }
```

3.1.4.2.2 LiveData LiveData[26] is an observable holder class that allows to react to data changes. The advantage of LiveData is that it is lifecycle aware, so you can observe the data by passing it an Activity or Fragment and will pause and resume accordingly when the Activity is paused or resumed. Otherwise, we could try refreshing the UI when the data changes and if the Activity is not in the foreground, the application would crash. LiveData allows us to always update our UI with the latest data, for example data from a Room Database.

You can just call the `observe` method on a LiveData instance and pass a lifecycle component, in this case a Fragment and an Observer callback to handle the data.

```
1 val user = userDao.findById(id)
2
```

```
//Here "this" is a fragment, activity or other lifecycle component
user.observe(this, Observer {
  //"it" is the data
  if (it != null) {
    //The user data changed
    //update view for example
  }
})
```

3.1.4.2.3 Putting everything together When putting everything together[27], we can see the interactions in figure 13 with the ViewModel providing LiveData to the Fragment or Activity that can update the UI by observing it. The `ViewModelProviders.of()` is used to retrieve the requested ViewModel from the system.

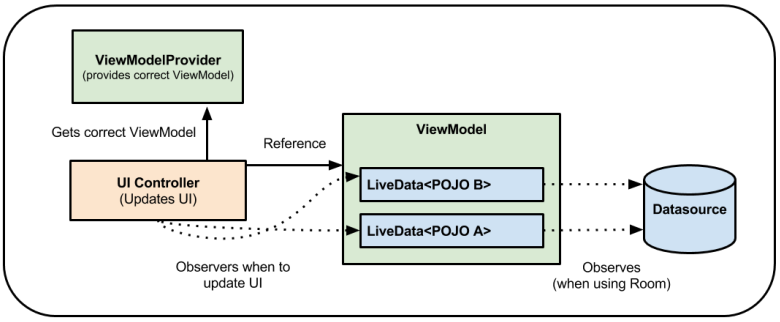

Figure 13: View model interactions[25]

If for example, we couple this with a RecyclerView and decide to get a list of all users from the database to display it, it gives us the following code:

```
override fun onCreateView(inflater: LayoutInflater, container: ViewGroup?, savedInstanceState: Bundle?): View? {
  // Inflate the layout for this fragment
  val view = inflater.inflate(R.layout.fragment_admin, container, false)

  viewAdapter = UserListAdapter(this.context!!)
  val viewManager = LinearLayoutManager(this.context!!)
  view.findViewById<RecyclerView>(R.id.users_recycler_view).apply {
    layoutManager = viewManager
```

```
9       adapter = viewAdapter
10    }
11
12    usersViewModel =
      ↪  ViewModelProviders.of(this).get(UserViewModel::class.java)
13
14    usersViewModel.users.observe(this, Observer {
15      if (it != null)
16        viewAdapter.setData(it)
17    })
18
19    handleFabDisplay()
20    return view
21  }
```

3.1.4.3 Work Manager - Background jobs

WorkManager[28] allows running background asynchronous tasks, for example downloading data from a backend. The advantage behind using WorkManager is that it will choose the correct implementation depending on the Android version it is running on and the available APIs. It will also adapt to the state of the app, running or not. Android has several background work mechanisms depending on the platform and WorkManager provides a way to avoid choosing one of them.

To use WorkManager, you have to create a class that extends the `Worker` class and implement the method `fun doWork(): Result`. This function returns a `Worker.Result` that can be either a success, a failure or a request to retry. You have access to the application context from this class, so you can save data to a database for example or access SharedPreferences.

For example, if we want to write a Worker to retrieve a `User` from the backend, we can do it this way[29]:

```
1   import android.util.Log
2   import androidx.work.Worker
3   import ch.maximelovino.pockethepia.PreferenceManager
4   import ch.maximelovino.pockethepia.data.AppDatabase
5   import ch.maximelovino.pockethepia.data.models.User
6
7
8   class SyncWorker : Worker() {
9
```

```
10      override fun doWork(): Result {
11
12          try {
13              val context = applicationContext
14        //If we don't get the current user or token, we can fail
15              val token =
                ↪  PreferenceManager.retrieveToken(context) ?:
                ↪  return Result.FAILURE
16              val currentUser = getCurrentUser(token) ?: return
                ↪  Result.FAILURE
17
18              val db = AppDatabase.getInstance(context)
19
20              val userDao = db.userDao()
21
22              userDao.insert(currentUser)
23
24              return Worker.Result.SUCCESS
25          } catch (e: Exception) {
26              Log.e("SYNC", e.toString())
27              return Worker.Result.FAILURE
28          }
29      }
30
31      private fun getCurrentUser(token: String): User? {
32          try {
33        val user: User = //..retrieve and parse user from server
34        return user
35          } catch (e: Exception) {
36              Log.e("SYNC", "Couldn't get current user because:
                ↪  ${e.message}")
37          }
38          return null
39      }
40  }
```

3.1.4.4 Navigation

Navigation inside an application has always been more complicated on Android than on iOS. For example, all Android devices have a ”back” button in the OS navigation bar at the bottom and the Android guidelines also define an ”up” button in the application toolbar that most applications implement. The ”up” button looks exactly like the ”back” button and most user think it

does exactly the same thing but that is not the case (see figure 14). The ”up” button should move to the hierarchical parent screen of the current screen, so let’s say that we are inside a messaging conversation, the ”up” button brings us back to the conversations list. Pressing the ”back” button brings us back to the screen that was used before arriving to the current screen. For example, if we were browsing the web and clicked on a notification that brought us to the messaging conversation, pressing ”back” brings us back to the web browser.

The problem here is that when deep linking in a screen directly, for example from a notification, we had to fill in ourselves in the backstack the hierarchical parents so that the ”up” button behaved correctly. Some apps do not implement this in the correct way and by default the ”up” button destroys the Activity or acts as a ”back” button. This does not guarantee an excepted behaviour of those buttons for the user.

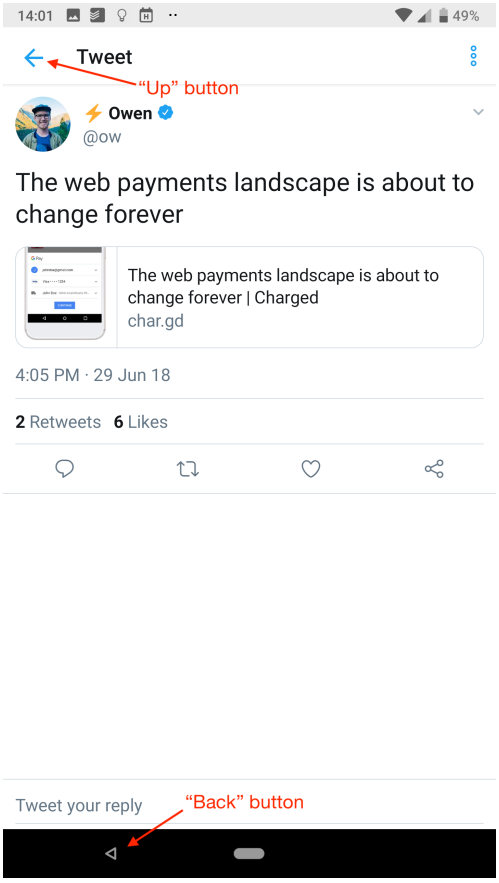

Figure 14: In the Twitter app, the ”up” and ”back” buttons have the correct behaviour, ”up” brings you back to your timeline and ”back” to the precedent screen

What Google aims to do with the new Navigation Architecture Component[30] is simplifying the life of developers and the implementation of complex navigations with clear hierarchy of screen and automatic handling of the backstack[31]. It also aims to move away from writing an Activity for every screen and instead handling navigation by switching Fragments inside the same Activity. It is introducing a new library to handle Navigation as well as a graphical editor to more easily setup relations between screens[7].

3.1.4.4.1 Visual editor As we can see in figure 15, we have a view of all our screens and the links between them. If a link exists between two screens, it means we can call the corresponding method to create a transition between the two screens and pass it to the Navigation Controller.

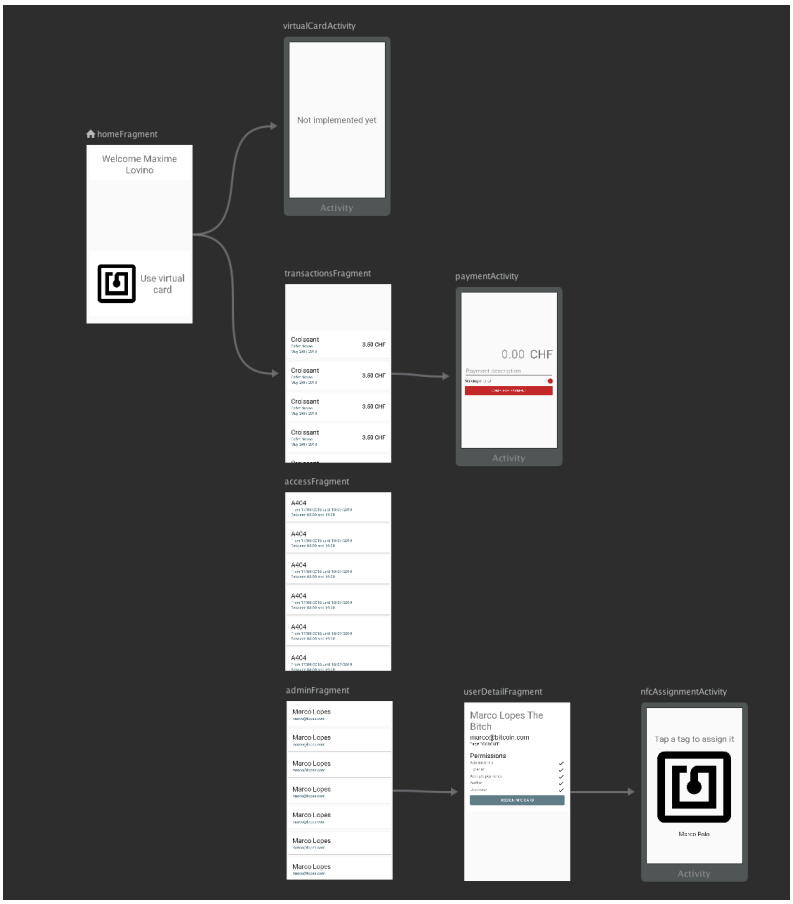

Figure 15: The new Navigation visual editor

[7]The graphical navigation editor is available as an experimental feature in Android Studio 3.2 (Beta at the time of this writing). You can use the navigation feature in XML as well

3.1.4.4.2 Integrating with Bottom Navigation View In most cases, what you want do is integrate the top level screens with a Navigation UI element, for example a Bottom Navigation View[32]. To do this, first of all you need to define the menu for the bottom navigation by specifying an ID for each entry in your Bottom Navigation menu (see source code 7). Then you have to create a Fragment in the layout of the Activity, link it to the Navigation XML file and specify that it is a `NavHostFragment` (see source code 8).

```
<menu xmlns:app="http://schemas.android.com/apk/res-auto"
xmlns:android="http://schemas.android.com/apk/res/android">
    <item
        android:id="@+id/homeFragment"
        android:icon="@drawable/ic_home_black_24dp"
        android:title="@string/title_home"
        app:showAsAction="ifRoom|withText" />

    <item
        android:id="@+id/transactionsFragment"
        android:icon="@drawable/money"
        android:title="@string/title_transactions"
        app:showAsAction="ifRoom|withText" />

    <item
        android:id="@+id/accessFragment"
        android:icon="@drawable/key"
        android:title="@string/title_access"
        app:showAsAction="ifRoom|withText" />
</menu>
```

Listing 7: Menu defining the bottom navigation

```
<FrameLayout
  android:layout_width="match_parent"
  android:layout_height="match_parent"
  app:layout_constraintLeft_toLeftOf="parent"
  app:layout_constraintTop_toTopOf="parent">

  <fragment
    android:id="@+id/nav_host_fragment"
    android:name="androidx.navigation.fragment.NavHostFragment"
    android:layout_width="match_parent"
    android:layout_height="match_parent"
    app:defaultNavHost="true"
```

```
13      app:navGraph="@navigation/nav_graph" />
14  </FrameLayout>
```

Listing 8: The container Fragment to define that will host the Navigation selected screen

Afterwards, when populating the Navigation using the visual editor, use the same ID used in the menu on the corresponding screen in the navigation. Finally, when created the Activity, you can find the Navigation Controller which, on Kotlin, integrates a method to directly link to the Bottom Navigation View. This will link active states on each button corresponding to the active screen and enable switching between the screens with the Bottom Navigation (see source code 9).

```
1  //Here "navigation" is the BottomNavigationView
2  //"nav_host_fragment" is the id of the container in our
   ↪  activity
3  val navController = findNavController(R.id.nav_host_fragment)
4  navigation.setupWithNavController(navController)
```

Listing 9: Linking Bottom Navigation View with Navigation Controller

3.1.4.4.3 Safe arguments Another pain point that the Navigation Controller solves is the passing of arguments between screens. Until now, if you wanted to pass arguments to another screen, you had to add them to the `Intent` bundle that you were starting or in the Fragment constructor. These were just key/value pairs and there was no verification that the arguments were correctly passed.

In the Navigation Controller, you can define input arguments for the screen. For example, a screen presenting the details for a `User` can take the ID of the `User` as a `String` argument. Then, if we want to navigate to that screen, we have to pass the corresponding argument otherwise the application will not compile. The arguments are type-checked as well.

When setting up a transition between two screens, you give it an ID (see figure 16) and then the library will generate a `<sourceScreenName>Directions` class that contains methods for each outgoing transitions available from the `sourceScreenName`. These methods take the required arguments as parameters and create a `NavDirection` instance that can be passed to the Navigation Controller.

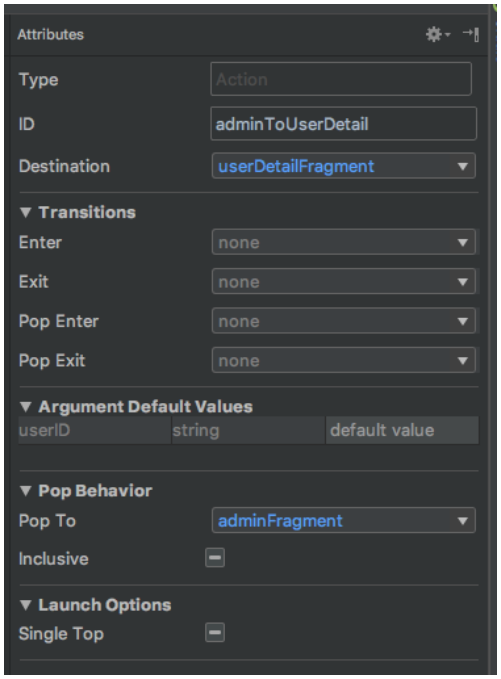

Figure 16: Setting up a transition between screens in Navigation Editor

For example, if we want to navigate from a users list (`AdminFragment`) to the user detail screen(`UserDetailFragment`), we can use the following code:

```
//"current" is the selected user
val directions =
↪  AdminFragmentDirections.adminToUserDetail(current.id)
view.findNavController().navigate(directions)
```

Listing 10: Navigating from a screen to another by passing arguments

Then in the destination screen, we can unwrap the passed arguments by using the generated `<destinationScreenName>Args` class like this:

```
//Here we can safely force unwrap because navigation provides
↪  compile check of argument presence
id = arguments?.let {
  UserDetailFragmentArgs.fromBundle(it).userID
}!!
```

Listing 11: Receiving input arguments when navigating

3.2 Angular 6

Angular[33] is a web application frontend framework. It is opne source and developed actively on GitHub[34] by the Angular team at Google and other individual contributors. Angular 1 was originally built in JavaScript (now AngularJS) and has now been replaced since version 2 by a new version of Angular (commonly called Angular 2, even though version 6 is out) built in TypeScript.

The main advantages of using a frontend framework are modularity and a clear code structure compared to not using any frameworks.

Angular provides a CLI tool called *Angular CLI* and used with the `ng` command that helps initialising and updating projects. The CLI also handles code generation, for example when creating a component, it will create all required files and register the component in the application module, more on that later. All Angular CLI commands should be run from the root directory of the Angular project.

Angular projects are usually installed and run through NPM, although Yarn can be used as well.

3.2.1 Single-page webapp

Angular is used to build web applications, as opposed to websites. While for most users the differences between these two are not noticeable, web applications behave more like native applications and allow interactions from the user.

Often, web applications are single-page applications. That does not mean that the application only has a single screen but it means that you only need to load one page and then all other navigation is handled by the page itself.
In the case of Angular web applications, you only have one entry point page and then the internal Angular Router in the web application will take care of the rest, without needing to load new pages or refresh the browser.

3.2.2 Architecture of an Angular Application

An Angular application is built around Modules (called *NgModules*)[35] that contain Components and Services. Each application has at least one root Module, called the AppModule. You can create additional Modules to group related Services and Components together and then import these Modules inside the AppModule.

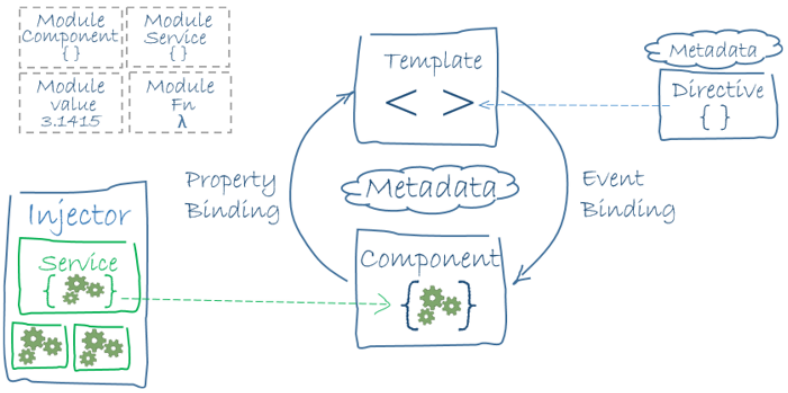

Figure 17: Architecture of an Angular application[36]

3.2.2.1 Folder structure

When initiating a new project with the Angular CLI, it will setup the default folder structure and a set of initial files to work with.
To create a new "demo" project, you can use the following command:

```
ng new demo
```

Listing 12: Command to create a new Angular project

And it will present you with this starting architecture:

```
demo
├── README.md
├── angular.json
├── e2e
│   ├── protractor.conf.js
│   ├── src
│   │   ├── app.e2e-spec.ts
│   │   └── app.po.ts
│   └── tsconfig.e2e.json
├── node_modules/
├── package-lock.json
├── package.json
└── src
    ├── app
    │   ├── app.component.css
    │   ├── app.component.html
    │   ├── app.component.spec.ts
    │   ├── app.component.ts
    │   └── app.module.ts
    └── assets
```

```
    ├── browserslist
    ├── environments
    │   ├── environment.prod.ts
    │   └── environment.ts
    ├── favicon.ico
    ├── index.html
    ├── karma.conf.js
    ├── main.ts
    ├── polyfills.ts
    ├── styles.css
    ├── test.ts
    ├── tsconfig.app.json
    ├── tsconfig.spec.json
    └── tslint.json
├── tsconfig.json
└── tslint.json
```

The main application files are contained in the `src/` directory.The `src/app/` contains the AppModule and an initial App Component created for us. The main `index.html` template file and the main stylesheet are also created. The `e2e` is used for testing using the `e2e` testing framework. The `tslint.json` files provides a configuration and code conventions for us to run TSLint with. The `tsconfig.json` contains the TypeScript compiler configuration for the project.

3.2.2.1.1 angular.json This is the main configuration file for the Angular project. It contains directory and path configurations for the project as well as options on whether to use CSS or SASS for stylesheets. It also contains the configuration about hostnames and ports to use as well as SSL configuration for the built-in development web server.

3.2.2.1.2 package.json As in all NPM projects, this files contains all the NPM module dependencies of our application with their respective version as well as define commands to be run with the `npm run` command. To update our application dependencies, for example when a new Angular version comes out, we can use the Angular CLI with the command and then follow the on-screen instructions:

```
1 ng update
```

Listing 13: Command to check for available Angular updates

When updating dependencies, the Angular CLI will update the `package.json` file with the new packages versions and then install the new dependencies.

3.2.2.2 Components

A Component[37] is used to control a subset of a view in the application. By creating small single-purpose Components, for example a Component showing only a User detail, you can easily reuse Components in multiple views.

To generate a new Component using the Angular CLI, you can use the following command:

```
ng generate component <componentName>
```

Listing 14: Command to generate a new Angular Component

This will create a folder containing four Component files:

- A stylesheet file (CSS or SASS depending on the project configuration)
- A HTML template file
- A TypeScript file for the logic
- A specification TypeScript file (used by the compiler and autocomplete tools for typings)

If we generate a Users component for example, we can use the command:

```
ng generate component users
```

Listing 15: Command to generate a Users Component

This will generate the following hierarchy in the `src/app/` folder:

```
users
├── users.component.html
├── users.component.scss
├── users.component.spec.ts
└── users.component.ts
```

The content of the TypeScript file of the component is the following:

```
import { Component, OnInit } from '@angular/core';

@Component({
  selector: 'app-users',
  templateUrl: './users.component.html',
  styleUrls: ['./users.component.css']
})
export class UsersComponent implements OnInit {

  constructor() { }

```

```
12    ngOnInit() {
13    }
14
15  }
```

Listing 16: Empty Component TypeScript file

Here in source code 16, we can see the Component metadata. The `templateUrl` and `styleUrls` are pretty self-explanatory, they reference the corresponding two other files and should keep their default value. The `selector` is the value of the HTML selector you can use in other HTML templates to insert your component. So, if we have another higher level, for example an homepage and we want to insert our users component, we can insert it using this selector (see source code 17). The selector by convention should start with `app-*` in order to avoid clashing with HTML default selectors.

```
1  <h1>This a homepage</h1>
2  <div>
3    <app-users></app-users>
4  </div>
```

Listing 17: Integrating Component in template with selector

Afterwards, you can create methods and properties in the Component TypeScript file that can then be called and mapped to the templates.

3.2.2.2.1 Templates Templates[38] are just HTML files on the surface with additional features inherent to Angular. One of these is interpolation of template expressions. If you have a public property in the TypeScript file or you want to display the output of TypeScript code, you can do so in the Template by wrapping it in curly braces.
For example, let's say we had a `name` property to the User component and we want to display it in the template, we can do so by using the `{{name}}` text in our template.

Moreover, we can define HTML elements properties with TypeScript code.For example, if we want to disable an input in HTML, we can use:

```
1  <input type="text" disabled>
```

Listing 18: Static disabling input in HTML

Now, if we want to have a boolean property in the TypeScript file that decides if the input is enabled or disabled, we can do this using the brackets notation

`[]`. This is useful for example if we want to enable according to a form validity. By putting the `disabled` properties in square brackets, the compiler will interpret the text passed as TypeScript code, this is called property binding. So if we have a boolean `formValid` that states if the input is enabled or not, we can use:

```
<input type="text" [disabled]="formValid">
```

Listing 19: Enabling/disabling input in HTML with TypeScript

Finally, we have access to control flow inside the Template. This is useful for example if we want to display all elements from a list. Let's take a property `users` in our template that is a list of User with each User having a name and we want to display each User has a bulletpoint with a simple message to tell that there are no users if the list is empty. We can use `ngFor` and `ngIf` control flow operators to accomplish this:

```
<p *ngIf="users.length === 0">There are no users</p>
<ul *ngIf="users.length !== 0">
  <li *ngFor="let user of users">{{user.name}}</li>
</ul>
```

Listing 20: Control flow inside Angular Templates

We can also use `ng-container` and `ng-template` to more visually separate our two branches with an `if-else` in the template:

```
<ng-container *ngIf="users.length===0; else usersAvailable">
  <p>There are no users</p>
</ng-container>
<ng-template #usersAvailable>
  <ul>
    <li *ngFor="let user of users">{{user.name}}</li>
  </ul>
</ng-template>
```

Listing 21: Alternative control flow inside Angular Templates

3.2.2.2.2 Communication between components - Event emission

Communication is useful between Components because often you have a parent Component handling a whole screen with children Components inside the view. In this case, the parent component can act as an intermediary in the communication between two children Components (see figure 18).

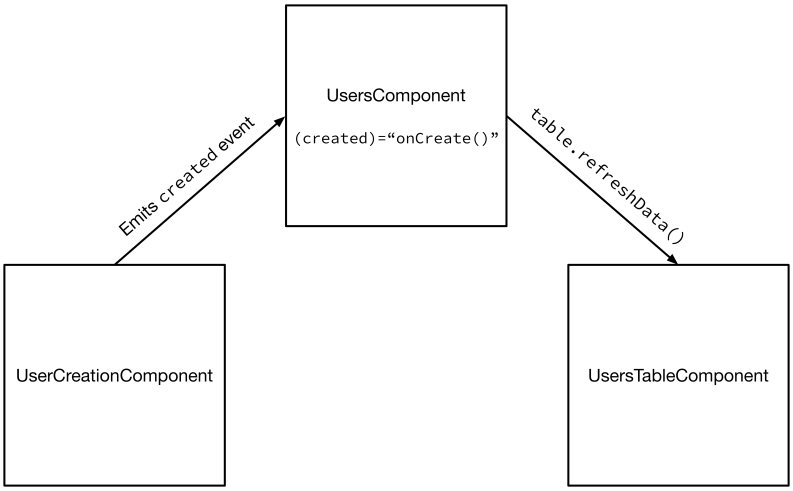

Figure 18: Event emission and communication between components

The parent Component can have properties for each child Component by selecting it as a property using the `@ViewChild()` annotation. As an example, we can take a `UsersComponent` which integrate a `CreateUserComponent` and a `UserTableComponent`. The goal here is to refresh the table when a new User is created. To accomplish this, the `CreateUserComponent` must emit an event when a new User is created and the parent Component will catch it and call a method on the table to refresh it.

From the parent component point of view, it looks like this:

```
<div class="row">
  <div class="col-xl-4">
    <app-create-user #userCreate
    ↪  (created)="onCreated($event)"></app-create-user>
  </div>
  <app-users-table #usersTable
  ↪  class="col-xl-8"></app-users-table>
</div>
```

```
import { Component, OnInit, ViewChild } from '@angular/core';

@Component({
  selector: 'app-users',
  templateUrl: './users.component.html',
  styleUrls: ['./users.component.scss']
})
```

```
export class UsersComponent implements OnInit {
  @ViewChild('usersTable') table: UsersTableComponent;
  @ViewChild('userCreate') create: CreateUserComponent;

  constructor() { }

  ngOnInit() {
  }

  onCreated(created: boolean) {
    console.log('User created');
    this.table.refreshData();
  }

}
```

Listing 22: Template and logic files of the parent component

When looking at source code 22 Template file, we can see `(created)` that is assigned to a function call and passing `$event` to that function. This is called event binding.

Inside the `CreateUserComponent`, the `created` property is defined as an `@Output()` `created = new EventEmitter<boolean>();`. With this event emitter, we can call the method `emit()` on it to emit a value of the specified type, in our case `boolean`. The `$event` passed to the function call in the parent component is the value passed at the emission of the event.
From there, we can just call any public method in the table component, in this case `refreshData()`.

3.2.2.2.3 Communication between components - Input parameters

Finally, you can also have parametric Components. These Components can be integrated inside other Components through their selector but you also have to specify a set of inputs for the Component. In the Component, these inputs are properties with `@Input()`.

For example, if we have a Component displaying a single User, this Component would take the User to display as a parameter. So in the Component, we can write the User property like this and it will behave like any other property:

```
@Input() user: User;
```

Listing 23: Input property in Component

To set this property when integrating the Component in a parent Component, we can simply specify it like this:

```
<app-user-entry [user]="User('toto')"></app-user-entry>
```

Listing 24: Setting an input property in Component

3.2.2.3 Services

Services[39] are a broader category than Component and can be seen as code that is not directly related to user interaction or user experience. Services are also often shared and used by different Components using Dependency Injection[40] (see 3.2.2.3.1). Services can contain methods to manage and save data, to fetch data from a server, validate inputs. All those methods can then be called by all Components simply by injecting the Service. You can use other Services inside a Service simply by injecting them in the Service (see 3.2.2.3.1).

To generate a new Service, you can use the Angular CLI:

```
ng generate service <serviceName>
```

Listing 25: Creating a new Service using the Angular CLI

This will create a TypeScript file and a specification file in the `src/app/` directory.

3.2.2.3.1 Dependency injection When you create a Service using the Angular CLI, it is annotated with the `@Injectable(...)` annotation. You then have to import it in the AppModule file and add it to the `providers` array of the Module. From then on, you can use it in any other Service or Component simply by adding it to the Component or Service constructor.

For example, if we have a `UserService` that we want to use in our `CreateUserComponent`, we can just use the following code to access the Service inside the Component:

```
@Component({
  selector: 'app-create-user',
  templateUrl: './create-user.component.html',
  styleUrls: ['./create-user.component.scss']
})

export class CreateUserComponent implements OnInit {

  //We can access the UserService anywhere in this file
  constructor(private userService: UserService) {
```

```
11    }
12
13    ngOnInit() {
14    }
15  }
```

Listing 26: Injecting a Service inside a Component

3.2.2.4 Routing

Routing[41] inside the application is handled by the Angular Router. Even though our web application is a single-page application from the browser point of view, it is important to use a Router and not just load and unload content in a single URL. This enables for example deep linking to directly access a page of the application.

To generate a Router, you need to generate a new Module to contain the Router. To do so, you can use the Angular CLI:

```
1  ng generate module app-routing --flat --module=app
```

Listing 27: Generating a routing module with the Angular CLI

In source code 27, the `--flat` parameter tells the CLI to put the new Module at the root of the `src/app/` without creating a separate folder and the `--module=app` parameter imports the newly created Module in the AppModule.

Then, we need to create the Router inside our Module. To do this, first you need to import the `RouterModule` and `Routes` class from Angular:

```
1  import { RouterModule, Routes } from '@angular/router';
```

Listing 28: Importing required elements for Routing

Then, we have to define the routes. Routes are defined as an array of Route, for each entry, we can specify several properties, such as a path, a redirection, a set of Guards (see 3.2.2.4.2) to pass to activate the Route and a Component to load. There are more properties, but these are the main ones and we will not dive further into the others.

The finality of each Route is to load a Component on screen, be it directly or through a redirection to another Route that loads a Component.

For example, if we have a `HomePageComponent` to load for the homepage and a `UsersComponent` to load for the `/users` and we want to redirect everything else to the homepage, we can use the following Routes:

```
const routes: Routes = [
  { path: '', component: HomeComponent },
  { path: 'users', component: UsersComponent },
  { path: '**', redirectTo: '' }
];
```

Listing 29: Two pages Routes setup in Angular

Then, in the Module that we created for routing, after defining the routes, we have to link the `RouterModule` with the Routes and export the Router as part of our Module:

```
@NgModule({
  imports: [
    RouterModule.forRoot(routes),
    CommonModule
  ],
  exports: [RouterModule],
  declarations: []
})
```

Listing 30: Setting up Router and exporting it in Angular

Finally, we can also create a hierarchy of Routes by adding children to Route entries. This is particularly useful if we want to protect a set of routes (admin routes for example) behind a Guard (see 3.2.2.4.2).If we take the example from source code 29 and want to add a `/users/create` create under the `/users`, we can refactor it this way:

```
const routes: Routes = [
  { path: '', component: HomeComponent },
  {
    path: 'users', children: [
      { path: '', component: UsersComponent },
      { path: 'create', component: CreateUserComponent },
    ]
  },
  { path: '**', redirectTo: '' }
];
```

Listing 31: Nested Routes in Angular

3.2.2.4.1 Router outlet Finally, to display the routed component in our page, we have to provide a Router Outlet. The Router Outlet is often inserted as the only element directly in the main `index.html` file but can also be inserted in a more complex layout or in another Component. The Router will attach itself to the first encountered Router Outlet from a hierarchical standpoint.

To insert the Router outlet in a template, you can use its selector:

```
<router-outlet></router-outlet>
```

Listing 32: Using a Router Outlet in Angular

3.2.2.4.2 Guards Finally, another important part of Routing are Guards. By default, anyone can navigate to all the Routes in the application but in many real use cases, you have to be logged in to access specific sections of an application or even have special permissions. Guards allow to perform checks before activating a Route and multiple Guards can also be chained to enable a Route activation.

The most basic will return a `Boolean` to specify if the user can pass the Guard or not. Inside the guard, you can also access the Router by Dependency Injection to provide a redirection in case the check does not pass for example.

As an example, we can take a look at one of the most common Guard used. This Guard is used to protect a Route only available to logged-in users and will redirect to the `/login` page if the user is not logged-in.

First of all, we can generate the Guard that we're going to call the `AuthGuard` using the Angular CLI, we have to add it to the `providers` array in the AppModule as well:

```
ng generate guard auth
```

Listing 33: Generating a guard using Angular CLI

Then, we can add the Guard to our Route. If we take the Routes from source code 29 and add a `/login` Route, we will then protect all other Routes behind the guard:

```
const routes: Routes = [
  { path: '', canActivate: [AuthGuard], component:
  ↪ HomeComponent },
  { path: 'users', canActivate: [AuthGuard], component:
  ↪ UsersComponent },
```

```
4     { path: 'login', component: LoginComponent }
5     { path: '**', redirectTo: '' }
6   ];
```

Listing 34: Routes protected by a Guard

Then we have to write the logic of the Guard itself with the redirection. To do so, we have a service that will returns an `Observable` that specifies if the user is logged-in (more info on `Observable` operators `pipe` and `tap` in section 3.2.3) and we are gonna return the logged-in value to the guard and redirect if it's false:

```
1   @Injectable()
2   export class AuthGuard implements CanActivate {
3     constructor(private userService: UserService, private
      ↪  router: Router) { }
4
5     canActivate(
6       next: ActivatedRouteSnapshot,
7       state: RouterStateSnapshot): Observable<boolean> |
        ↪  Promise<boolean> | boolean {
8
9       return this.userService.isLoggedIn().pipe(tap(isLoggedIn
        ↪  => {
10        if (!isLoggedIn) {
11          console.warn('You need to login');
12          this.router.navigate(['/login']);
13        }
14      }));
15    }
16  }
```

Listing 35: Guard redirecting not logged-in users to login page

3.2.3 RxJS - Observables

RxJS Observables[42] are similar in concept to LiveData on Android (see section 3.1.4.2.2). The idea behind Observable is to return a value that can change over time and on which you can "listen" for new changes and update the UI accordingly for example. It is used for changing data, for example when subscribing to breakpoint changes in browser window (resizing the window) or for data that is not yet available and is being loaded asynchronously from memory or another server.

In most project, RxJS Observables are mainly used by the Angular HTTPClient[43]. Since HTTP requests are asynchronous, when making a request the client returns an Observable on which you can subscribe to get the parsed result once it comes back from the server.

3.2.3.1 The HTTP Client

The HTTP Client is used to retrieve JSON Data from a backend API. It returns an Observable of the data already parsed to the correct type. Its recommended to use the HTTP Client in a Service and you can access it by Dependency Injection in any Service.

If we want to retrieve the list of all users from the backend, we have to create a `User` TypeScript class in our Angular project to match the data returned from the backend. Then we can simply use the HTTP Client to make a request and it will return an `Observable<User[]>`:

```
const GET_ALL_USERS_ROUTE = '/api/users/all';

@Injectable()
export class UserService {
  constructor(private http: HttpClient) { }

  public getAllUsers(): Observable<User[]> {
    return this.http.get<User[]>(GET_ALL_USERS_ROUTE);
  }
}
```

Listing 36: Using the HTTP Client to retrieve data

Then, when calling this method from a Component for example, we can `subscribe` to the Observable and get two branches: one if data is available and another if an error happens, we can supply functions for each case:

```
this.userService.getAllUsers().subscribe(data => {
  //data is the array of users of type User[]
  console.log(data);
}, error => {
  console.error('There was an error')
});
```

Listing 37: Subscribing to data from an Observable

3.2.3.2 Pipe and other operators

Sometimes it can be useful to handle the data of an Observable before the subscribers are notified of new data. This is done using the `pipe` operator. When returning an Observable, you can append a call to `pipe` at the end of it and insert operations that will be run as part of the Observable before it triggers the subscribers. These operations are function calls that take a `function(data)` as parameter.

One of the operations that can be run is the `tap` operation. This operation does not make any change to the data being sent to the subscribers but allows to use it before sending it untouched. For example, it is used in the the `AuthGuard` presented before (source code 35) to access the returned data so that it can redirect to the `/login` page if the user was not logged in. Basically, we pass the value to the function caller, but we can use it too when it comes back.

Another useful operator is the `map` operator. This is used to transform data before it triggers the subscribers. It will return an Observable of the type of the returned value in the map function. For example, if we need to return an `Observable<boolean>` to say if the user is logged-in and we have a `getToken` function that sends us the authentication token or `null` if no user is logged in, we can use the `map` operator to transform our `Observable<String>` in an `Observable<boolean>`. We can do this by using the following code:

```
1 public isLoggedIn(): Observable <boolean> {
2   return this.getToken().pipe(map(token => {
3     return token !== undefined && token !== null;
4   }));
5 }
```

Listing 38: Transforming an Observable using the map operator

3.2.4 TypeScript

TypeScript[44] is an open source language developed by Microsoft. It adds optional static typing and classes to JavaScript as well as implementing its own module import syntax. TypeScript files can be ”compiled” to JavaScript to be used on the web or on the server-side using Node.JS for example. TypeScript is regarded by Microsoft and others as the way to build large scale JavaScript application thanks to the ease of mind provided by statically typed languages.

TypeScript also includes the ability to write definition files to add typing information to existing JavaScript code to provide completion in code editor as

well as compile-time check when using third-party libraries.

The whole static typing logic is checked when ”compiling” (actually transpiling) to JavaScript. The generated JavaScript files are plain JavaScript files and can be configured to use ES6 syntax or earlier by providing compatibility code for older JavaScript standards.

The syntax of TypeScript is similar to JavaScript with the main addition being the ability to specify the type of a variable or the return type of a method by appending `:<type>` to its declaration, for example:

```
1 let age: number = 10;
```

Listing 39: Defining the type of a variable in TypeScript

3.2.5 Angular Material

Angular Material[45] is an open source[46] Components library built by the Angular team to be used with Angular. The library provides Angular Components that follow the Material Design Language[47] used by Google on Android and the web.

Contrary to a simple stylesheet library, Angular Material provides Angular Components that incorporate their own logic and not only look but also behave according to the Material Design specification. These Components range from side navigation drawers to tables complete with sorting and filtering. It also provides extensive theming capabilities with the ability to change theme colors globally or on a component basis.

Finally, a Component Development Kit is provided to simplify building custom Material-inspired Components.

3.3 NoSQL Database - MongoDB

NoSQL databases have existed for a long time, since the late 1960s but only recently have they started become more and more popular, due to the advent of Big Data and real-time applications. While most people believe that NoSQL databases are named this way because they are *NOT* SQL, it actually should mean *Not-Only SQL* as some NoSQL system support SQL-like syntaxes for queries.

According to the *CAP Theorem*[48], it is impossible for a distributed data store to provide more than two out of: Consistency, Availability and Partition tolerance. NoSQL stores often compromises some consistency in favour

of better availability and speed as well as simplified scaling.

NoSQL databases do not use the same data structures as SQL databases and there are several categories of NoSQL databases classified by the data structures they use. Some of these categories are:

- Key-Value store
- Document store
- Object database
- Graph databases

MongoDB is a document-oriented database[49] launched in 2007 that store JSON-like documents in collections. It is currently one of the most used NoSQL data stores. The document would be the equivalent to a row in SQL and the collection is the equivalent to a table.

3.3.1 Schemas

By default, MongoDB does not impose a strict Schema inside a collection, meaning all documents inside the collection can have a different structure. While it is not a best practice, it provides flexibility when the project is still in development phase because you can modify the schema and save new documents with newly added or modified fields while already present keep their structure. When running in production, the schema should be strict in all collections.

3.3.1.1 How to handle references

Often documents you save in the database will have a relation with other documents from another schema. These relations would be stored in a SQL Database as a Foreign Key linked to the Primary Key of the entry we want to reference. In MongoDB, there are three solutions to handle references depending on the number of references that are necessary from one document to another. You should think from the beginning about the maximum number of references you can have between two documents before choosing one of three references design. The limitations of the designs come from the maximum size of a MongoDB document, that is capped at 16Mb, and if you need to update referenced documents often.

To illustrate the three options, we are gonna take an example where we people and cars. There is one schema for a person and one schema for a car and a person can have multiple cars but a car is only owned by a single person.

The first option to store this information is to embed the car documents in the person document[50]. We don't need to have a car collection, we can just store in the person document an array of cars. We should make sure that a person will not have a lot of cars because by embedding entire car documents we will take more space and we could more easily reach the MongoDB document size limit. This option though provides the easiest way to retrieve the person and all its cars and to remove all cars when the person is removed.

```
{
  "id": "user001",
  "name": "Mickael Hoerdt",
  "job": "Teacher",
  "employer": "hepia",
  "cars": [
    {
      "brand": "Ferrari",
      "model": "458",
      "plate": "CAFE"
    },
    {
      "brand": "Lamborghini",
      "model": "Huracan",
      "plate": "DEADC0DE"
    }
  ]
}
```

Listing 40: Embedding referenced documents in MongoDB

To reduce the size taken by embedding full car documents in a user's document, we can store an array of car IDs in the person's document[51] instead of full cars and store the cars in their own collection as standalone documents. This is more efficient in term of document size but it means that we have to retrieve the referenced information when accessing a person (see 3.3.2.2) as well as deleting all linked cars' documents when we remove a person (see 3.3.2.3).

```
{
  "id": "user001",
  "name": "Mickael Hoerdt",
  "job": "Teacher",
  "employer": "hepia",
  "cars": [
```

```
    "car001",
    "car002"
  ]
}

{
  "id": "car001",
  "brand": "Ferrari",
  "model": "458",
  "plate": "CAFE"
}

{
  "id": "car002",
  "brand": "Lamborghini",
  "model": "Huracan",
  "plate": "DEADC0DE"
}
```

Listing 41: Storing children references in MongoDB

Finally, the last option[51] is the most similar to the SQL Foreign Key idea and is also the one that will scale better to a big number of references. Instead of storing an array of the IDs of the cars in the person's document, we store the owner person ID in the car 's document. While it is the most complicated design to quickly retrieve information or delete all cars when we delete a person (see 3.3.2.3), it is the most space predictable design because no documents can individually grow as the number of references increase.

```
{
  "id": "user001",
  "name": "Mickael Hoerdt",
  "job": "Teacher",
  "employer": "hepia"
}

{
  "id": "car001",
  "owner": "user001",
  "brand": "Ferrari",
  "model": "458",
  "plate": "CAFE"
}
```

```
15
16 {
17   "id": "car002",
18   "owner": "user001",
19   "brand": "Lamborghini",
20   "model": "Huracan",
21   "plate": "DEADC0DE"
22 }
```

Listing 42: Storing parent references in MongoDB

3.3.2 Mongoose

When using MongoDB, you will often integrate it in a MEAN[8] stack and so you will access MongoDB with a Node library called Mongoose[52]. Mongoose allows to connect to MongoDB databases, define schemas and create, update and delete documents. Mongoose can be integrated with JavaScript ES6 Promises (see section 3.4.3).

3.3.2.1 Defining a Schema

You can define Schemas[53] for the database by using the `Mongoose.Schema` class constructor and specifying the field names and types as well as adding validators on fields. Some default validators are already included, for example the `required` validator or a `max` validator for fields of type `Number`.

Hooks (see 3.3.2.3) can also be added to the Schema to be triggered before creating or removing documents for example, and it is possible to override the `toObject()` method that defines the fields returned when converting a returned document to a JavaScript object.

Finally, you have to register the Schema with a name in Mongoose and require the Schema file once in the main file of the server for the registration to take place.

An example of a simple `Person` Schema can be seen in the following code:

```
1 const mongoose = require('mongoose');
2 const Schema = mongoose.Schema;
3
4 const PersonSchema = new Schema({
5   name: {
6     type: String,
7     required: true,
```

```
    trim: true
  },
  birthdate: {
    type: Date,
    required: true,
  },
  email: {
    type: String,
    required: true,
    lowercase: true,
    unique: true
  },
});

module.exports = mongoose.model('Person', PersonSchema);
```

Listing 43: Person MongoDB Schema using Mongoose

3.3.2.2 Populating references

As stated before in section 3.3.1.1, when using references to link two documents, it means that we have to specifically retrieve the referenced documents when finding documents in the database. This can be easily done with Mongoose. First of all, when creating the Schema that contains a reference, we need to specify what Schema is the reference linked to and then when making query we can just `populate` this field.

First of all, if we're using the third design option, where children link back to parents, we would need to write the Car Schema in this way:

```
const mongoose = require('mongoose');
const Schema = mongoose.Schema;

const CarSchema = new Schema({
  owner: {
    type: Schema.Types.ObjectId,
    ref: 'Person',
    required: true
  },
  brand: {
    type: String,
    required: true,
    trim: true
  },
```

```
  model: {
    type: String,
    required: true,
    trim: true
  },
  plate: {
    type: String,
    required: true,
    trim: true
  },
});

module.exports = mongoose.model('Car', CarSchema);
```

Listing 44: Car MongoDB Schema with references

Then, when finding a Car, we can just append the query with `populate(owner)` to retrieve the linked Person from the Person Collection:

```
const mongoose = require('mongoose');
const Car = mongoose.model('Car');

const entries = await Car.find().populate('owner');
//entries contains all Cars with the full Person in the
↪  'owner' field
```

Listing 45: Populating a reference with Mongoose

3.3.2.3 Hooks

Finally, sometimes we need to take actions before we create or remove a document for example. In the case of references for example, if we want to *cascade* the deletion of the references like we would do it in SQL, we need to do this inside a *Hook* that we can set to run before an action, in this case `pre('remove')`.

If we remove a Person and we want to delete all the Cars he owns, we need to remove the Cars in the `pre('remove')` of the Person so that it will run when we delete the person. In the *Hook* we can run:

```
const mongoose = require('mongoose');
const Car = mongoose.model('Car');
```

```
3
4  PersonSchema.pre('remove', function (next) {
5    Car.remove({ owner: this._id }).exec();
6    next();
7  });
```

Listing 46: Removing referenced documents using a *Hook*

3.4 NodeJS et Express

3.4.1 JavaScript ES6

3.4.2 NPM Modules

3.4.3 Promises

3.4.4 Middlewares

3.4.5 PassportJS

3.5 Containers

3.5.1 Docker

3.5.2 Orchestration with Docker Compose

3.5.3 Google Cloud

3.5.3.1 Kubernetes

3.5.3.2 Google Container Registry

3.5.4 Azure

Chapter 4

Implementation

4.1 Project modules

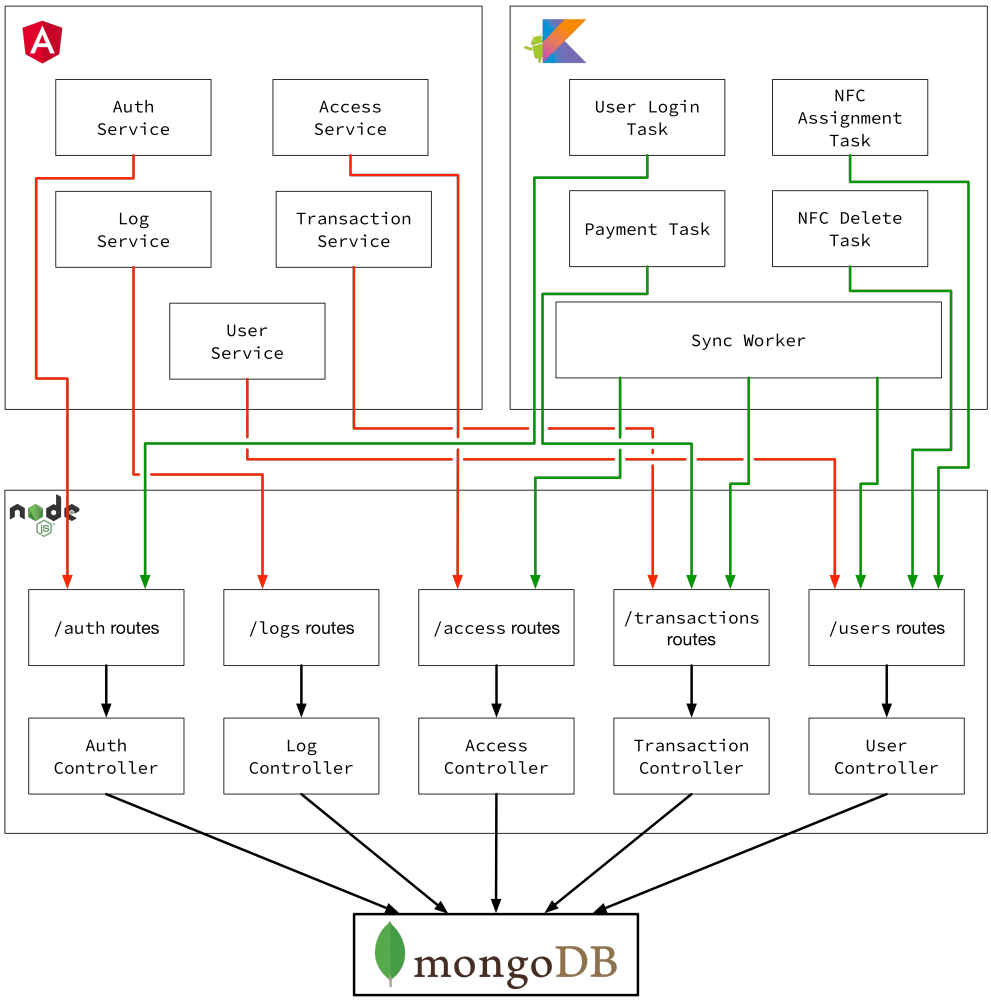

Figure 19: Interactions between the components

4.2 Deployment

4.2.1 Deployment architecture

4.2.2 Nginx Proxy

4.3 Backend

4.3.1 Authentication

4.3.2 Endpoints

4.3.3 Interaction with MongoDB

4.4 Angular frontend

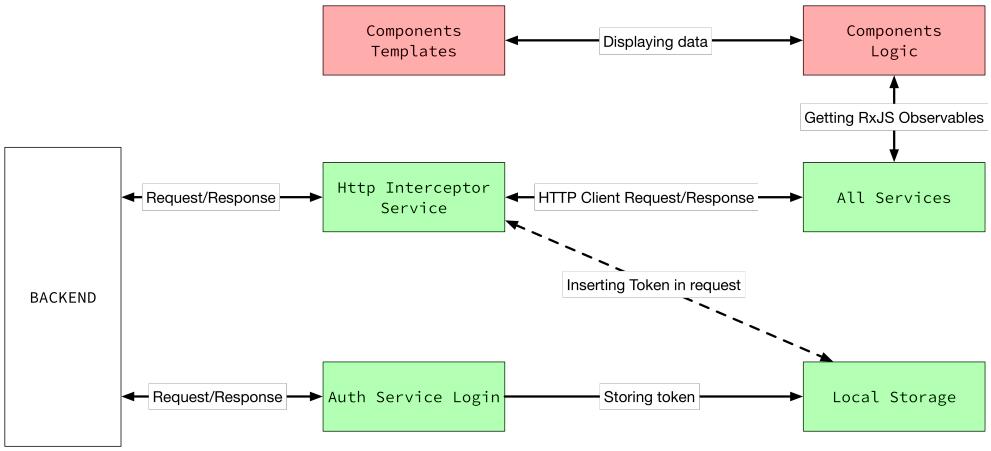

Figure 20: Interactions in the Angular Frontend (Components in red, services in green)

4.4.1 Authentication

4.4.2 Routing

4.4.3 Components

4.5 Android application

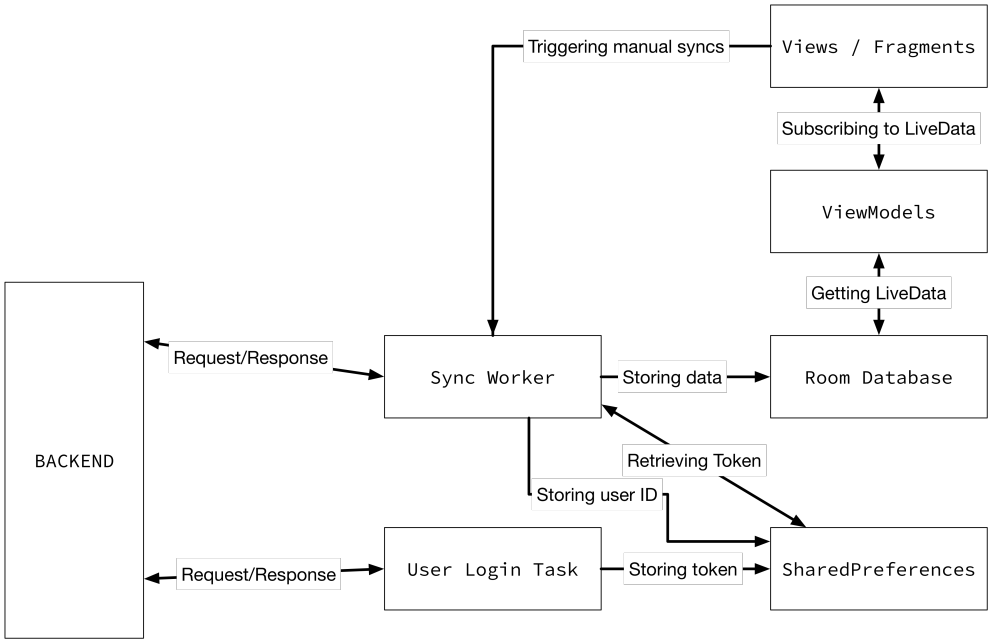

Figure 21: Interactions in the Android application

Chapter 5

Résultats

Chapter 6

Conclusion

6.1 Future works

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