Universidade de Aveiro Departamento de Engenharia Mecânica
2019

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Automatização dos procedimentos de check-in no sector Turístico.

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestrado Integrado em Engenharia Mecânica, realizada sob orientação científica de José Paulo Oliveira Santos.

O júri / The jury

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Palavras-chave Controlo de accessos; Industria Torística; Automatização de check-in, Empreendedorismo

Resumo Este trabalho aproveita tecnologias como *IOT* e *Web* para remover a necessidade de terceiros nos procedimentos de check-in. A inovação tem o objetivo de melhorar o setor de alojamento na indústria turística. Para a escolha da tecnologia mais adequada, foi realizada uma análise cuidadosa sobre o público-alvo e as possíveis tecnologias. Em seguida, foi desenvolvido um plano de negócios para explicar como o produto pode ser rentável, gerar valor para a sociedade e apresentar-se como uma inovação. Somente depois disso, foi desenvolvido um protótipo para testar a viabilidade desse modelo de negócio. O protótipo consiste numa plataforma e fechadura que permite a utilização a gestão automática dos acessos para os laboratórios de engenharia mecânica da Universidade de Aveiro.

Keywords Access Control systems; Touristic industry; Check-in Automation; Entrepreneurship;

Abstract This report takes advantage of *Web* and *IoT* technology to remove the necessity of 3^{th} people into the check-in procedures. The innovation has the objective to improve the accommodation sector in Tourism and Travel activities. For choosing of the most suitable technology, a careful analysis was performed about the target audience and the possible technologies. Then, a business plan was developed to explain how the product can be profitable, generate value to society and present itself as an innovation. Only after that, MVP was developed to test the viability of this business model. The MVP consisted on platform and locker that allow the user to manage and use their desired accesses to the mechanical engineering laboratories in university of Aveiro.

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Part I

Introduction

Chapter 1

Introduction

The objective of this thesis is to take advantage of the benefits of Internet Of Things (IoT) to improve the accommodation sector into the Tourism and Travel activities. The IoT solution to be implemented have as main goal the removal of 3^{th} people into check-in process.

This chapter will start by developing the relation between internet and the tourism itself, then explain the problem to solve, it's importance and finally a initial proposal of the solution.

1.1 Introduction

Since the mid-1990s, the internet has been changing the way the world works, communicates and entertains itself. Following Litan & Rivlin(2001) [1], by the early 2000s, internet already had a deep impact on product development, supply-chain management, health care and government information flows. Since then, it have become quickly a pillar of our society expanding to the most diverse areas such as education, entertainment, commerce, communication, economy etc... [2]

Now is taking the next step, the internet is moving from the realm of connecting people to people by computers, tablets and smart-phones, to the realm of connecting people to everyday devices and everyday devices to each other by embedded systems. This phenomenon is called by *Internet of Things* (IoT).

Internet of Things formal definition is "the worldwide network of interconnected objects uniquely addressable based on standard" [3]. But in a nutshell, is the ability to enable devices to send and receive data over the internet, then store and analyse it (on the cloud) to contribute to multiple business sectors.

Of course, the tourism industry is no exception. Following, Poupineau (2016)[4] IoT, cloud computing, mobile technology and artificial intelligence are the 4 technologies essential to a smart-tourism system.

These technologies are important to create smart tourism experiences that enhance the destination attractiveness and provide considerable competitive advantages. For that reason, the hotel industry is already implementing these technologies into entertainment, food, beverage, guest security, energy efficiency, guest relations, check-in procedures and much more. [4].

The goal of this thesis is to continue the development of this relationship between

Technology and Tourism, by improving the accommodation sector via a better IoT smart locker. That will be explained above.

1.1.1 Problem to solve

Nowadays, the accommodation sector still requires a reception 24h a day to provide the check-in service to their clients.

Contrary to the hotel services where the tourists have access to 24/7 to staff that solves any unexpected problems, check-ins and check-outs. In the small accommodation businesses such as hostels, low budget hotels/motels or "peer-to-peer short-term rental" platforms (eg. AirBnB), check-in procedures still causes a lot of unnecessary costs and inconveniences.

In this lower end of the accommodation sector check-in procedures must rely on a host who likely has many other responsibilities and may not be present every time, or in a reception 24/7 that proves very expensive, because there are barely no times on which new costumers are doing their check-in or needing in-person-help.

This check-in process also causes inconvenience in the tourist experience by increasing the check-in time and unsuspected occurrences.

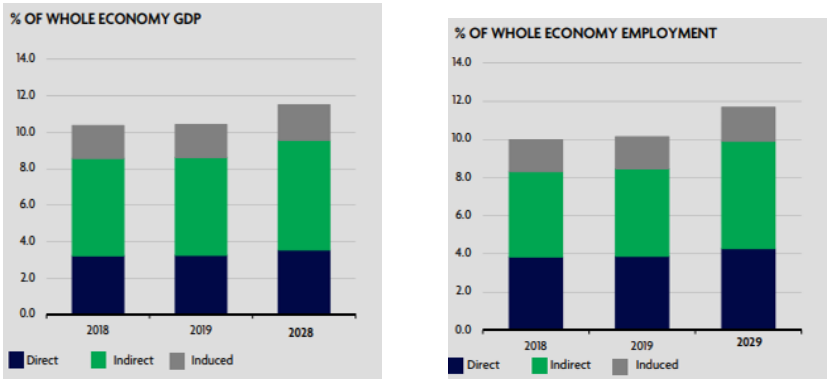
For this reasons, the first product globally implemented able remove of 3^{th} people into the check-in process is going provide considerable advantages to the accommodation sector [4].Based on the importance of the touristic sector, explained in the next section 1.1.2, this product have the potential to become a largely profitable product.

1.1.2 Tourism Cultural and economical importance

The tourism sector is growing his impact in nowadays world. Following the research from WTTC(World Travel and Tourism Council) [5], this sector brings tremendous economical and non-economic value for the world. Being not only one of the largest and fast-growing economic sectors in 2019 but also by being an important vehicle for sharing cultures and building mutual understanding between individuals.

Though touristic consumption, this economic sector touches several industries directly and indirectly, such as accommodation, transportation, food & beverage, retail, culture, entertainment and much more. This broad group of industries that provide services and products to the travellers make the tourism industry. And the numbers are outstanding [5].

In 2018 this sector was one of the leading job creators contributing to 14% of the world's net job creation, supported 10% of all the employment and contained 10.4% of the global GDP (Figure 1.1)[6].



(a) (b)

Figure 1.1: GDP and employment from Tourism and Travel [7].

In the case of Portugal, Tourism and Travel activities is even more critic to the economy. In 2018, it represented 60% all new jobs created and 21.8% of the total employment. Also, represented 19.1% of the total country GDP and is in the second place in terms of sector growth in Europe, just behind Turkey [8].

By this analysis is clear the importance that tourism and travel have booth in our society and in our economy.

1.2 Initial Solution

With this problem in mind, the author will develop a system capable of eliminate the need of 3^{th} people into the check in process, and that are likely to be implemented into a larger scale.

That would inevitably pass by an *IoT* system composed by hardware (embedded systems and access control systems) and software (app/web platforms and databases) that possibilities the sending of necessary data to the tourist to open easily the door.

However, before setting off to the system's specifications, a deeper understanding of the target population, in this case, the owners of lower-end businesses on the accommodation sector and the tourist itself, is needed. This means understanding their difficulties, problems and routines while performing the activity in study.

The solution have to be based in access control actual technologies and makes no sense to develop a system which already exists, making it important to conduct a good state of the art research in order to understand benefits and downsides of current solutions.

For that effect, in the chapter 2, an analysis of the actual implemented solutions, studies and target population will be preformed help to clarify what is the best solution.

1.3 Motivation

Personally the author is highly motivated to develop this solution due to the following reasons:

- Firstly, because of the love and enthusiasm that the author shares with touristic adventures. Is important to make this adventures more convenient and available

to everyone for matters of fun and exploration.

- Secondly, because of the importance that tourism have in sharing cultures and building mutual understanding between individuals. More incentives to tourism can actually change the altruistic levels in the world.
- Thirdly, because of the desire of the author to learn website related technologies and electronics. Being a perfect match to learn it while contributing to touristic experience.
- Lastly, for economic purposes. Nowadays this opportunity is wide open in the market, a product that can solve this problem conveniently can become highly profitable as shown in the section 1.1.2.

1.4 Why IoT based solution?

It must be a solution that is easily available to everyone, in a distance of few clicks. It also must be a solution that can share important payment information and provide secure access control instantly across to all tourists over the world.

Nowadays, the only possible way to perform this kind of operations is by using the *World Wide Web*, information protocols such as *HTTP* and *IoT* devices (in this case *IoT* lockers to receive the access key automatically). So, an embedded system to create the *IoT* locker and some kind of web platform, are going to be inevitable.

1.5 Methodology

In order to provide efficiency in the decision making process of the product development and market analysis, this thesis has to stand in the shoulders of giants. Therefore, the product development decisions presented in this thesis will be based on the following leading business product development and management methodologies, which are:

- **Stage-Gate**:

  Works with gates, that are requirements between each stage of the project. These gates are important to ensure that the project is apt to follow to the next stage. The gates developed to this thesis are adapted from an thesis written by Taiwanese and Indonesian manufacturers to evaluate their products. [9] [10]

- **Lean**: Is a cyclical methodology, based on: build-measure-learn. It focuses of minimal waste, high speed and learning. One of the best practical references for this methodology is Eric Ries' book, The Lean Startup [11].

There other methodologies like agile [12], scrum [13], Kaban [14], Waterfall [15], Six Sigma [16] and PMI/PMBOK [17] however taking in consideration the market, business in question and the academic nature of the work the author decided to follow a combination between State-Gate and Lean methodologies. This means the following rules to guide all product development and management aspects:

- Focus on the consumer, their needs and characteristics, by cyclical research and possibly interviews.

- Identify what is missing in the market, take advantage the holes in the market by our advantage.
- Prototype and experiment – utilising simpler and cost effective prototype to iterate effectively while learning about the consumer.
- Systematically follow the strategy in the development [18].

1.6 Structure of the Document

Chapter 2 (State of the Art): In the chapter 2, will be analysed the actual developed technologies at disposal for this solution, the already implemented ones and the target audience. To then, following the previous methodologies, clarify what is the best solution the problem.

Chapter 3 (Business Model): In the chapter 3, will be developed a business model to the solution chosen. In order to understand how it can be profitable and how to test rapidly the product assumptions.

Chapter 4 (Conceptual solution): In the chapter 4, the chosen solution will be explained with detail. The theoretical aspects about the solution will be discussed, the technologies will be defined, it's functionalities and principal activities.

Chapter 4 (Final considerations): In the chapter 4, final considerations will be discussed such as future work, difficulties on the product development and limitations.

Part II

State of art

Chapter 2

State of art

Any technology that limits the access to a place, good or system is a form of access control system, like a locker or login system. The importance of these systems relies on the privacy and security that they provide to the valuable resource at hands.

In the case of space, these systems have been taking many forms over the years, evolving into different ways to achieve the same privacy and security on different situations [19].

It has all started with purely mechanical systems until the twentieth century, with traditional locks. And, exploded to a lot of different kinds of authentication digital systems in the twentieth century, such as keypads, barcodes, RFID technologies and biometrical systems [20]. This digitalization presents a huge market opportunity, because they provide multiple convenience and security advantages depending on the situation.

For the problem of this thesis, this chapter is divided in 3 major parts, the target population (understanding its characteristics, needs and important factors), the possible technologies (where are they used, how they work and its actual implementation into the Travel & Tourism sector) and finally the decision of the characteristics of the product.

2.1 Target Population

Understanding the consumer behaviour (CB), is the background of all product development due to the need to understand how tourists buy the product they do, and how they make their decision.

If their average behaviour patterns, characteristics and needs are understood, then we will know where it is needed to intervene in the product to obtain the desirable results. Therefore this study is crucial to make the product successful, both in its development and marketing [21].

Following [22], CB is one of the most researched areas in the marketing and tourism, although it still have a lack of comprehensive reviews due to the complexity of the task.

Just between 2000 to 2012 there was 519 studies about the subject in tree main tourist organisations indicated in the Figure 2.1. The objective of these studies was to understand the tourist in variables such as Decision-making, Values, Motivations, Personality, Satisfaction, Influence of technology, of Ethical initiatives, etc.

2000–2012	*Annals of Tourism Research* (ATR)	*Tourism Management* (TM)	*Journal of Travel Research* (JTR)	Total number of articles
Key concepts	**77**	**139**	**167**	**383**
Decision-making	15	11	23	49
Values	2	4	3	9
Motivations	12	40	37	89
Self-concept and personality	4	7	5	16
Attitudes and expectations	17	12	12	41
Perceptions	8	21	33	62
Satisfaction, trust and loyalty	19	44	54	117
Influences	**11**	**20**	**14**	**45**
Technology	4	18	7	29
Generation Y	2	1	4	7
Ethical consumption	5	1	3	9
Research contexts	**33**	**41**	**17**	**91**
Group and joint decision-making	3	5	1	9
Under-researched segments	5	15	4	24
Cross-cultural issues in emerging markets	9	8	7	24
Emotions	7	9	4	20
Consumer misbehaviour	9	4	1	14
Total	121	200	198	519

Figure 2.1: Key concepts, influences and research contexts reviewed in the three leading mainstream tourism journals (2000-2012) [22] .

A downside of these studies is that they are mostly based upon empirical data and therefore, they tend to show considerable differences across situational and behavioural factors such as (1) tourism-related sectors, (2) tourism products and destinations and (3) consumer types [22], what makes very difficult to predict *CB*. This behavioural and situational variables are inumerous, for example only inside (1) tourism-related sectors it has: Business tourism, Leisure tourism, Educational tourism, Religious tourism and much more [23].

Recognising high number of variables and the complexity *CB*, the author will have to develop the product to fit into only a niche segmented tourist and owner. Because, covering all the needs and characteristics of the general touristic public, its practically impossible.

Saying this, is known that the pain of the problem to solve is more felt in the smaller accommodation businesses, such as hostels and low budget hotels/motels that do not have the need of having an 24h reception open. Also, in the "peer-to-peer short-term rental" (*PSR*) sharing platforms such as AirBnB where ordinary people rent out their residences as tourist accommodation.

In the next sections the typical costumer of this small accommodation business and their respective business owners will be studied in detail as the target audience. Note that, during this analysis the tourist is going to be the central focus for product decisions, as marketing theories put the final consumer at the central focus for all their activities [24].

2.1.1 Understanding target tourist: *Generation Y*

Times are changing and the tourists as well. Now the new tourists are no longer spectators in their travel, they are participants seeking for experiences, adventures, freedom and feelings. They want to have an high involvement into the organisation of their trip, with an ever increasing education, experience, tools and independence [32].

For reasons presented in further topics, these "new tourists" are the target tourists for the product of this thesis. Also, they are a consequence of the new generation emerging into the work force nowadays, they are generally called by *Generation Y*, *Millennials* or *Net Generation*. Despite no absolute definition, following [22] this generation refers to individuals born between 1982 to 2002, and forecasts point that in 2020 this touristic public will became the most relevant segment economically.

In the literature, there are inumerous evidence that this generation have clear differences from all others, due to the unbelievable change of society in the past decades (see articles in Figure 2.1). Factors such as technology, mass marketing, different political times and pop-culture made the *Generation Y* grown up with completely different mindset, ambitions and world views to previous generations [29].

The last tree generations, represented in the Figure **??**, are known as the , *Builders generation*, *Baby Boomers* and *Generation Y*. The *Generation Y* are generally the children of Baby Boomers and as expected each generation are deeply different in terms of their motivations, values & beliefs and overall personality.

For reasons presented in the further topics, the author decided that *Generation Y* will be the target tourist. So, to have an overall overview of this persona, here are some of the most important characteristics:

- Generally much more relaxed, creative, life-style focused [33].
- Technological savvy. With 97% of them owning a computer, 94% owning a cell phone, 76% using Instant Messaging, 34% using websites as their primary source of news and 44% reading blogs [27].
- Used to high degree of multitasking. Due to the influence of technology (ex: interacting with the phone, surfing the net and listening to their iPod at the same time) [27].
- Used to fast outcome in life and much higher quality of life without the proper sacrifice. This trait by consequence, is viewed negatively in the context of work. They do not want to start at the bottom of the work hierarchy they want instantaneous challenges and with it, recognition and respect. Without the years of dedication to develop their carrier [29].
- Generation with high disposable income , more educated and more ethically diverse (open minded) [28].

- Constantly seeking for intellectual challenges and seeking for ways to make a difference or succeed in is own manner [28].

Why Segment the target tourist by generation is viable?

Due to the ever increasing differences in generation behaviour, the generation behaviour comparative analysis has been an growing area of study the past decade. This way the marketeers can simplify the tourist segments into bigger groups with more general characteristics in common. What is clearly more easy to manage and also efficient.

To prove the validity of the previous argument, in 2006 the Travel Industry Association (TIA)[34] pointed out the following: "One of the most common and useful ways to classify any population is by the ages of the individuals who comprise it or, more broadly, by generational groups that are distinct not only in terms of their ages, but by the common events that helped shape their lives". Although the beliefs and behaviours of a generation are rarely uniform thought all members, empirical data suggests that a specific generation is expected to be identified with some core values, behaviours and consumption patterns , unlike in comparison with previous generations [35, 36].

In the case of tourism, the following hypothesis have been already proven by empirical studies, such as, the tourists of different generations differ in their [31]:

- Information source preferences.
- Destination visitation history.
- Future destination preferences.
- Destination evaluation criteria.
- Travel activity preferences.

Why *Generation Y* is the target audience?

As previously said, is known that the problem to solve is more felt in the smaller accommodation businesses like hostels, budget hotels/motels or "peer-to-peer short-term rental" (*PSR*), because contrary to the hotel services where the tourists have access to 24/7 to staff that solves any unexpected problems, check-ins and check outs, the lower-end of the accommodation businesses must rely on a host who likely has many other responsibilities and may not be present every time [38]. For this reasons obviously, the target audience of the product to develop is same target audience of this accommodation services, both tourist and owner.

The idea of the author is deducing the maximum of the target audience by going to the well researched literature about AirBnB audience, and then by pointing similarities between AirBnB (a typical *PSR* platform) and the rest of the small accommodation businesses.

The AirBnB tourist research is based on the following articles [37, 38]. In first place, lets evaluate business similarities between *PSR* and the rest of accommodation sector.

PSR platforms have partially the same tourist segment than hostels since many of them are incorporated into those platforms with good results [37]. By contrast, *PSR* platforms does not have the touristic segment of the hotel industry, AirBnB claim to be

merely a complement to hotels attracting a whole different type of tourist [39], without offering competition. Also Anderson (2012) [41], refereed that AirBnB affects on the hotel industry are minimal because it is a very different product, with a different set of market standards.

To further support that idea , Zervas(2015) [42] studied the relation between revenue changes in the Airbnb listings and several hotels in Texas, and found that the impacts were considerable in lower-end hotels, independent hotels and hostels that did not have business travellers. Neeser (2015) [43] replicated this approach to examine Airbnb's impacts in Norway, Sweden, and Finland. Neeser found that Airbnb appeared to negatively impact, only the hostels. This evidence shows that the AirBnB audience is similar to lower-end hotels and hostels and clearly the big companies in the accommodation sector have completely different audience.

Also, the AirBnB business model, is a proof for itself that small businesses and *PSR* platforms have the tendency to came together. For a very simple reason, *PSR* type platforms offers all the technology infrastructure, specialised marketing and exposure freely to everyone that registers on their platform. Something that before only the larger companies had access to, nowadays small business have it effortlessly being able to price their spaces very competitively with traditional big accommodation enterprises all around the world.

Saying this, there are evidence that AirBnB and Hostel industry have similar segmented touristic public [37, 38]. So, for the rest of this work the author will admit that the AirBnB well documented target audience not only represent the *PSR* target audience (on platforms that require payed services) but also represent the target audience of the hostel industry. In regard to low budget hotels and motels is viable to say that the AirBnB target audience might have high similarities.

In regard to the target audience of AirBnB, there are multiple evidence the AirBnB target audience are individuals from *Generation Y*, young adventurous open minded leisure travellers with no much money. While hotel tourist segment is inclined to on *Builders Generation* or *Baby boomers* leisure travellers and business travellers in general, this public will remain loyal to hotels due to their corporate travel policies, loyalty programmes, and standardised service [37].

For example, the growing desire for unique, unplanned and spontaneous local experiences, from the *Generation Y* is very favourable for a service like Airbnb (and other small business accommodation sectors), because they present easily present themselves as a provider of such experiences. Evidence of that is the company original motto "Travel like a Human" and the new company logo, 2014, that is a symbol for "belonging". Also, the AirBnB co-founder stated: "We're not just a provider of accommodation, we're a provider of experiences. And so we're thinking about, 'How do we make those experiences meaningful in terms of being local, authentic?'" [46].

Also, following (Delo, 2014; Mortimer, 2014)[44, 45] , throughout the years Airbnb advertisement campaigns have always focused on the unique, personal experiences by staying in people's homes, again appealing to the lifestyle that *Generation Y* takes. Another evidence, is that AirBnB also promote a environmentally sustainable way of travelling, something that *Generation Y* is much more concerned than the others generations [38].

From all evidence presented above and much more evidence not worth mentioning, it's clear that *Generation Y* individuals are the AirBnB target audience. Therefore,

from the analysed similarities between businesses, they are likely to be the audience of hostels, other *PSR* platforms and have similarities with the audience of low budget hotels & motels.

These are the exact type of businesses the author wants to focus on because are the ones that feel more the problem to solve in this thesis. So, in the next topic the author will dive into the *Generation Y* touristic choices and concerns.

What are the touristic choices and concerns of *Generation Y*?

Today's *Generation Y* traveller are more experienced, informed, educated, environmental aware, flexible, independent and "harder to please" than ever before.

One of the biggest differences is that new tourists are participators not spectators, they are proud to be the decision makers of their trip, looking to experience and learn rather than merely stand back and rest. To decide they avoid conventional marketing advertisement, instead they make their own independent research though the Web (mainly via social media, tourism web platforms, trusted publications and mainstream films) and by advice from friends and fellow travellers (word of mouth).

For this reasons and the reasons presented in Figure 2.2, things like guided tours, are not attractive to the *Generation Y*. To catch their attention the attraction must offers an exciting, authentic, interactive and educational experience (just what AirBnB offers), where the comfort should not compromise the authenticity of the experience [32].

Comparison of Old and New Tourists

	New Tourists	
Search for the sun	=>	Experience something different
Follow the masses	=>	Want to be in charge
Here today, gone tomorrow	=>	See and enjoy but not destroy
Just to show that you had been	=>	Just for the fun of it
Having	=>	Being
Superiority	=>	Understanding
Like attractions	=>	Like sports
Precautions	=>	Adventurous
Eat in hotel	=>	Try local fare
Homogeneous	=>	Hybrid

Source: Tourism, Technology and Competitive Strategies, Auliana Poon

Figure 2.2: Old Vs New Tourist [32].

Although *Generation Y*, do not care about comfort as much as the other generations, they care about safety and security. This attribute is still the most important attribute when evaluating destinations by all generations [31]. By contrast attributes such as accommodation, service quality, ease of getting to country, language differences, domestic transportation, food and cleanliness. Both *Builders Generation* and *Baby Boomers* place more importance than *Generation Y* [31].

The lack of interest for this attributes by *Generation Y*, supports that *Builders generation* and *Baby Boomers* are critical consumers when comes to comfort and excellent costumer services, willing to pay for it, into more expensive hotels and destinations. Where young tourists by contrast are more likely to be adventurous or near-adventurous,

seeking more non-mainstream destinations with worst infrastructures that have potential to offer more meaningful experiences (like AirBnB).

Now, having all the characteristics of our target audience laid out and knowing what are their choices and concerns in their tourism activities. It is concluded that our target audience, *Generation Y*, desire experiences as opposed to products and services, they also do not care as much with accommodation as the previous generations. These are indicators of probable non-adherence to the IoT Looker to develop though this thesis.

Moreover, they are a technological savvy generation, that are very adaptable to technological advances and constantly seek for more efficient ways to reduce the time of the activities that are not related to the experiences they want to feel, like check-in and check-out process. If the product reduces the time of that chore activities and provide more safety security, certainly the product will catch their attention.

2.1.2 Understanding target owner

There are few literature that study the necessity of the hosts in this industry. In order to hosts achieve cost-savings and profit earning, there are tree primary motivations by the hosts (1) controlling the misbehaviour of the guests, (2) striving to have a good reputation between the guests and (3) secure and reliable payment system.

In regards to the first topic, there is an implicit assumption in tourism consumer behaviour and models that consumers will behave properly, so the tourist "dark side" has received limited attention until now [29]. Following Fullerton and Punj [48], misbehaviour can be anything that violates the previously accepted norms defined between hosts and guests, like damages to the propriety, lack of payment and negative emotions of the guests(such as worry, anger and regret).

Regarding the second topic, the hosts want to strive to have a good reputation by the guests in order to have quality rates into the platform and receive more guests. To improve this, Airbnb incentives both guests and hosts to insert the most personal information as they are comfortable to in the platform. Then, give them a private instant message communication to promote potentially meaningful inter-personal discourses even before the check-in.

Another factor of bad reviews is when despite the host effort, he can't understand the needs and wants of the costumer (mainly due to generational differences) and therefore can't adjust to the guests values. This problem can be partially solved by offering the necessary information to the host about the public that usually uses his home.

Finally the last topic is pretty strait forward, today the payment procedure in the low-end accommodation sector is a task performed by the reservation platform. Following the results in [40], AirBnB complaints about their platform are the ones represented in the Figure 2.3.

Table 1. Complaints against Airbnb organized by themes.

Themes	Percentage reporting
Customer service – basic service and resolution	27%
Web functionality	7%
Verification process	5%
Pricing/fee structure	14%
Payment process	7%
Misrepresentation/no vetting	13%
Uncertainty	21%
Biased reviews	6%

Figure 2.3: Complaints against Airbnb organized by themes [40].

To solve this host motivation, is important to develop the software to improve the areas: Pricing/fee structure and payment process. As is represented the payment process is stable being only 7% of the total complaints to AirBnB company.

2.1.3 Factors to use one accommodation over another

There are substantial literature on the reasons why tourists choose one hotel over another (ex. [49, 50, 51, 52, 53]), where objective is to rate the importance of different individual hotel attributes by individual interviews or surveys to the costumers.

Curiously in this literature, the hotel attributes that are consistently identified by the costumers as most important match perfectly with the attributes that were previously identified for the generations of *Baby Boomers* and *Builders Generation* to chose their destination. Such as: cleanliness, location, reputation, price, value, service quality, room comfort, and security. Clearly not what *Generation Y*, our target tourist values.

Also in this literature, various secondary attributes tend to be perceived as less important such as: restaurant quality, fitness infrastructures (ex. swimming pool or gym), parking facilities and the check-in and check-out procedures.

These studies present important information: hotel costumers, mostly *Baby Boomers* and *Builders Generation*, do not perceive check-in and check-out procedures as important and crucial to their choice. This reenforce that targeting another audience and accommodation sector, where the owner also cares much more about this problem is a good choice.

Finally this literature, highlighted the importance of having easy information on the Web and intuitive online reservations.

In regards on the choice to use non-hotel forms of accommodation over each other (ex. AirBnB, Booking, hostels, home-stays and Couch Surfing), the literature is much more limited.

But again, the most important accommodation attributes identified by the costumers match the attributes of their previously identified target tourist for this sector(*Generation Y*). Such as: unique nature of the experience, freedom that homely accommodations give, personalised service (ex. personal interaction with the hosts and opportunity to receive useful local knowledge from the hosts) and flexibility of having house amenities (kitchen, washing machine...) [54].

Here is a downside point: normally the *Generation Y* tourists like to be in contact

with the hosts to a have a more personalised service. The product to develop is exactly trying to remove the host into the check in process, is this a problem? Does the product interfere with the personalised service?

2.1.4 Overview: Segment challenges and opportunities

Based on the previous analysis, the author will present some challenges and opportunities on the implementation of this technology:

- *Generation Y*, desire experiences as opposed to products and services and do not care as much with accommodation as the previous generations. Therefore, the product must be seen as an efficient way to reduce the time of the activities that are not related to the experiences they want to feel, like check-in. For that the product developed must be convenient and user friendly.
- *Generation Y*, is technological savvy and very adaptable to technological advances. With the proper UI/UX the generation will quickly pick up the technology.
- *Generation Y* like to be in contact with the host to a have a more personalised service. Our product is exactly trying to remove the host into the check in process. How can the product offer this flexibility of not needing an 3^{th} people into the check-in process and simultaneously incentive to a personalised experience?
- The hardware costs have to be covered individually by the hosts so, it must be financially viable for them. How to reduce the cost of hardware and implementation?
- The way to advertise the product to the tourist is via internet (social-media, tourism web platforms, trusted publications) and promoting word of mouth. So, what product extra functionalities can advertise more guests to the hosts that have adopted the system into their accommodation?
- The challenge of developing an product that provides more safety and security, as it stands the primary attribute in touristic choice. For example, it must provide no chances of hacking the door.
- The challenge of developing an product with an easy way of consulting information via web and intuitive online reservations for the guests needs.
- The challenge of developing an product with a solid payment process for the hosts needs.

2.2 Access Control Technologies

This section have as objective explaining the possible technologies that can be used as an access control system. To understand which one is the best fit to solve the problem of this work (removing 3^{th} people into the check-in system, accordingly with the audience needs).

For that each technology is explained sequentially in the following topics:

1. where it is used.

2. How it works.

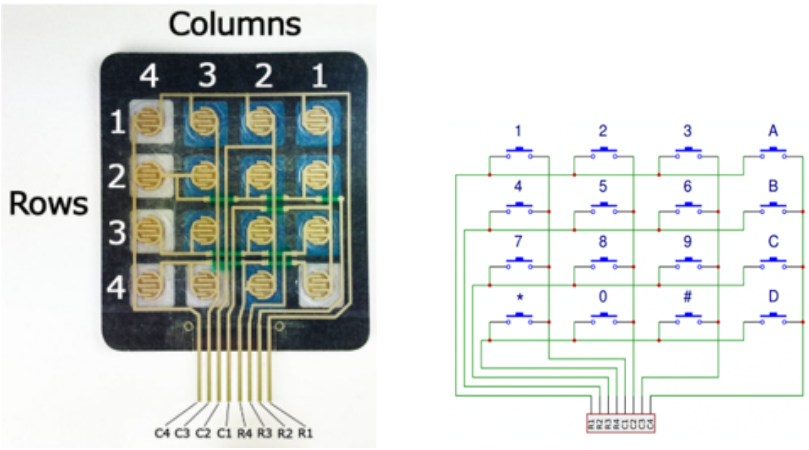
3. What is its actual implementation into the Travel & Tourism sector

2.2.1 Keypads

Keypads remain very useful for access control systems due to their simple implementation and scalability, however they have been used less and less over the years for a very simple reason: it is not a secure and convenient solution. The user only needs the PIN to access the place, it means that this information can be shared an infinite number of times between people. Also, if it is used only for a short period of time, it might be inconvenient for the user to have to memorise the PIN or access it every time.

Figure 2.4: Keypad examples [55].

A keypad is divided in rows and columns, for example a 4x4 keypad (Figure 2.5) is divided in 4 rows and 4 columns. Beneath each number there is a membrane switch. Each row switches are connected though a conductive wire underneath the pad and the same happens to each column. The Figure 2.5 shows how the rows and columns are connected in a 4x4 keypad. The detection method is simple, when a button is pressed, it closes the switch of a column and a row, allowing the current to pass between column pin and row pin. Knowing the row and column pin obviously the number is known.



(a) (b)

Figure 2.5: Keypad workings [56].

There are already multiple products with this technology into the market such as [57, 58, 59]. In every of these systems a servo motor is used to turn around the key or spindle of the lock and open the door. In terms of hacking the door, they are all secure systems with the restriction of course about the pin can be shared infinite number of times.

2.2.2 Barcodes

Barcodes are a very used and suitable solution for product and service identification, this technology is relevant for this work because it also contains few applications in control access systems.

The principle is simple, white points reflects barely all the light and the dark barely reflects none. So, with a scanner or camera the vision software algorithm treats dark columns as 1's and white columns as 0's. Then, from this result is possible to extract valuable information about product or person in question.

Barcodes can be 1D or 2D. 1D barcodes only measure one direction, the parallel white or black columns and a 2D barcode measures two directions, symbols and shapes, being able to present more data per unit area.

Consequently, the result is an array of numbers associated with the parallel white or black columns for the case of 1D barcodes, and matrix of 0's and 1's associated with the shapes and symbols, for the case of 2D barcodes [60].

By the simplicity of the system, the cost is mainly associated with the hardware, camera or scanner (shown in Figure 2.6). Because the cost of printed or digital generated barcodes is almost none.

(a) (b)

Figure 2.6: Scanner and camera barcode readers, respectively [61].

1D Barcodes

Inside 1D barcodes, there are many barcode symbologies, each different protocol have a different symbologies on codding this information, some of the main protocols are: *UPC* (Universal Product Code), *EAN Code, Code128, ITF* and *S1 DataBar* [63].

The UPC protocol is the most commercialised and used protocol, requires 95 parallel columns per barcode and some numbers bellow the bar code (see Figure 2.7). In this manner, the result extracted are a set of 95 numbers (0´s and 1´s) divided into 12 sections.

From the 12 sections, only 9 sections contain information about the product the remaining 3 are designed to help the software figure out which is the position of the barcode. Their names are right guard, centre guard and left guard, shown in Figure 2.7. They have common patterns making possible to the software to identify if the product is turned left/right or upside down.

The remaining 9 sections only contain the information necessary to the identification of the product in question (the primary keys). Then, the changeable information is obtained indirectly. The scanner sends the code to a database where it can fetch all kinds of other information, that is easily changeable and manageable. For example, product prices are managed and changed from the database [62].

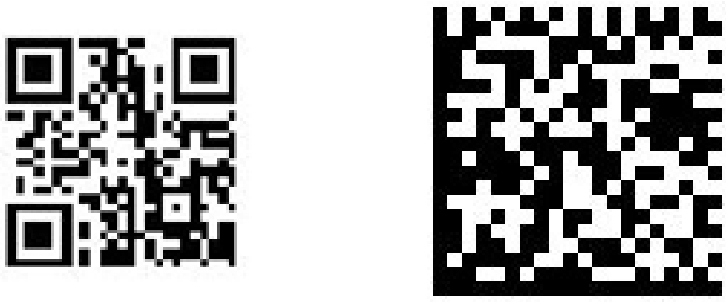
Figure 2.7: UPC 1D Barcode [62].

The importance of understanding how UPC protocol works resides on the fact that all the other protocols follow different rules but the same principle. The software of all them is simple and therefore cheap and scalable.

2D Barcodes

The Two-dimensional requires more complex vision systems but also follow the same principle. The difference is that the result is a 2D matrix of 0's and 1's instead of an array. Also, a camera is needed instead of a scanner and more complex vision software. This possibilities the support to additional modes of data like, numeric, alphanumeric and byte/binary.

The two main protocols for encrypting information into 2D barcodes are *QR code* and *Datamatrix Code* shown in Figure 2.8.



(a) (b)

Figure 2.8: QR code and Datamatrix Code, respectively [60].

The potential 2D barcode technologies was unlocked by its integration with mobile devices [64]. For example, with this integration 2D barcodes can be easily be implemented into control access systems in the tourism sector, by simply using the barcode as "key" printed into the phone screen.

Some prototypes with this concept have already been developed, for example the LibTech project [65] and [66].

In these prototypes, the "keys"(Qr-Codes) have to be changing dynamically and sent via web to the respective user filtering the apartment and check-in time. Simultaneously , the hardware have also to be automatically updating to accept the different Qr-Codes received by the user.

This is a suitable solution allowing the tourist to conveniently access his apartment with the Qr-Code on phone screen. A printed Qr-Code by the user could also could be the "key" allowing even the tourist without smartphones to use the system and to open the door without phone battery. Although, due to the high price of a reader (camera) needed in each access, products of this type have not been adopted by the market.

2.2.3 RFID

RFID system (Radio Frequency Identification), is an automated identification and data capture technology that in a form of contact-less cards have been rapidly implemented in industries such as access control, transportation, instant payments. Also, contains big applications in retail to product identification and more recently on tagging animals [67].

This technology relies mostly on radio frequency (RF) and consists of three major components: the reader, the tag and the information system (Figure 2.9). In a nutshell, the tag contains the relevant information that is read by the reader. Then, similar to the barcode system, the reader connects to an information system (database) where can be added or fetched all other kinds of information [68].

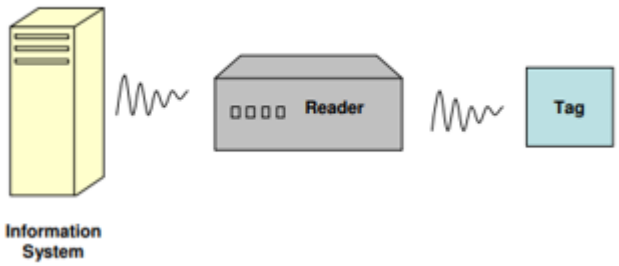
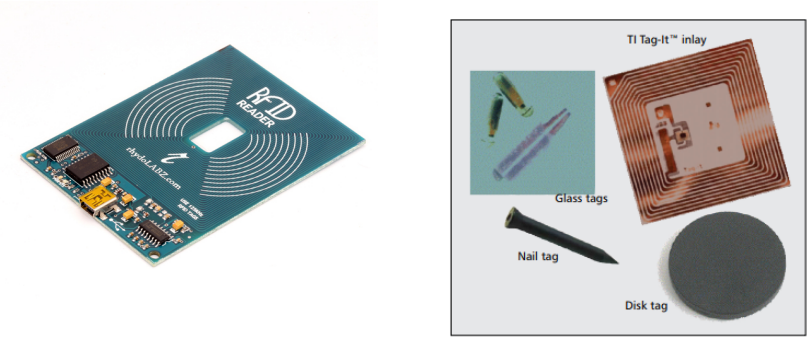


Figure 2.9: RFID System [68].

The tag is the data carrier made by an antenna, a semiconductor chip and some form of encapsulation. The reader is an electronic circuit that transmits and receives radio frequencies across a larger antenna. The function of the tag is to capture energy and transmit the tag's ID via RF, when the reader is responsible for powering the tag and receiving that data.

The tags encapsulation take multiple shapes depending of their business application (Figure 2.10). But more importantly, there are two main types of tags: The active tags and passive tags.



(a) RFID reader (b) RFID tag

Figure 2.10: RFID reader(a) and different types of RFID tags(b) [69].

Passive tags don't have on-tag power sources requiring to be charged by the reader and active tags require on-tag power sources. This causes multiple advantages disadvantages represented in Table 2.1.

Table 2.1: Active Tags Vs passive Tags [68].

Proprieties	
Active tags	Passive tags
1. Higher Functionality 2. Higher Communication range 3. Need of a battery 4. Higher cost cost, size 6. Battery changes (limited lifetime)	1. Less functionality 2.Lower communication range 3. No need of a battery. 4.Lower cost and size 5.Higher durability 6.More volatile to obstructions in the enviroment

Note that higher communication ranges do not present necessarily an advantage, because higher communication range causes higher privacy and security issues. The tags information can be easily tracked and hacked, when exposed to a greater distance [68].

Far field communication vs Near field communication

Without a power supply of their own, passive RFID tags need to be charged by the reader and the only way that happens is by taking advantage of the Electromagnetic (EM) proprieties associated with the RF antennas.

For that, there are two fundamental ways to perform this charging: by magnetic induction or by EM wave capture. This results in two different RFID systems – the near field communication (NFC) and the far field communication, respectively.

The traditionally RFID systems are the ones supported on far-field communications. Near-field communication appeared more recently and is generally called by NFC [69].

RFID systems (Far-Field communication)

To the support of far-field communication, in 1999 MIT developed EPC (Electronic Product code), which is a protocol for a global RFID product labelling, similar to UPC for barcodes [69].

The principle behind far-field communication is the generation of EM waves from the reader´s antenna to capture it from the tag's antenna. A smaller antenna in the tag captures EM energy created by the reader antenna that converted into potential is enough to power its electronics.

Then when the tag is powered a phenomenon called EM backscatter is used to transfer data from tag to reader. In this phenomenon, the antenna will reflect back some of the energy towards the reader, creating a signal that encodes the tag´s ID. The hole process is defined in Figure 2.11 [70].

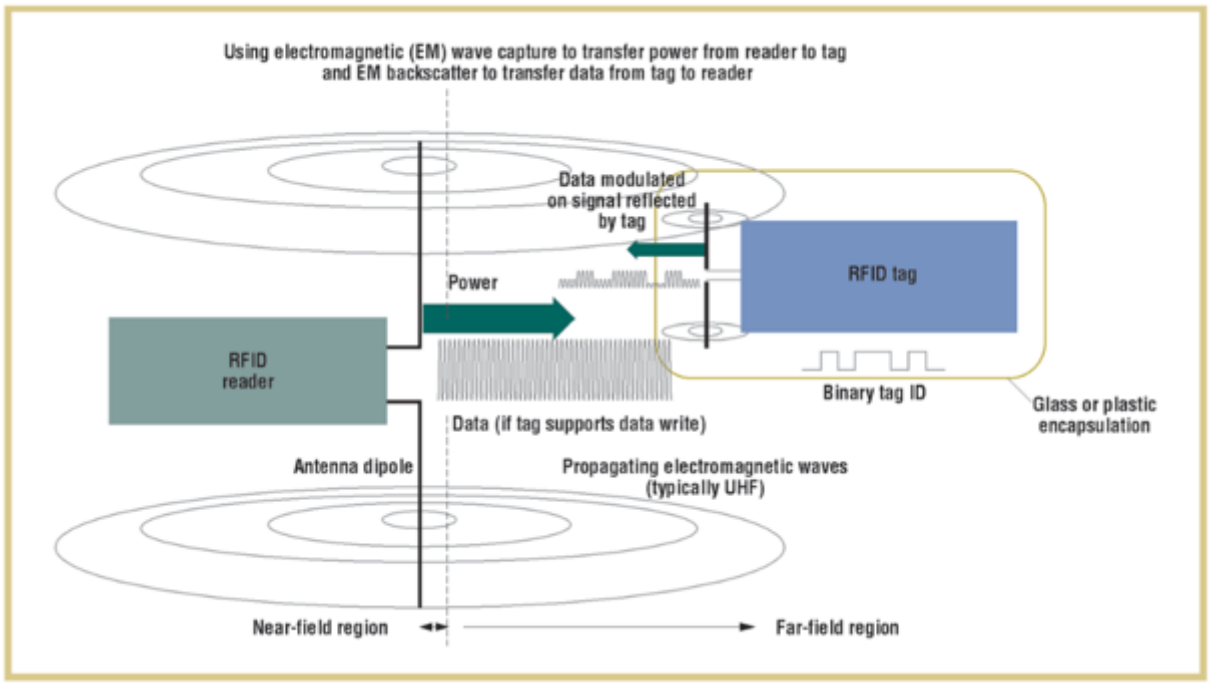


Figure 2.11: RFID System [70].

As said in the beginning of this chapter, this system is massively used from its convenience, small size, reading long range and flexibility. Although, RFID systems are still expensive compared to other technologies and not secure.

2.2.4 NFC (Near-Field communication)

NFC is a technology that only differs from RFID in the way the passive tag is recharged and it is based upon Faraday's principle of magnetic induction (Figure 2.12). The biggest advantage of NFC is that is possible to manufacture NFC devices capable of being both NFC readers and NFC tags, opening a hole new world of communication between peer-to-peer (smartphone-to-smartphone, smartphone-to-tablet, tablet-to-tablet , etc. . .).

Also, the limiting range of this technology has recently became an advantage for security reasons, the power of the magnetic fields used in NFC drops with $1/r^6$, where r is the distance between the reader and the tag. This makes much more difficult the extraction of data at longer distances. At least in comparison with far-field coupling, where the power of the EM waves drops with $1/r^2$ [70].

Of course, it has some disadvantages such as larger antenna coils and slower data transfer rate. But it is compensated with all this advantages plus a simpler system and hence lower costs as well. The Figure 2.12, explain how this technology works.

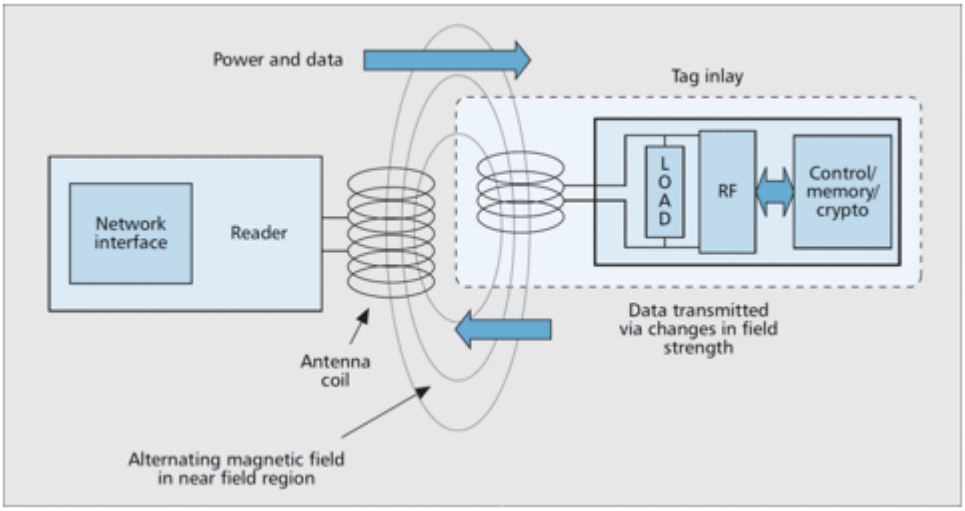


Figure 2.12: NFC System [69].

Both tag and reader antennas are conductive coils on which can pass electric current.

The reader passes an alternating current through the antenna coil to create a magnetic field in the surroundings. When the tag approaches this generated magnetic field, by magnetic induction a small voltage will appear in the tag's antenna coil that is used to power up the tag´s chip.

Then, after tag is powered, mutual inductance appears between the two, per say any variation in tags current also generates a magnetically field that causes small variations on readers voltage. This variation will be primarily caused by the tag´s chip which will decode the tag's ID. Making the connection between tag and reader successful, and making possible to fetch all the user data from the information system.

Like in the case of 2D barcodes, this technology unlocks his potential when integrated with mobile phones. Recently, mobile phones started to appear with the requirements to use NFC with big applications on areas like, payments of bills, electronic ticketing, setting up Wi-Fi/Bluetooth connections (Wi-Fi Direct), control access systems and social networking [71].

In access control systems, NFC can enable people to unlock/lock the door just by proximity between the mobile device and the NFC reader. For example, was a already developed an NFC access control system to manage university access [72] and to manage hotel access [73, 74, 75]. This is a ever growing solution in extreme growth in access control systems.

Despite of its convenience and increased security compared to RFID, this a super

competitive market and this solution have still some security/privacy issues, reduces phone battery life and is not supported by all smart phones yet [76].

2.2.5 Biometrics

The way animals naturally recognise each other is by biometric traits such as face, voice, behaviour etc... Therefore, this kind of information is crucial to human interactions being what we are naturally adapted to use for individual identification.

Due to globalisation and the necessity of scale this process of individual identification, the individual started to be identified by (1) what he knows (password, personal ID number...) and (2) what he have (keys, ID card, passport, phone ...), instead of his intrinsically physical or behavioural traits (biometric traits).

Recently with biometric systems made us came back to the origins. This process of user identification that we humans are so familiarised can be scaled in a fully automated way [77] by biometric systems. In the Figure 2.13 is presented some advantages and disadvantages of biometric systems.

Method	Examples	Properties
What you know	User ID Password PIN	Shared Many passwords easy to guess Forgotten
What you have	Cards Badges Keys	Shared Can be duplicated Lost or stolen
What you know and what you have	ATM card + PIN	Shared PIN a weak link (Writing the PIN on the card)
Something unique about the user	Fingerprint Face Iris Voice print	Not possible to share Repudiation unlikely Forging difficult Cannot be lost or stolen

Figure 2.13: Ways to user identification [78].

Clearly this process is more advantageous for all the reasons presented in the figure 2.13 but also because of the convenience it offers: the user does not need anything new to make his authentication, just his own biological traits. Moreover, this technology have downsides, for example the user have to be subjected to a biometic procedure in order to extract his data, then the user have to trust that unique data to the control access system, and following [78], this systems are still venerable to hackers attacks.

The complete list of biometric traits is shown in Figure 2.14 it consists on voice, face, facial thermogram, hand thermogram, hand vein, fingerprint, gait,hand geometry, iris, palmprint, retina, signature and voice [79].

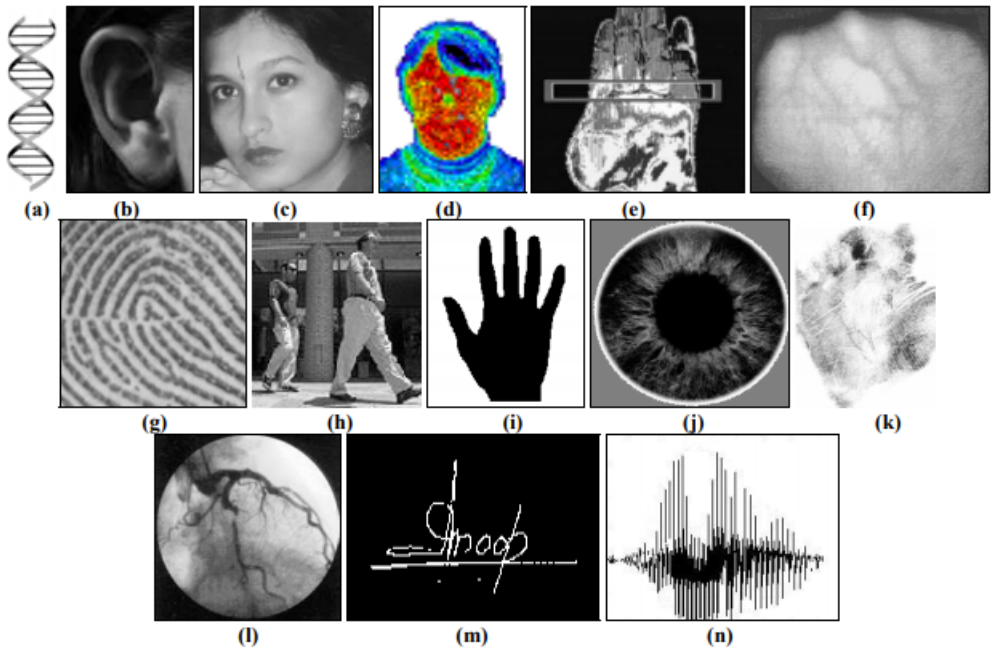


Figure 2.14: Examples of biometric characteristics: a) DNA, b) ear, c) face, d) facial thermogram, e) hand thermogram, f) hand vein, g) fingerprint, h) gait, i) hand geometry, j) iris, k) palmprint, l) retina, m) signature, and n) voice [79].

Of course many of them due to their expensive nature are not suitable to control access systems. So to clarify the reader, the most used biometric traits in control access systems are voice, face, signature(hand writing), palmprint hand geometry, fingerprint, retina and iris, shown on Figure 2.15 ordered by cost and accuracy [80]. Notice that the fingerprint is the most used one due to its better performance in cost and accuracy, however all this systems are still expensive compared to other access control technologies.

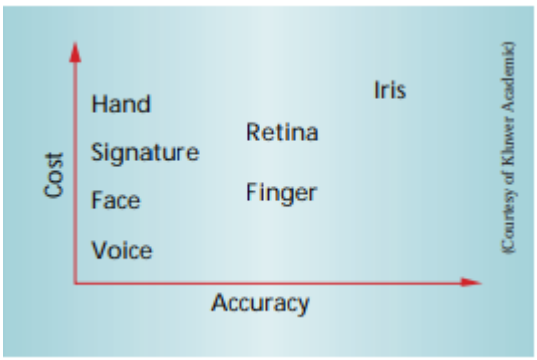


Figure 2.15: Ways to user identification [80].

Despite of all this biometric characteristics a general biometric system is identical in all of them. Following [81] and Figure 2.16, a general biometric system has five subsystems: data collection, transmission, signal processing, decision and data storage.

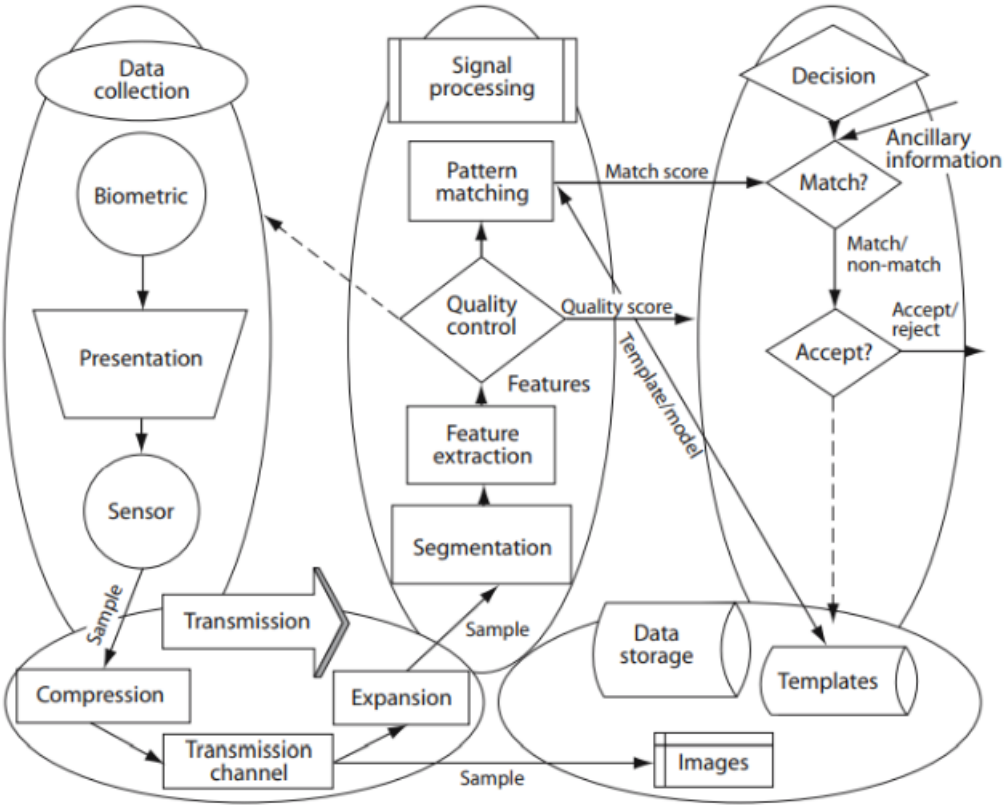


Figure 2.16: Generic biometric system. [81].

The process happens chronologically by this order:

- Data collection: The user characteristics are presented to a sensor to extract the user biometric data.
- Transmission: In most cases, the biometric system collect data in one location but store and process it in another (example: smart-phones). This step is required multiple times because its function is to send the data via web thought the whole process.
- Signal processing: Having acquired the biometric data and transmitted it into the process location, is needed to prepare it to match with other similar measures (user access data in the future). For that there are 4 tasks between this step: segmentation, feature extraction, quality control, and pattern matching. After this tasks the data is highly reduced and only the unique patterns of the individual remain.
- Storage: After Processing the final data is transmitted and stored into a database. To then, be generated a template or model for each individual.
- Decision: The last step, that occurs every time the user tries to access using his biometric trait. Every time the user tries to open the door with his biometric trait, the system determines if there is a "match" or not, by calculating the distance or similarity between the storage data and the input given.

The most used biometric trait in control access systems and in general is the fingerprint, as is exposed in the Figure 2.15 it provides the best ratio between accuracy and cost. Also is the most accepted one by the population, is safe quick and easy to use, for example the company Kimaldi [82] is already commercialising this kind of solution into the hotel industry.

This solution continues to grow because, as said in the beginning of this chapter, it does not represent any burden into the costumers life since they do not need to know or have anything. Also, represents a significant improvement in the security of the guest, because biometric traits cannot be copied, determining by default that is the real user doing the authentication (The authentication process is inherently coupled with the user identification). But still is a high cost solution and do not remove 3th people out of the check-in process [83].

2.2.6 Electronic lock

The trend of smart houses, resulted recently in multiple smart locks companies trying to create more convenient IoT electronic locks. At the time of this writing, company´s such as August [84], Danalock [85], Kevo [86], Okidokeys [87], and Lockitron[88] have smart locks available on the market to purchase and shipping to each one of ours houses. Furthermore, all of them have the ability to connecting the locker via mobile devices or laptop.

All of them are based on the same system. It contains 3 main parts, the IoT lock, the user interface (as phone app or website) and the remote web manufacturer server (Figure 2.17). The only thing that varies is the connection between these subsystems.

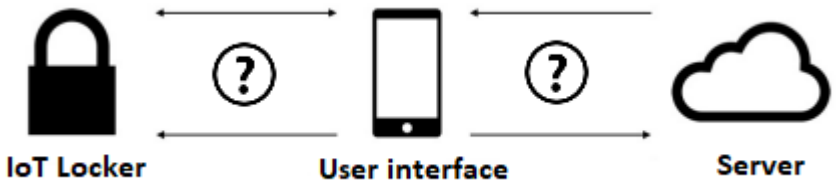


Figure 2.17: IoT lock system.

The first architecture, shown in Figure 2.18, the IoT locker is not directly connected to the internet. Instead the locker is connected via BLE (Bluetooth Low Energy) to the app, being the mobile phone the internet gateway. Which makes the requests to the server and receives the accesses in real time, depending on the log-in account.

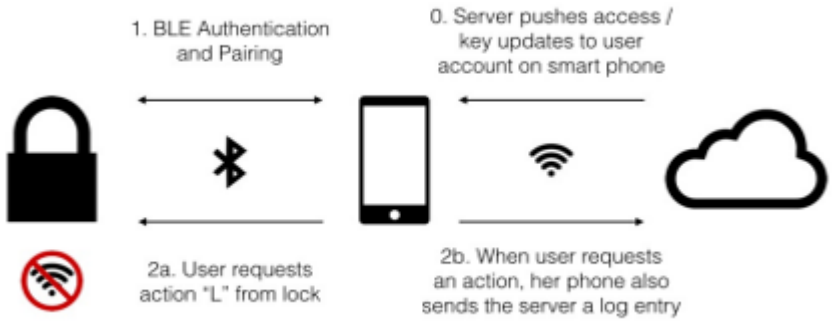


Figure 2.18: Bluetooth Low Energy IoT lock system [89].

In this way users can use their mobile devices to control their accesses, by just installing the company mobile app, creating an account and then paring their mobile via BLE to the locker. Of course, internet connection is needed for the functionality of the system, but this can be easily achieved by the home local wireless channel or mobile data.

The second architecture, shown in Figure 2.20 is only used by Lockitron [88], is very similar to the first one. The difference is the IoT locker have a direct internet connection to the servers by the Wi-Fi apartment network. Then with the provided App and Website, the users depending on their login accesses can change the states of the of server that will open or close the locker.

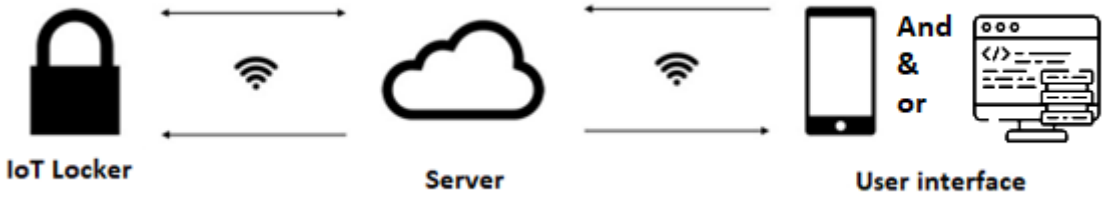


Figure 2.19: WIFI IoT lock system.

Excluding the software development and software maintenance costs, the hardware is cheap and easily implemented requiring only a replacement from traditional deadbolts to electronically controllable ones that can communicate via BLE or via internet and a battery.

Also, this kind of systems are very convenient , to open the door it only takes a press in an app or a click in the website. Even for farther improvement in convenience, August [84] and Danalock [85] have a feature that when the authorised user gets near the door, it unlocks automatically. They can identify the user by the BLE connection and its proximity.

In the next image is presented what is offered by each of this companies.

	Architecture	Interaction model	Devices	Admin interfaces
Kevo	DGC	touch-to-unlock	smartphone, keyfob	mobile app, website
August	DGC	press button in mobile app; automatic unlocking	smartphone	mobile app
Dana	DGC	press button in mobile app; automatic unlocking	smartphone	mobile app, website
Okidokeys	DGC	press button in mobile app	smartphone	mobile app, website
Lockitron	direct Internet connection	press button in mobile app or web interface	smartphone, website	mobile app, website

Figure 2.20: Product architecture of Kevo, August, Dana, Okidokeys and Lockitron IoT lockers [89].

The implementation of this technology is growing rapidly and market competition as well. Recently, August made a partnership with Airbnb to allow keyless access to Airbnb´s hosts and guests though via app. By this solution they reduced completely the need of 3^{th} people creating an safer and time efficient check-in and check-out process [4].

Also, many hotel chains are trying to integrate this solution into their native hotel applications integrating the control access system as just more one service, making it practical and convenient [90].

The hardware of this solution is also an advantage, in this case there is no need of additional hardware such as keypads, RFID readers, BarCode Cameras and so on. It is only needed an microprocessor, like in all other systems, to receive and send data via BLE or Wifi and trigger the action to open the door.

However, this technology is still venerable to attacks from unauthorised people to gain access to the users access information [89].

2.3 Chosen Technology: Characteristics of Hardware & Software

The objective of this section is to chose the most appropriate technology for the product to develop.

Knowing in detail, all technologies that can provide a solution as access control systems and the target audience. The next step, is taking what was previously concluded and compare the possible solutions to our target audience. Following, the target audience the product must have this major characteristics:

1. The product must solve the problem: It must be able to eliminate the necessity of 3^{th} people into the check-in process.
2. The Product must be reliable and provide a clear reduction in the check-in time in a convenient manner, to free this time to the activities the tourist want to experience. In other words **quick-to-use** and **user friendly**.
3. The hardware and implementation costs have to be covered individually by the hosts, so **low cost** is key.
4. The Product must provide **safety and security**, being the primarily attribute that all generation's value most. In this case, provide no chances of hacking, both hardware and software.

For this decision, the next Table 2.2 summarises all the advantages and disadvantages of the previous analysed technologies.

Tecnology	Advanteges	Disavanteges
KeyPad	-Reduced cost, hardware can be scaled. -No need of smartphone to enter.	-Needed to memorize the PIN by the user or to store it. -PIN can be easily shared an infinite number of times. -Slow process of opening the door, the user have to type the PIN.
Barcode	-Quick process of opening the door. The user only needs to show the qr code	-Hardware is hardly scalable due to the high cost of the readers (is needed one camera per door) -Need of some sort of support to carry the QrCode (Phone or paper)
RFID	-Quick process of opening the door. User only needs to tag proximity	-Need of 3th people to deliver the tags(normally in form of cards). -Need of the user to carry the respective tag. -Insecure system vunerable to hack attacks.
NFC	-Quick process of opening the door. User only needs smartphone proximity -The system offer good security against haking atacks	-Need of smartphone to open the access. Not every smartphone have NFC chips. -Need of 3th people to register the necessary information for the configuration of the smartphone NFC chip
Biometric	-Most convenient system since the user doesn't need to know or have anything -Quick process of opening the door -Most secure system which identifies the user by their unique biometric trait.	-Need of 3th people to previously, extract the tourist biometric data. -The tourist have to trust important information to the system. -Hardware & Sofware is hardly scalable due to the high cost (is needed one biometric reader per door, and careful data analysis)
Eletronic Lock (Login credentials)	-Quick process of opening the door. User only needs a press in an app. -Highly scalable system due to the low hardware needs , the user identification is done by the software which is cheap in scale.	-Need of smartphone and battery to open the access. -The system is still vulnerable to unhatorized people attacks.

Table 2.2: Advantages and disadvantages of different control access systems.

The first requirement already eliminates 3 technologies, such as biometric systems (which is needed 3^{th} people to subject the tourist to a biometric procedure and extract

his data), RFID (which is needed 3^{th} people to deliver the tag to tourist) and NFC (which is needed 3^{th} people to register the necessary information for the configuration of the smartphone NFC chip).

Regarding the second requirement, the literature indicates that all technologies are reliable and stable. Although every technology have a different convenience and user-friendly level. In the next bullet topics, the author will present all the technologies from best to worst regarding convenience and user-friendliness from his own judgement.

1. **Biometric** are the most convenient system, since the data capture the requires no time (only fingerprint of the costumer) and user doesn't need to know or have anything.
2. **Electronic Lock**, it provides quick access to open the door, for that the user only needs WiFi connection and press a button (it can be done from distance). It can be a problem in case of no phone battery.
3. **NFC**, also super convenient as the user only needs smartphone proximity. It can be a problem if the smartphone is lost or with no battery. Also may prove inconvenient because not every smartphone have NFC chips.
4. **RFID**, is quick on opening the door and the user only needs tag's proximity (card, bracelet...). It requires the user carrying extra stuff and can be problem in case of tag lost.
5. **KeyPad** is a slow data capture in comparison to others because the user have to insert a pin to enter, what requires some effort. The user doesn't need to have anything to open the door, although the process takes more time and can be a problem in case of PIN forget.
6. **Barcode**, the user needs to open the QrCode in his phone and put it in the right position in front of the camera. This is a process that do not require carrying extra stuff but takes more time and can be a problem in case of no phone battery.

The third requirement is quantitative, hardware plus implementation costs, therefore is easy to evaluate. Again a list is presented from best to worst regarding the cost of the technology.

1. **Electronic lock**: The cheapest technology due to almost no additional hardware needed per door and easy implementation. The only hardware needed is a micro-controler and some motor to open the previously installed deadbolt (something that every other needs).
2. **Keypad**: Needed one keypad plus the electronic lock hardware per door. The keypad cost is low, the lowest of all others data capture mechanisms.
3. **RFID**: It's needed one RFID reader per door, that is still highly costly when is implemented in scale.
4. **NFC**: The same as RIFD, the difference is that the NFC readers are lightly more expensive that RFID readers
5. **Barcode**: Still very expensive due to the high price of a reader (camera) needed in each door.

6. **Biometric**: Undeniably the most expensive system are due to the need of a biometric reader per door, and a complex data analysis software.

The fourth requirement is also well documented, the information researched in this chapter indicates that all managing software's are vulnerable to hackers attacks in the same manner. So the comparison from best to worse, will be based on the security of the hardware capturing and storage data:

1. **Biometric**: Most secure data. Although the management software is still vulnerable to hacker attack's as all the others are. It represents a significant improvement in the security of the guest, because biometric traits cannot be copied, determining by default that is the real user doing the authentication (The authentication process is inherently coupled with the user identification). The captured data is very hard to replicate.

2. **NFC**: The power of the magnetic fields used in NFC communication drops with $1/r^6$. This physical phenomenon makes very difficult the extraction of data at longer distances. The user information into the NFC telephone tags are less likely to be hacked than any other system.

3. **Electronic Lock**: There are studies where Log-in credentials of the systems have been hacked. However, this is still more secure than all others technologies bellow. Because in a login system can be added a lot of security functionalities.

4. **Keypads**: It is not a safe and secure. The user only needs the PIN to access the place, it means once the information is hacked this information can be shared an infinite number of times between people, with no security restrictions.

5. **Barcodes**: It is not a safe and secure. The user only needs barcode as "key" printed into the phone screen, once the information is hacked this information can be shared an infinite number of times between people (in form of PDF or printed Qr Code), with no security restrictions.

6. **RFID**: The opposite of NFC. The power of the radio frequency used in NFC communication drops with $1/r^2$. This physical phenomenon makes easy the extraction of data at medium distances. The user information stored the the RFID card (or any other tag) can be easily hacked.

Following the previous analysis the technology that meets the first requirement and have a better overall performance into the another tree requirements is the Eletronic Lock. Therefore, the **technology chosen to the proposed solution in the next section will be electronic lock**.

Finally, there are secondary important characteristics, that do not affect the choice of the hardware technology they are characteristics that must be implemented into the software functionalities:

- The product must appeal to a better personalised interaction between host and guest. However, the objective of the product is the removal of the host into the check in process. To overcome this challenge software functionalities can be used to increase meaningful contact between host and tourist. Such as, direct private

instant message, communication before the check-in, and personalised information to the host about his average guest.

- The product must be known and relevant to the tourist to generate more guests to the hosts. The key is to promote the product by online information and word of mouth. It can be achieved by adding, marketing functionalities such as social-media sharing buttons and more.
- The Software must provide an easy way of consulting the web accommodation information, intuitive online reservations system and solid payment process.

Following the Lean methodology and taking all the considerations of the research, next chapter will explain which prototype will be developed and the its business model.

Part III

Business Model

Chapter 3

Business Model

The importance of linking efficiently the R&D and product development with the business world has become increasingly evident. For that, business models were developed.

In this thesis makes sense to develop a business model, in order to understand better the product applicability's into the business world.

This chapter will firstly explain what is a Business Model Canvas (*BMC*), then explain what are their adaptation to Start-Up products (Lean business model canvas). To therefore, create a business model to the business idea in this thesis.

3.1 Business Model Canvas, *BMC*.

The Business Model Canvas identifies the essential parts of a business. This business model is actually the most famous with more that 650,000 people all over the world using it and it is represented in the Figure 3.1.

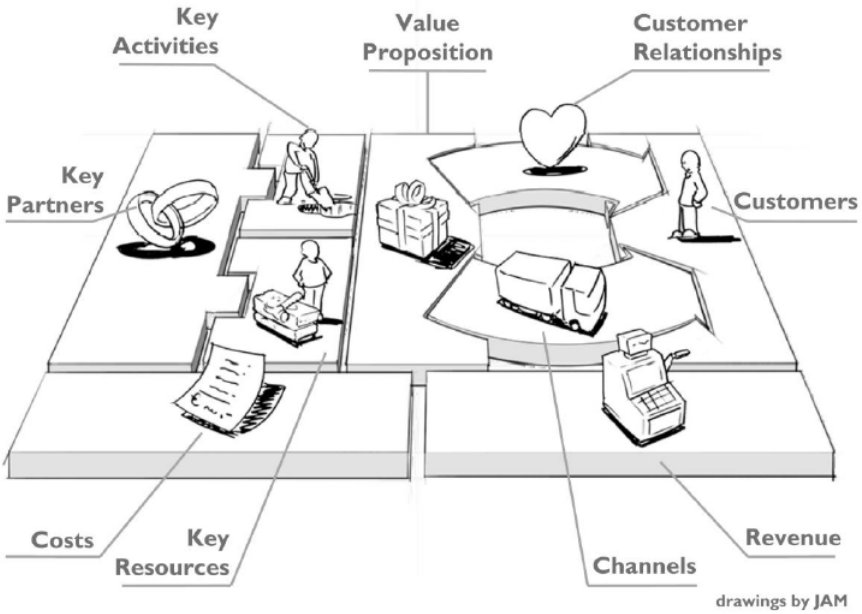


Figure 3.1: Business Model Canvas, *BMC* [94].

Following [94], the business model canvas is divided by:

1. **Right side**:

   - Customers: Describes all the people that are receiving value, from simple users to paying costumers.
   - Value proposition: Describes the value that is offered to each consumer.
   - Channels: Describes the ways you are interacting with your customers and delivering value.
   - Customer relationships: Describes the relationship that you want to establish with your costumer.
   - Revenue streams: Describes how to capture the offered value, though price mechanisms.

2. **Left side**:

   - Key resources: Indispensable Assets for the business.
   - key activities: The essential things you needed to perform well.
   - Key partners: All those who help leveraging you business model.
   - Cost Structure: The variable and fixed costs of the business.

BMC is appealing due to their simplicity, although it was created to well established businesses and is not very really applicable to Startup's that live under extreme uncertain conditions.

So, in order to help entrepreneurs in a early stage of their business, an variation of *BMC* based Lean Methodology was created by Maurya (2010)[95]. This variation is called Lean Canvas business model (Lean *BMC*) and is a problem-solution approach oriented to the costumer, explained in the next section.

3.2 Lean Business Model Canvas, *Lean BMC.*

Based on the issues of the *BMC* model, Maurya (2010) proposes to replace four boxes of the original *BMC* with: problem, solution, key metrics and Unfair advantage (represented in Figure 3.2). Fauvel, C. (2013) [94] presents multiple arguments that this model is more adaptable to Start-Up products and entrepreneur-focused projects, therefore provides a better framework for the product developed in this work.

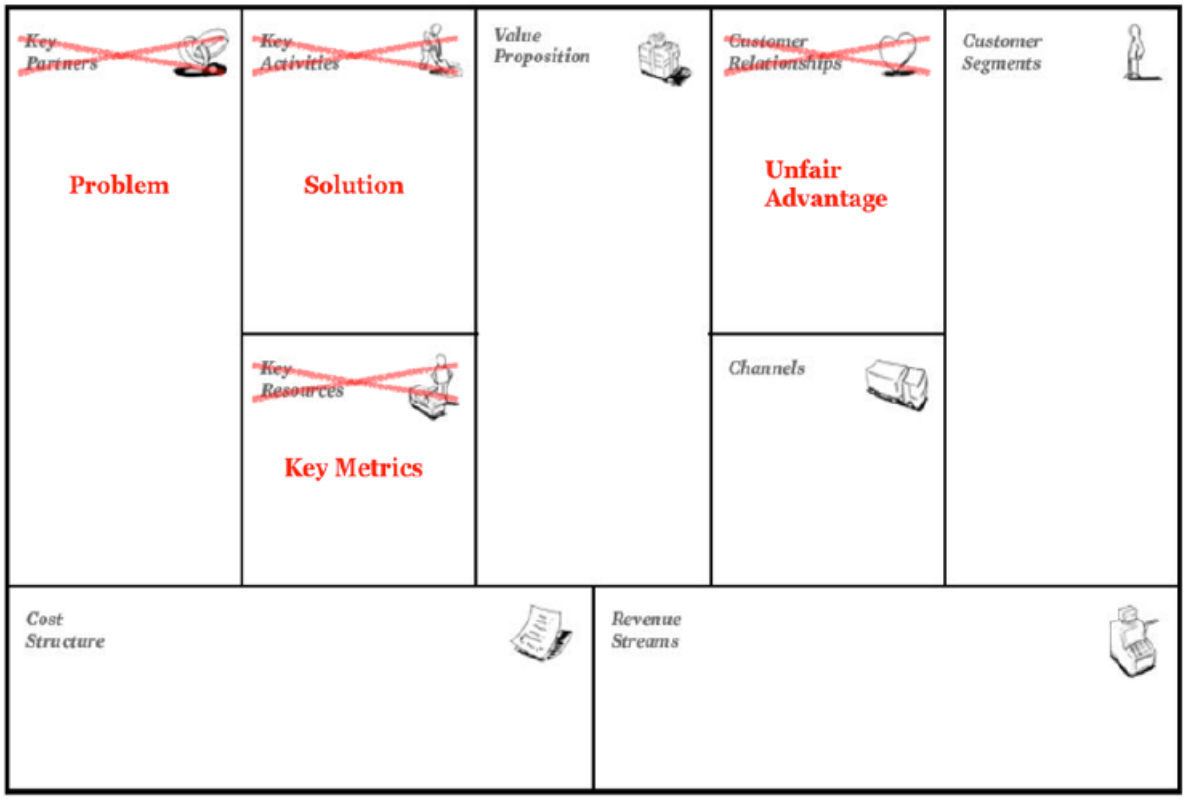


Figure 3.2: Lean Business Model Canvas, *Lean BMC* [94].

The next step is understanding each block of this model and adapt them to the business idea presented in this thesis. This will explain how the product developed in this thesis can be profitable, generate value to society and present itself as an innovation.

The Lean BMC blocks are the typical questions from investors, business angels and venture capitalists.

Some blocks are intuitive to understand and are already studied in detail during the course of the last chapters, such as:

- **Problem**: Maurya (2010) wants the entrepreneurs to find the real problem first in order to build the right product or service to solve it. To the case of this work, there are 2 problems one for the accommodation host and one for the tourist (previously defined in the sections 1.1.1 and 2.1.1):
  1. In this lower-end of the accommodation sector, check-in procedures must rely on a host who likely has many other responsibilities and may not be present every time, and may not have the capital for a reception 24/7.
  2. This traditional check-in procedures (via traditional keys) also causes inconvenience in the tourist experience, due to their increased check-in time and unsuspected occurrences.
- **Costumer segment**: It is important to identify which personas feel the most pain out of that problem to further adapt the solution to their needs. There are 2 costumer segments:

1. The owners of the lower-end accommodation sector (mainly hostel, PSR platforms owners and low budget motel/hotel). Explained in detail in 2.1.2.
2. The tourists from Generation Y, the normal users of lower-end accommodation sector. Explained in detail in the section 2.1.1.

- **Solution**: Based on the product and target audience a solution was chosen.
  1. An IoT locker and web platforms capable of removing 3^{th} people into the check-in procedures. It is based on Electronic Lock technology (explained in chapter 2.2.6), which allows the user to make online reservations and then open the requested door quickly via a software button.
- **Unique Value Proposition**: Is no accident that the Unique value proposition takes the central part of Lean BMC (Figure 3.2), it is a message meant to catch the attention of our costumers by describing the uniqueness of our product and it's key differences from the existing alternatives.
  1. This is the solution that can remove 3^{th} people into the check-in procedures and simultaneously have the best overall performance in the main costumer segment's concern's pointed in section 2.3 (Cost, security and quick-to-use).
  2. Also contains several secondary functionalities designed for the consumer needs and concern's (referenced in the final of the section 2.3, based on the conclusions presented in the section 2.1.4).

The rest of the topics will be evaluated in the next subtopics. There is recommended to fill the Lean BMC in the following order: (1) Costumer Segment, (2) Problem, (3) Revenue Streams, (4) Solution, (5) Unique value proposition, (6) Channels, (7) Key Metrics, (8) Cost Structure and (9) Unfair Advantage. Although is not obligatory because every topic is linked with each other.

3.2.1 Revenue Streams

The objective would be to implement the solution as a service into the PSR individual owners, low-budget hotel/motel or hostels that are interested in the value that the product can add to their costumers. With this service they would receive an web platform were their clients could make an online reservation and have keyless access to the room via a button in their device.

For example, the service could be delivered as monthly payment for the installations and maintenance, plus a payment by each individual locker installed. The monthly payment could vary with the number of lockers installed into the client accommodation business.

With this configurations our revenue streams would come from the accommodation businesses payments, having a business-to-business (B2B) philosophy. Also, as the product would be sold as service with a monthly fee, what will create a much more stable revenue stream good for the financial viability of the idea.

It's also important to note that the product could benefit by having partnerships with PSR platforms. For example, to integrate the service into their platforms where the interested hosts payment remains exactly the same and those platforms retain a commission.

3.2.2 Channels

Different communication Chanel's must be specified for each one of the consumer segments: The *Generation Y* tourist and Lower-end accommodation host.

The channels to the owner will be mainly word of mouth, person to person sales (because we want them to compromise with the service into the long term) and of course also creating a greater awareness in the tourist itself to develop an greater interest in their part.

For selling to the owner, we should look the value proposition which part interests them most. The ability to save time and money by managing automatically their check-in procedures should be the primary message. Also, must be re-enforced that is the cheapest model in the market because of its cheap hardware and implementation, is secure and have a reliable payment system. The needs of the owners such as: controlling the misbehaviour of the guests and the need to have a good reputation between the guests (referenced in section 2.1.2). Could be used as well, referring how the secondary functionalities (represented in the end of section 2.3) could help in these topics.

For creating more awareness on the tourist, the preferential communication channel's of generation Y must be used. Those channel's are social media, web trusted publications, tourism web platforms and mainstream-films (studied in section 2.1.1). However the biggest channel of this product would be always word of mouth and it depends on the service quality.

In order to sell this product to the tourist it must be sold as an experience. The product must be seen as an convenient and safe way to reduce the time of the activities that are not related to the experiences they want to feel, in this case check-in activities.

Secondary characteristics can be also used to trigger interest. Such as the product have features that allows the tourist to have more personalised integration with the host.

3.2.3 Cost structure

It consists in the variable and fixed costs for the enterprise to run. Normally it have variables such as Product development, marketing expenses, salaries, hardware, etc... Those costs will not be possible to evaluate inside this thesis, although the hardware cost of the MVP developed will be explained the section 4.28.

3.2.4 Unfair Advantage

Maurya (2010) [95], also suggests having a box for the unfair competitive advantage. This means a special thing about your idea that competitors are not able to obtain in any possible way. Although the product contains multiple competitive advantages, an unfair advantage is not present in this business idea. Due to the over saturated market of control access systems into the tourism sector, this unfair advantage have to be generated by analysing user response.

3.2.5 MVP (Minimum Valuable Product)

The Key Features, the only remaining block to fill out, will be tested by an *MVP* (Minimum valuable Product).

In the startup enterprises, businesses models are only hypothesis where some of them are confirmed and others don't. This confirmations are usually done by MVP, following the Lean management methodologies [11].

Following Eric Reis (2011) [11], the MVP is that version of the product that enables a full turn of the Build-Measure-Learn loop with a minimum amount of effort and the least amount of development time.

This Build-Measure-Learn feedback loop is at the core of the Lean management model. The fundamental activity of a startup to cyclically, **build** turning ideas into products, **measure** how customers respond to then, **learn** with that information. To therefore, adapt the product to the costumers needs once again and iterate again (Process represented in the figure 3.3).

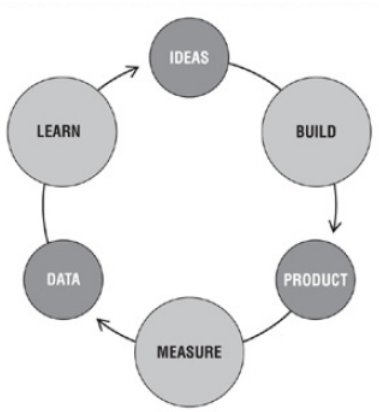


Figure 3.3: Minimise the time though the loop an MVP [11].

The hypotheses to test by the *MVP* is if the value proposition offered to the booth costumer segments is sufficiently to the market to adopt the business idea.

To enter in the build-measure-learn feedback loop as quickly as possible and to the product have some academic utility, the *MVP* was developed as an access control system to the university ambient. It makes sense because the public using this product would be students that are a considerable part of the Generation Y tourist consumer segment. The students can be an early adopter inside a bigger Generation Y touristic public.

Although, due to adaptation to university environment the MVP presents one major limitation: It does not have potential to test the owner costumer segment of the business model. The equivalent to the "Owner" in the developed MVP would be the professor, which are two very different public's.

But quickly the developed MVP is adapted with an payment system and different layout of information being ready to ship to an accommodation business and measure booth audiences. For now, the MVP will only test the tourist(students) by the key metrics presented below:

- **Key Metrics**: Following Maurya (2010) [95], the entrepreneur's must focus on the few Key Performance Indicators KPIs to evaluate the validity of the business model. The KPIs of the developed *MVP* be:

    1. Registered Students.

2. Number of clicks to open the door.
3. Number of doors opened.

The next chapter will explain in detail the *MVP* and its technological intricacies. Also how the research in the state of art and the business model changed the MVP to adapt itself to the consumer needs.

Part IV

Conceptual solution

Chapter 4

Conceptual solution

This chapter objective is to explain in detail the MVP and its technological intricacies.

The MVP main objective is the automation of the check-in process into the tourist accommodation sector following all the characteristics referenced in the section 2.3 and the business model, chapter 3.

Some secondary characteristics were pointed out (in the final of section 2.3), although not all of them are needed to validate the business. So into the MVP not all the secondary characteristics were implemented. Finally, for the reasons explained in the section 3.2.5 the *MVP* was developed to be used into Aveiro university mechanical engineer laboratories, that can be quickly put into the costumer's hands, learn and iterate with them.

The costumer experience offered by the MVP, from opening the website to open the desired laboratory must be as follows:

1. **Sign Up**: The user need to sign up in order to the system know who he is.
2. **Request an Access**: The user chose when and where he want to enter.
3. **Wait for confirmation**: A confirmation email will be sent to responsible host to approve the user access or not.
4. **Open the door with one click**: When the responsible host approves, the user receives an email with a button to open the door. In his smartphone or any other device.

The user must be able to consult the rooms information before logging in, however for the system to work the actions above must be performed sequentially and the user experience must be intuitive with tips along the way of what is missing and what have already been done. For example:

- Reminding the user that needs to be logged in to request an access.
- Alert and block the user, if in a small period of time he is asking multiple requests for the same access.
- Alert the user of what accesses he have requested with validation of the host. To then motivate him to use those accesses.

4.1 Solution General overview

In general terms, for this to happen there are some interactions that the system have to perform. Firstly the Web platform must link the user and the database, inserting automatically into the database all the necessary data to the access of the user and other important information. Secondly, the host must have access to that database to keep track of all the client data (check-in times, information, accesses...) and thirdly, the control access system (*IoT* locker) have to communicate with the database to know what are the valid reservations and decide to give access to the user or not (when he tries to open the door on the web platform). The Figure 4.1, summarises this interactions and requirements that the system have to meet.

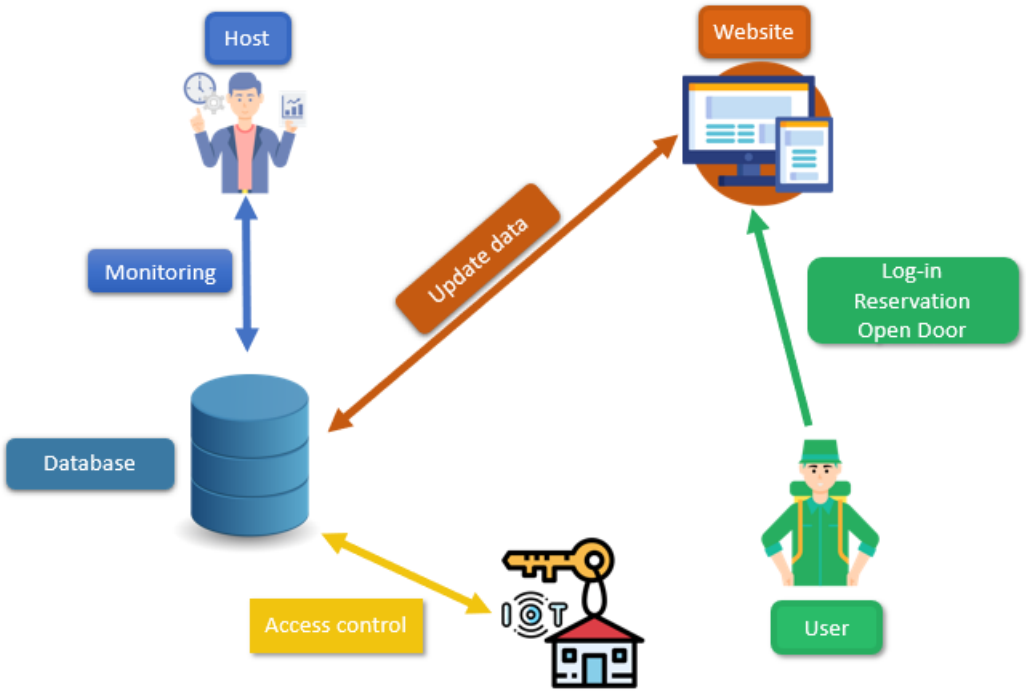


Figure 4.1: General functionality.

However to understand the solution in detail the explanation needs to get more technical.

To make all this functionalities possible the system must communicate, by *HTTP* (Hypertext Transfer Protocol) and *MQTT* (Message Queuing Telemetry Transport), between all the fundamental blocks presented in the Figure 4.2, which are: Email client; React.js client; Node.js server; MongoDB Database; *MQTT* Broker; All the individual *IoT* lockers associated to each room.

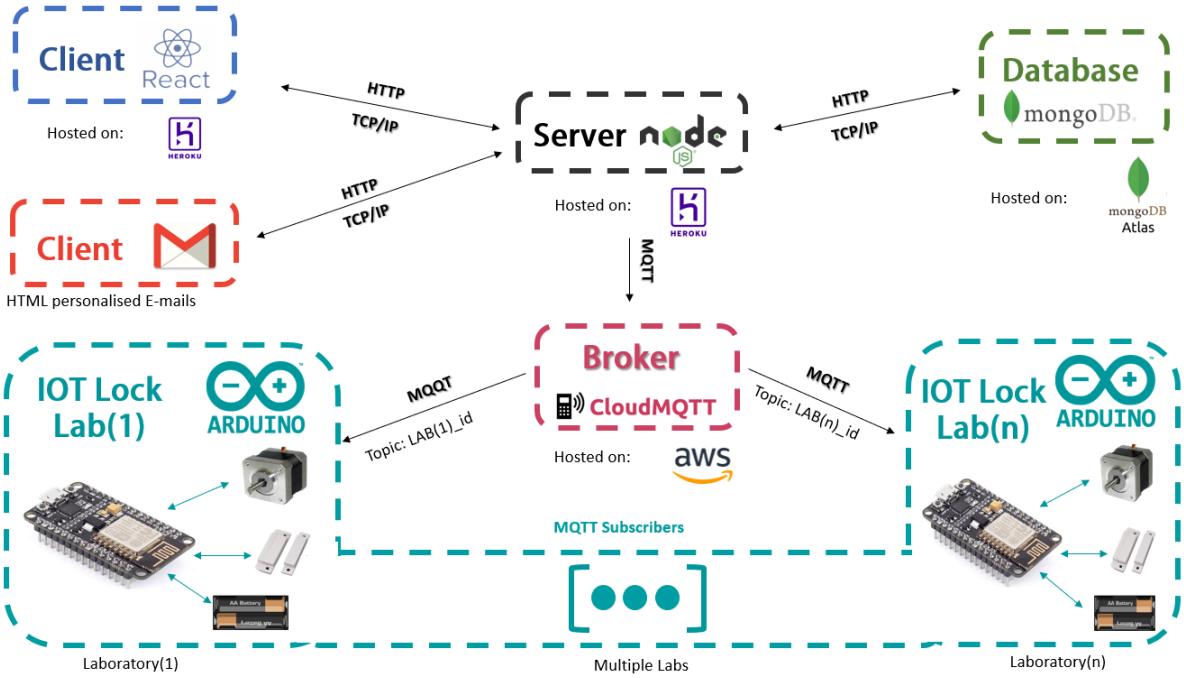


Figure 4.2: General Technological Shema: Wi-Fi *IoT* lock system.

Each block of this system is a different technology. By their coordination and interaction the product can perform all the tasks presented in the Figure 4.1.

This chapter will start by presenting some fundamental knowledge about web development to further explain what is each solution technological block individually, how they interact and finally how the fluxes of information are performed between them (to accomplish the desired tasks presented in the Figure 4.1).

4.2 Technological Overview

4.2.1 How internet works, fundamentals

Web develop is a vast and complex area. Therefore some fundamentals about this area are mandatory to understand the product's software and following topics.

The most important and fundamental steeping stone of web development technologies is the *client-server model*. This model have tree fundamental pieces:

- **Client**: Entity that asks for the service, normally the browser.
- **Server**: Entity who provides the requested service to the client.
- **Communication Protocol**: Way of communicating between those two entities. These communications are based on *TCP/IP* transfer data protocols.

The servers are in the central place, being the entity that have to answer to all the requests made by the client and provide the service. Also, the server should be always available to receive requests, by their public server *IP* address.

Browsing Google

Let's take the example of browsing google.com to understand this model in practice.

Take in consideration the Figure 4.3. The process starts when the user inserts the link of google.com in the top of the browser (Client). By this action, in technical terms, the user is telling the browser to send a *TCP* request to google's servers, and return the service the user wants.

However, the browser can't make that request already because the he does not know the Google servers *IP* address. For that, the browser by *TCP* communication protocols and using the ISP, internet service provider, infrastructure (such as: NOS, MEO, SAPO, Vodafone...) goes all the way until reach the *DNS* associated with that specific domain.

The *DNS* is the Domain Name Service, it consists on a database that have a list of all server *IP* addresses associated with that domain (in google case is the ".com" domain, but there are a lot other domains such as the Portuguese normal one ".pt"). After the request reach the *DNS*, it returns to the browser the server *IP* address (see example Figure 4.3).

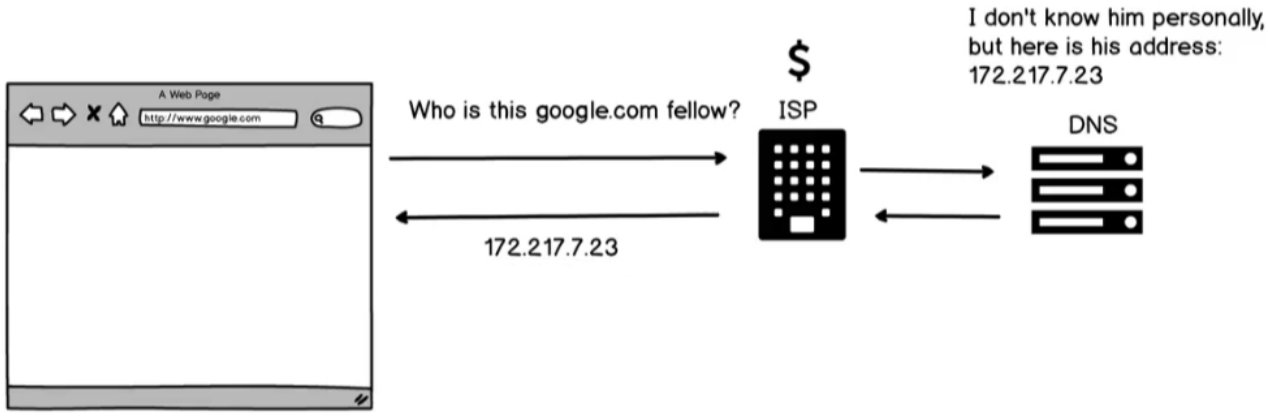


Figure 4.3: The process until the browser gets the Server *IP* address. Example of google.com, the *DNS* returns "172.2.17.7.23" that is exactly the server *IP* address of "www.google.com".

The process continues with the Figure 4.4. Finally, the browser have the server *IP* address and proceed with the communication to the google servers. This time, using google's server *IP* address the browser asks google's servers to return the necessary data for the service in question. Then, the server return that information in the form of *HTML*, *CSS* and *JavaScript* files (see Figure 4.4).

The server can only send *HTML* files to the browser with linked *CSS* and *JavaScript* files, for a simple reason: because the browser is a piece of software in our operating system (such as: Google Chrome; Opera; Internet Explorer; Firefox...) that are purposely developed to only understand and read those type of files.

So, the main function of the browser is to receive information and render it to the user, called the "Front-end development", and the main function of the server is to return the correct files to the browser, called the "Back-end development". Where each file extension have a different purpose:

- **HTML**: File extension to insert content into the website. Like, to write text into the website, inserting tables, hyperlinks, images, forms... But with no styling.

- **CSS**: File extension to add styling into the website, every *HTML* tag can be fully personalised and styled by *CSS* classes and *IDs*.

- **Javascript**: File extension that allows actions to be performed in the web pages. *JavaScript* is a programming language, therefore it can be used to perform any type of computation offering great flexibility to website functionalities.

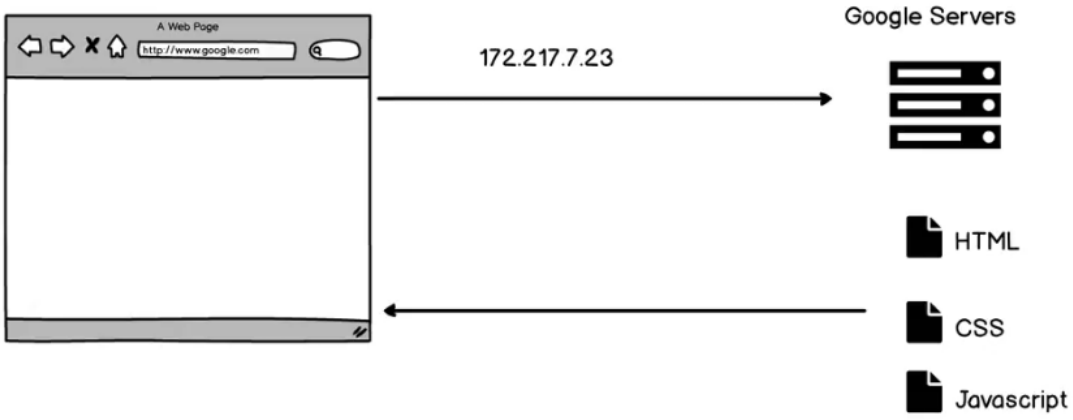


Figure 4.4: Getting the response from google servers.

Finally, the *TCP* communication exchange information all over the world, by a huge infrastructure all around the globe to transfer the data, wireless and non-wireless. It is represented in the Figure 4.5 and is called the *internet infrastructure*.

In a nutshell, all starts at our home wireless *TCP* communication point by the *router*, this device communicates with the modem and the modem communicates with wireless transmitters until reaching the ISP network, that are a series of cables around the country that perform *TCP/IP* communications. This network of cables are centralised in the respective in ISP (Internet Service Provider) and this infrastructure is only a tiny point inside the Internet Backbone. The internet Backbone is an outstanding network of submarine cables that are responsible to transmit the information between countries and other longer distances, this outstanding network can be consulted here [92].

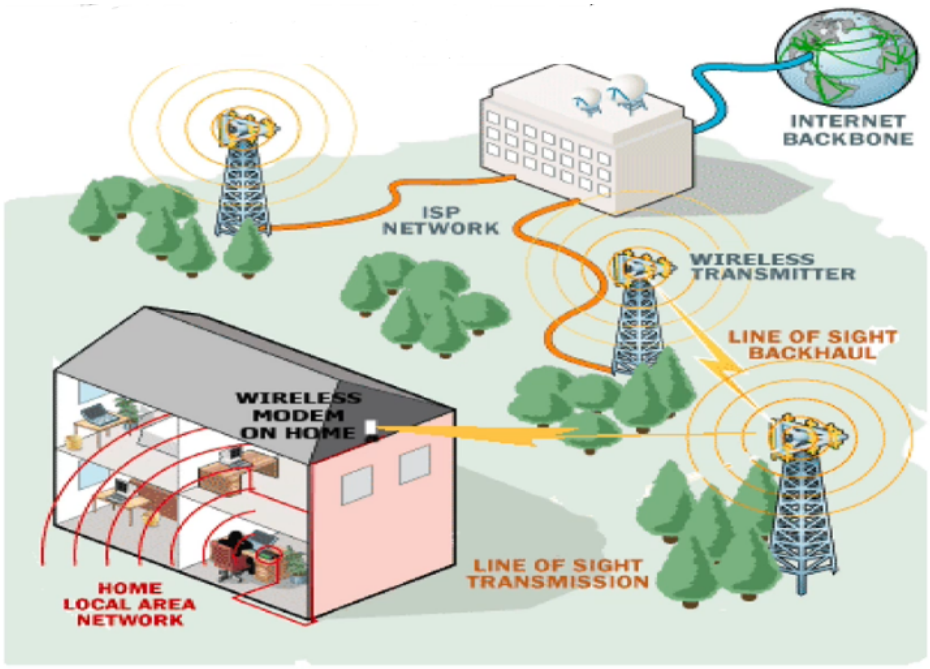


Figure 4.5: Internet infrastructure.

So each time a request is made by a client at any point of the globe, this request have to navigate though the internet infrastructure by *TCP* data transfer protocols all the way until the desired server location, and then the response of the server have to go, in the same way, back to the browser. The time that the user is waiting for the browser response is exactly the time that this trip takes (this trip is divided into many trips). This time is mainly increased by 3 factors: Location of the server, number of trips and size of the files (see Figure 4.6).

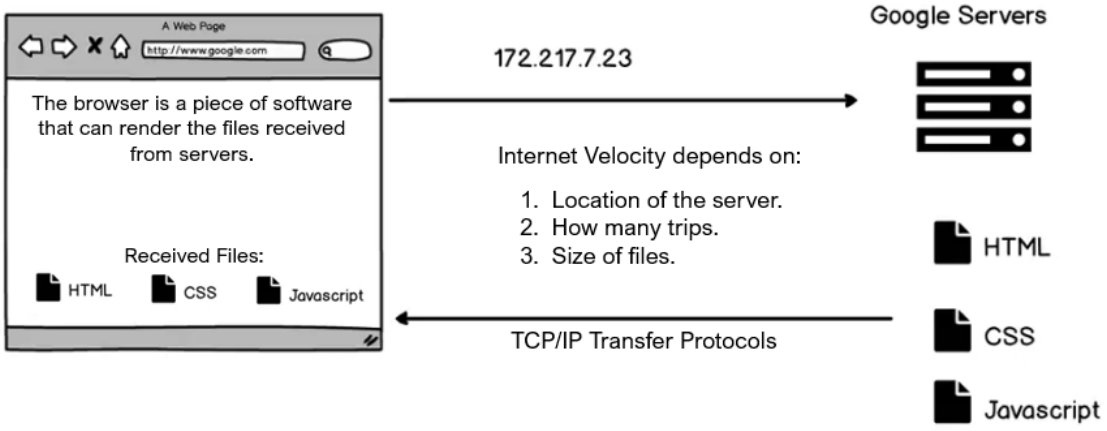


Figure 4.6: Time that the user is waiting for the browser response.

4.2.2 In practical terms: Front-end and back-end

After this small introduction about the internet, the reader have the foundations to understand how the different areas of web software are developed, a process that is represented in the Figure 4.7.

In practical terms the web software is divided in 3 big areas, the front-end development (everything that the client, browser, receives and the user see), the back-end development (making sure the client receives the requested files with the correct information) and the communication between the two (by *TCP* transfer data protocols such as *HTTP*).

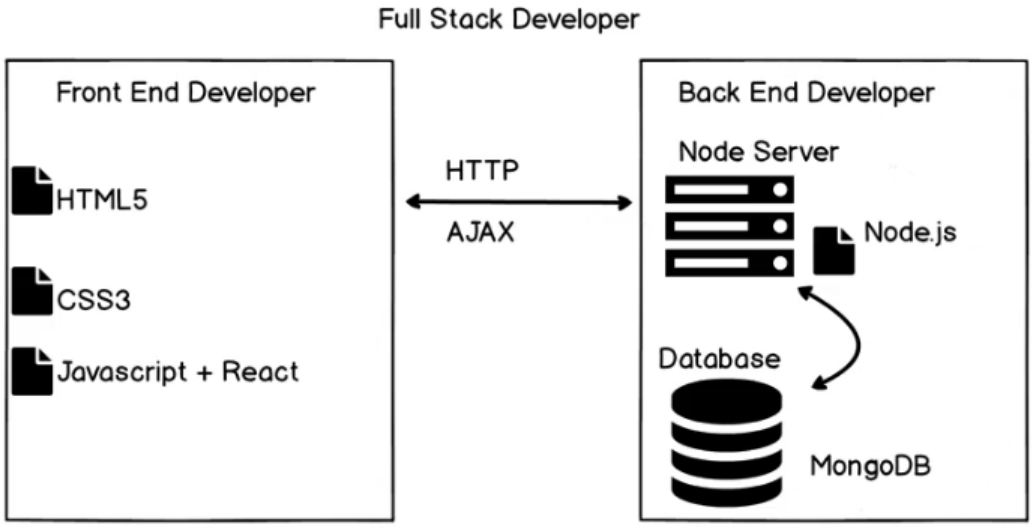


Figure 4.7: Front-end, back-end and interaction between them.

Front-end

The front-end is everything the user sees or interact with, which is contained on the browser *HTML*, *CSS* and *JavaScript* received files. In order to understand the technologies used in this work, there are two front-end topics that have to be explained: (1) the interaction between *JavaScript*, *HTML* and *CSS* and the (2) workings of the browser.

Firstly, *JavaScript* allows actions to be performed in the web pages by changing dynamically the *HTML* and *CSS* on the website. Above, there is a list of some manipulations that *JavaScript* can do:

- Change all the *HTML* elements in the page
- Change all the *HTML* attributes in the page
- Change all the *CSS* styles in the page
- Removing existing *HTML* elements and attributes
- Add new *HTML* elements and attributes
- Can react to all existing *HTML* events in the page
- Can create new *HTML* events in the page
- Can create new *HTML* events in the page

Secondly, this is possible because all browsers in their core are a *JavaScript* engines, being able to read and compile *JavaScript* language and storing every information within the data structures of *JavaScript* language.

The *HTML* and CSS content are no exception, it is stored within *JavaScript* object named "document" inside the browser general scope, see Figure 4.8. This object is so important that have its own name *DOM* (Document Object Model). By having the *HTML* and *CSS* content inside a *JavaScript* data structure, the browser can use *JavaScript* to change the *HTML* and *CSS* without the need to make requests to the server. And, this is exactly the role of *JavaScript* in front-end development: *DOM* manipulation, minimising time and resources by reducing the requests to the server.

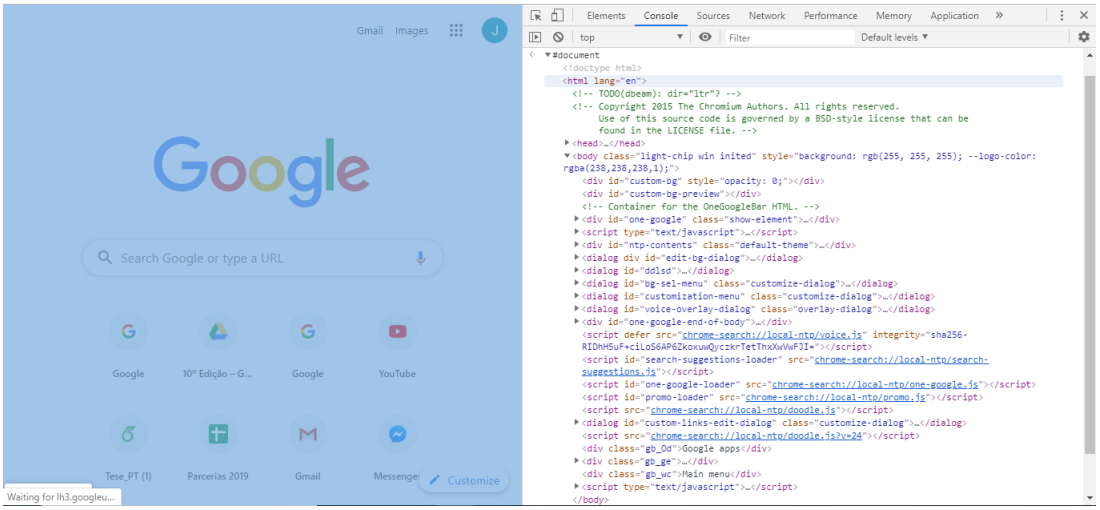


Figure 4.8: Document object model(DOM) of google's web page.

For manipulating the *DOM*, the browser have built in methods to facilitate this process [91]. But nowadays this task is made much more efficiently and effectively by frameworks such as react.js and angular.js. On these frameworks, the developer incorporates the *HTML*, *CSS* and *JavaScript* following the framework documented set of rules and then all the *DOM* manipulation are performed automatically.

In this product React.js front-end framework is used.

Communication between Client and Server

The communication is based on *TCP* protocols, to the request know were to go and how to do it, this communication needs to be supported by transfer data protocols such as *HTTP* or MQTT.

Hyper text transfer Protocol (*HTTP*) is the most common communication used between client and server. This protocol defines the interaction between server and browser using *URLs*. The *URL* contains the necessary information to give the *TCP* connection the direction to the server. The *URLs* works as follows:

$$Protocol : //Server : [TCP\_port\_number]/[Path\_to\_the\_Server\_document]$$

$$HTTP : //www.google.com/search\_something$$

By giving the Server TCP_port_number (Server *IP* adress) and the path inside the server, the *HTTP* request knows how to reach its destination. The whole *HTTP* process of requesting the data until receiving it, is the following:

1. The browser establishes an *TCP* connection with the server in question.
2. Before the *TCP* connection is established, the browser sends the *HTTP* request (*GET*, *POST*, *PUT* or *DELETE*) to the server.
3. When the message reach the server. The server processes the *HTTP* message, generates a response with a status string (in case of success : "HTTP/1.1 200 OK") and add ther necessary files to the response.
4. The server returns the response to the respective browser.
5. After the information is received by the browser. Finally the browser and the server end the TPC connection.

This steps happen sequentially. In the 3^{th} step depending on the situation four different types of *HTTP* requests (*GET*, *POST*, *PUT*, *DELETE*) can be used to provide different functionalities:

- **GET**: Get a File or response from the server. (possible to send information to the server via query string).
- **POST**: Add browser information to the server, the browser information is sent by the body of the *POST* request.
- **PUT**: Update some information in the server, the browser information is sent by the body of the *PUT* request.
- **DELETE**: Delete data from the server.

The Figure 4.9 summarises the hole process: the sequential steps that the *HTML* request takes , the different request messages, the response from the server and how the browser send information to the server.

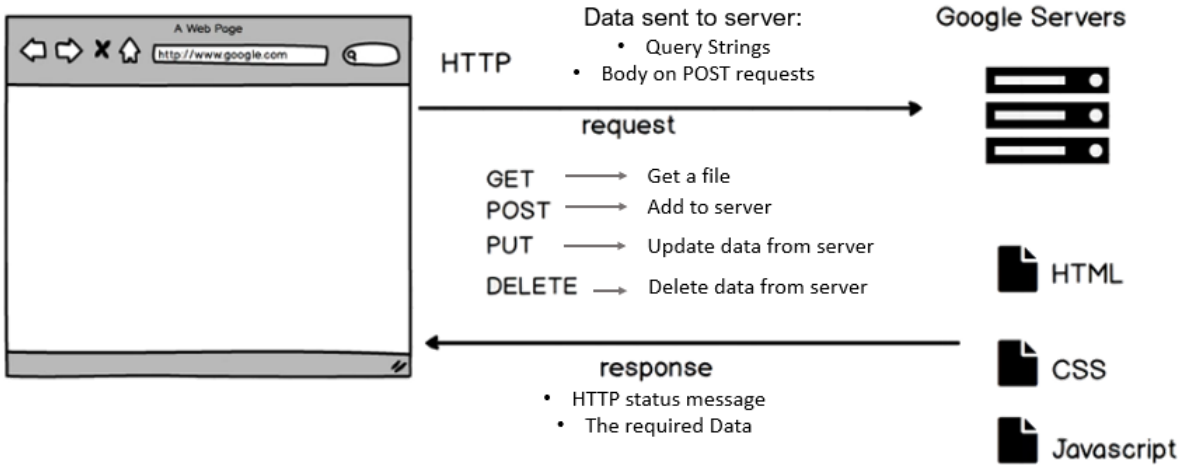


Figure 4.9: Sequential steps of a *HTML* request.

On top of the *HTML* simple requests, the product developed in this thesis also used a technology called AJAX. This technology will not be explained in detail. But bassically, it allows the server to respond in *JSON* files (which contains only strings) instead on the typical *CSS*, *HTML* and *JavaScript* Files. *JSON* is a universal language, understood by all servers and browsers. When a server sends a *JSON* file the browser, it can update only the necessary variables in the *HTML* & *CSS* instead of refreshing the whole *HTML* & *CSS* files.

Finally, the *MQTT*(Message Queuing Telemetry Transport) communication protocol was also used in the product developed.

It is a simple messaging protocol, based on a lightweight publish and subscribe system where an *IoT* device or server can receive and send messages via Internet.

The *MQTT* transfer data is represented in the Figure 4.10. In this system any server or *IoT* device can be a publisher or a subscriber of a certain topic. Then, everything that a publisher sends to a certain topic all the subscribers of that topic will receive these information.

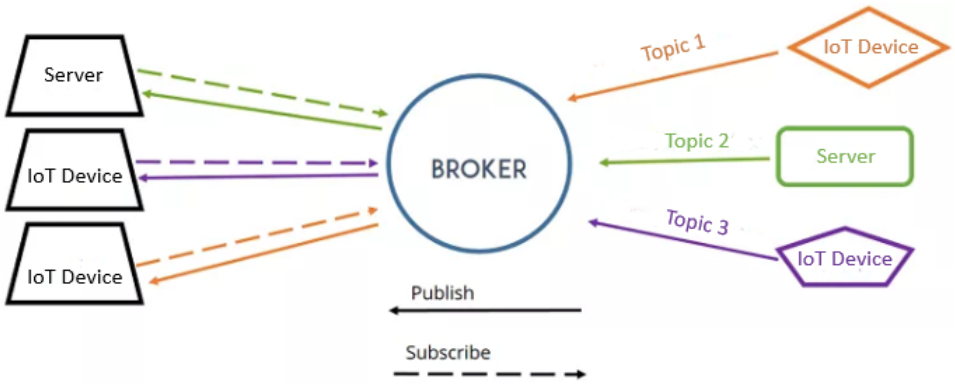


Figure 4.10: *MQTT* transfer data structure.

The broker responsibility is to receive all the messages, filter it, decide who is interested and then publishing the messages to all subscribed clients.

There are several brokers. Localhost brokers such as *Mosquito broker* that can be installed in any device or online Cloud *MQTT* brokers.

This system provides a really easy and efficient way to establish a communication between multiple devices, and that's exactly why this protocol is used into the product development.

Back-end

The back-end makes sure the client receives the requested files with the correct information. In other words, it decides which response to send given an specific request, and is normally divided into two big sections, the database and the server.

Firstly, a web server can refer either to the hardware (computer) or the software (the computer application). In very simple terms a server is just a computer that is somewhere connected to the internet infrastructure and is listening for *HTTP* requests.

To be a server, the computer must have the server software and code running, otherwise it would not be able to receive the request and send a response properly by the internet infrastructure. To perform this there are multiple software's that allow your computer to become a server in almost any language such as Phyton, C, PHP, *JavaScript*, etc...

The 2 most used web servers software's are Node server and PHP Apache server (represented in the Figure 4.12)

Secondly, the Database Management Systems (*DBMS*) allows the developer to organise the data, store it efficiently, perform any kind of manipulations (update, insert, delete) and connect the database to any server using the *SQL* or *No-SQL* languages.

This *DBMS* are divided into 2 big groups, the ones that use *SQL* language and the ones that use *No-SQL* language to communicate with the server. Many *DBMS SQL* based are presented in the Figure 4.11 (a), this systems contain relational databases where the information is divided by tables, columns and rows (each row represents an entry of information and each column serves a very specific type of information). Also this systems provide the creation of relations between tables, and therefore offer good tools to very effectively organise our data.

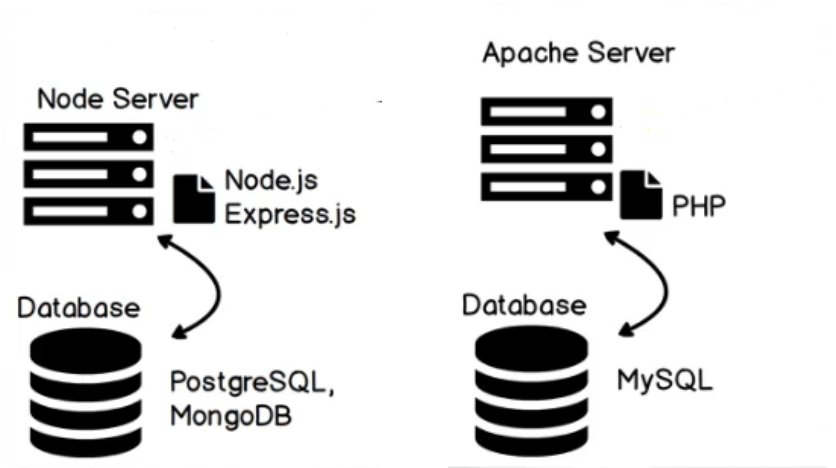
On other hand, *DBMS* based on *No-SQL* language are much more simple having less functionalities than relational databases. They are called "Non relational databases" (see Figure 4.11 (b)), this databases allow the user to store data without tables and any relation between the data. These systems are document oriented, and tend to store all information about a topic inside a single document (this databases will be further explained in the section 4.3.3).

(a) Relational Databases, using *SQL* language

(b) Non Relational Databases, using *No-SQL* language

Figure 4.11: Most common *DBMS* services.

Nowadays, the two most used back-end configurations in web develop are represented by the Figure 4.12 . The configuration used by this thesis product is going to be the option (a): Node Server with the *No-SQL* MongoDB database.



(a) Node Server with PostgresSQL or *No-SQL* MongoDB Databases

(b) Apache Server with MySQL Database

Figure 4.12: Most common back-end configurations.

4.3 Solution Fundamental Blocks

In this section each technological block of the product presented in the Figure 4.2 will be explained in detail and individually. To understand, what is its role in the overall system.

Note that, each subsection will explain one technological block of the Figure 4.2 and the name of the section corresponds to that specific block.

4.3.1 Client React.js

As explained in the section 4.2.2 react.js is a front-end web framework. It is composed by multiple *JavaScript* libraries and its main purpose is the automatic manipulation of the *DOM*, without any developer action. Its function in the developed *MVP* is to take care of all content showed in the browser and all the user interaction.

The website was organised sequentially in four main parts: the **banner section**, **the instructions section**, the **ask request section** and the **contact section**.

The **banner section** is represented in the Figure 4.13. In the banner there is a small explanation of what the website is about, buttons on the top to automatically scroll down to the other sections and the login system.

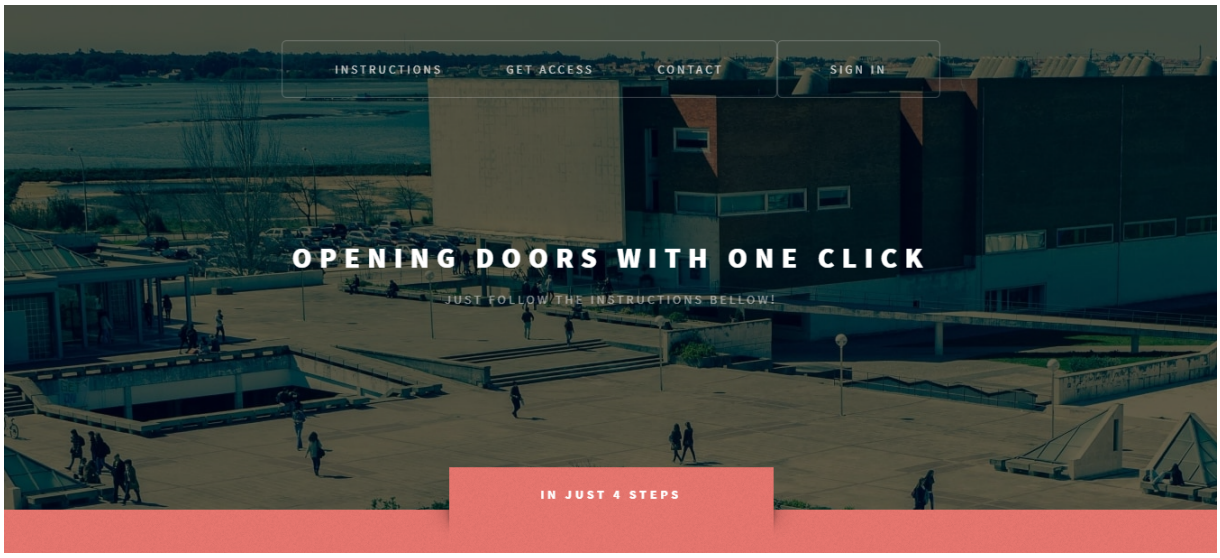
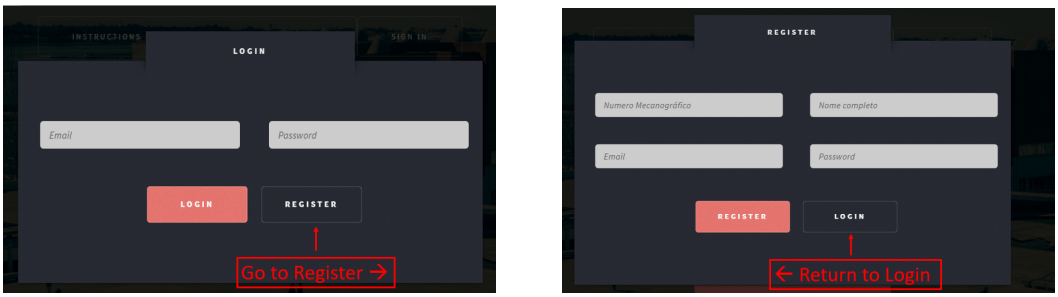


Figure 4.13: Banner section on website.

When the user is not logged in by clicking on the "Sign In" button (top right), he is redirected to the login and register system represented on the Figure 4.14.



(a) Sign in front-end (login).

(b) Sign up front-end(register).

Figure 4.14: Font-end of the login system.

The **instruction section** is represented in the Figure 4.15, it is merely explanatory. It indicates to the student what are the steps that he have to take in order to achieve his goal. The steps are the same as the ones presented in the section 4.0.

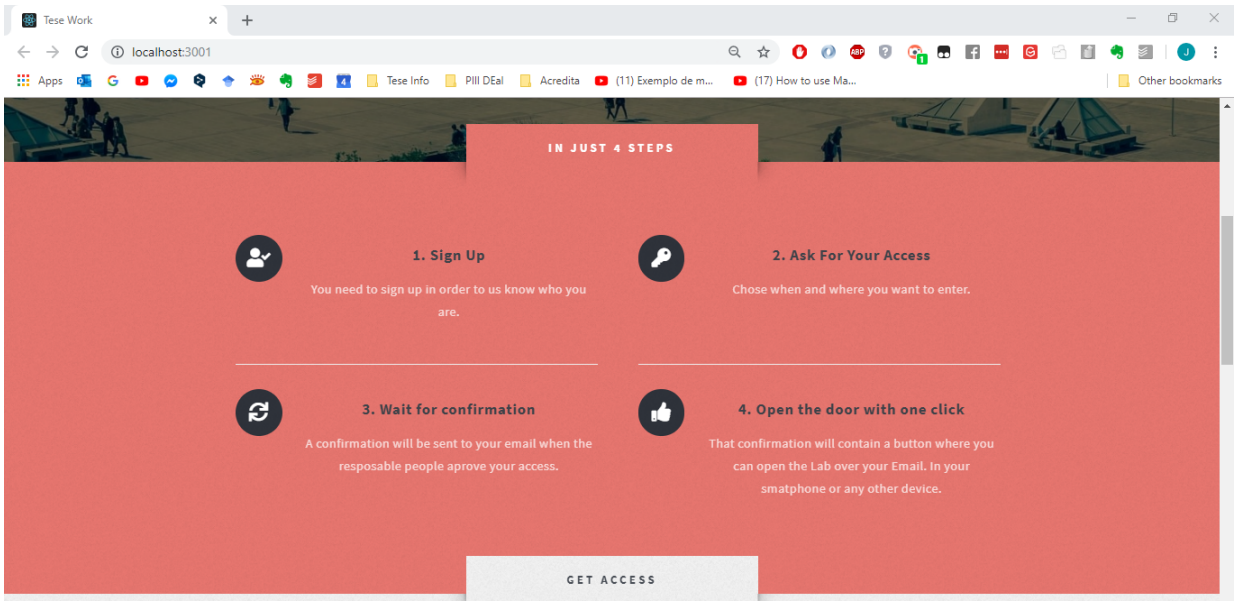


Figure 4.15: Instructions on the website.

The **ask request section** is the most important to the user and is represented on the Figure 4.16. It is the most important section because is the one that allows the student to send the request to the responsible professor. For that, the information about the multiple laboratories must be clear, the user must be able to filter this information in a effective way, to chose a check-in date and finally send the request. All this is possible in the front-end presented in the Figure 4.16.

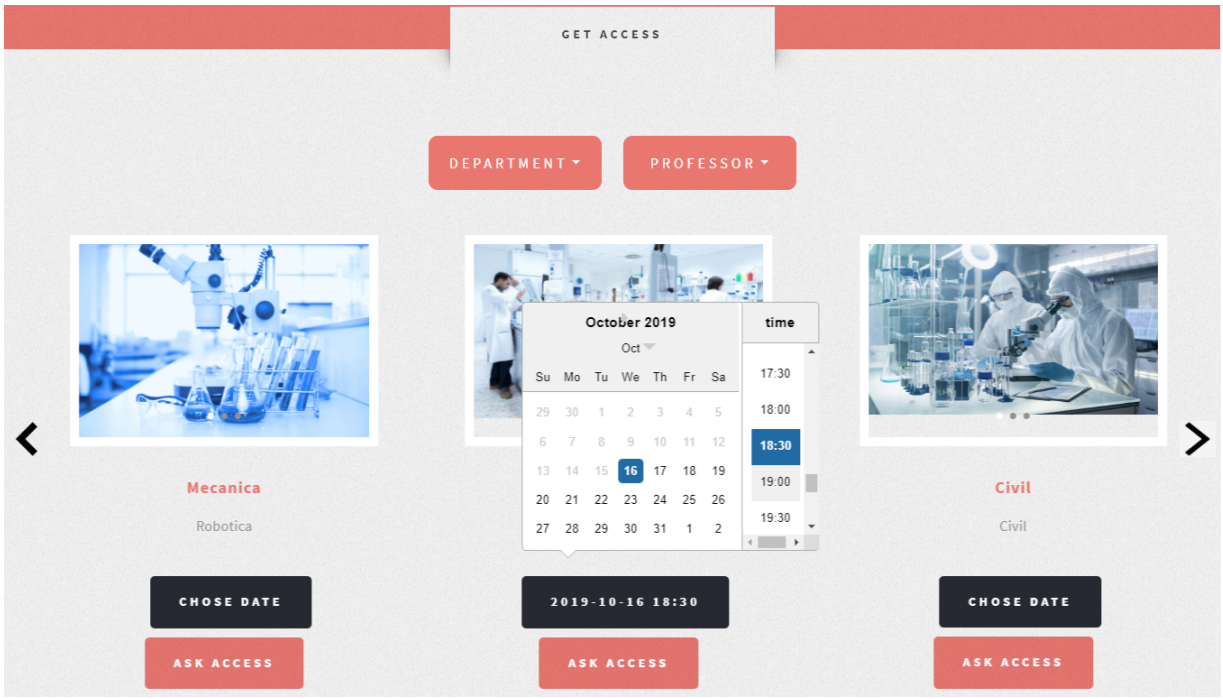


Figure 4.16: All the functionalities to request a laboratory.

The functionalities are simple and intuitive:

- The laboratories are presented inside a carousel, when the user clicks the arrows the at edges it shows another laboratory and so on.
- Each laboratory contains its name, a description and multiple of photos.
- The user by the two buttons on the top can filter the Laboratories by department and Professor, see Figure 4.17
- The "Chose Date" button, allow the user to choose a date to that specific laboratory
- And finally the click on the "Ask Access" button send the request to the respective professor with the data from the user and his request.

Also there are some pop-up alarms implemented into the "Ask request" button to, when is needed, remind the user that needs to be Logged in to request the access, to block / alert the user if in less than 30 minutes he have asked multiple requests for the same access and of course, in case of success, ensure the user that the request was sent.

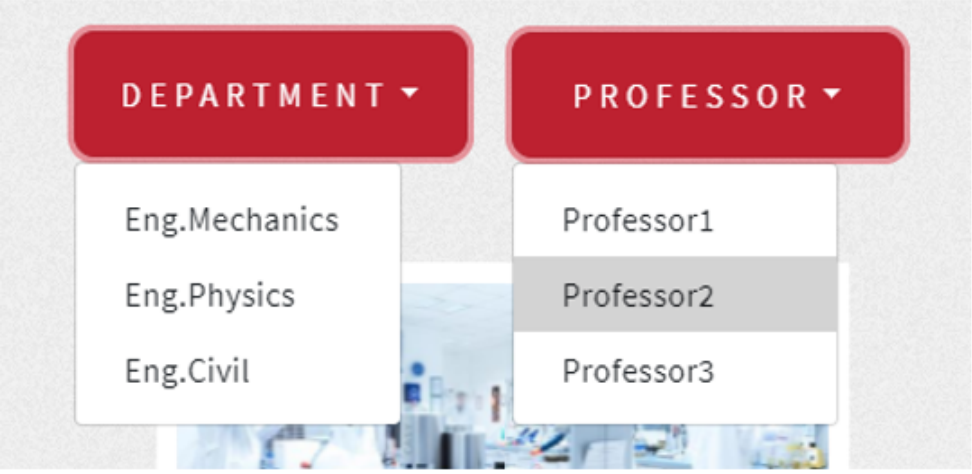


Figure 4.17: Filter information on the laboratory.

Finally, the **contact section** represented in the Figure 4.18. This one is the least important section in the website, it only allows the user to send an email to the author and indicates some contact information. Its purpose is to answer any doubt that the users might have.

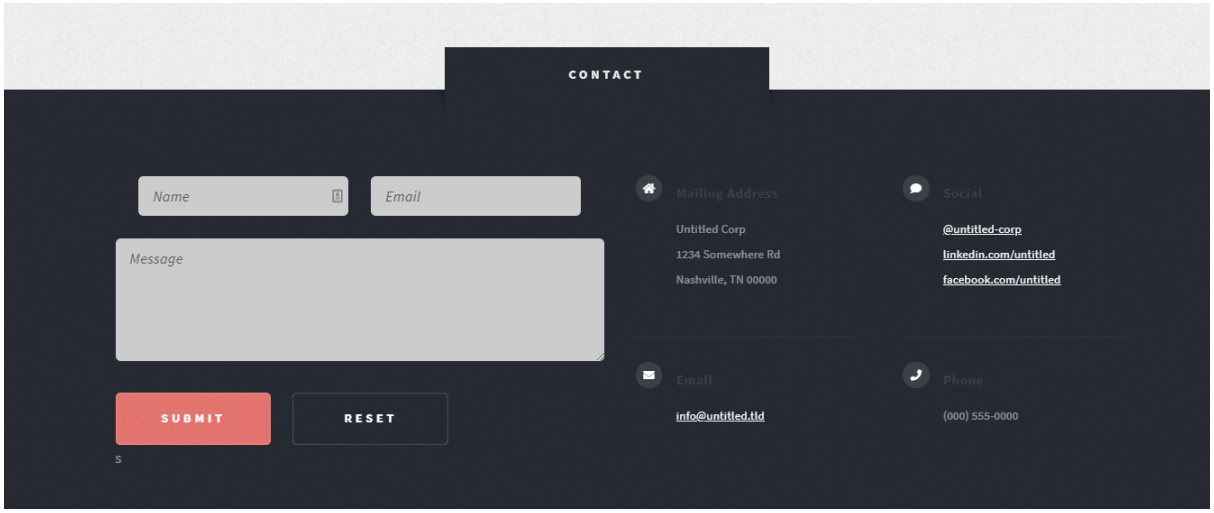


Figure 4.18: Contact section on the website.

There also some secondary additional functionalities, such as:

- The user credentials are saved into a cookie in the browser. This allows the user, during a period of time, to login instantaneously with his previous login.

- During the login, the user is informed if he is missing something or inserting the wrong data.

- After the login, the user is automatically alerted by a pop-up, about what accesses he have previously requested that are already validated by the professor. This is useful to motivate the user to use those accesses.

4.3.2 Client Email

This part of the product consists on the sending of personalised *HTML* emails, both to professor and the user (student). The the flow proceeds as explained in the Figure 4.19.

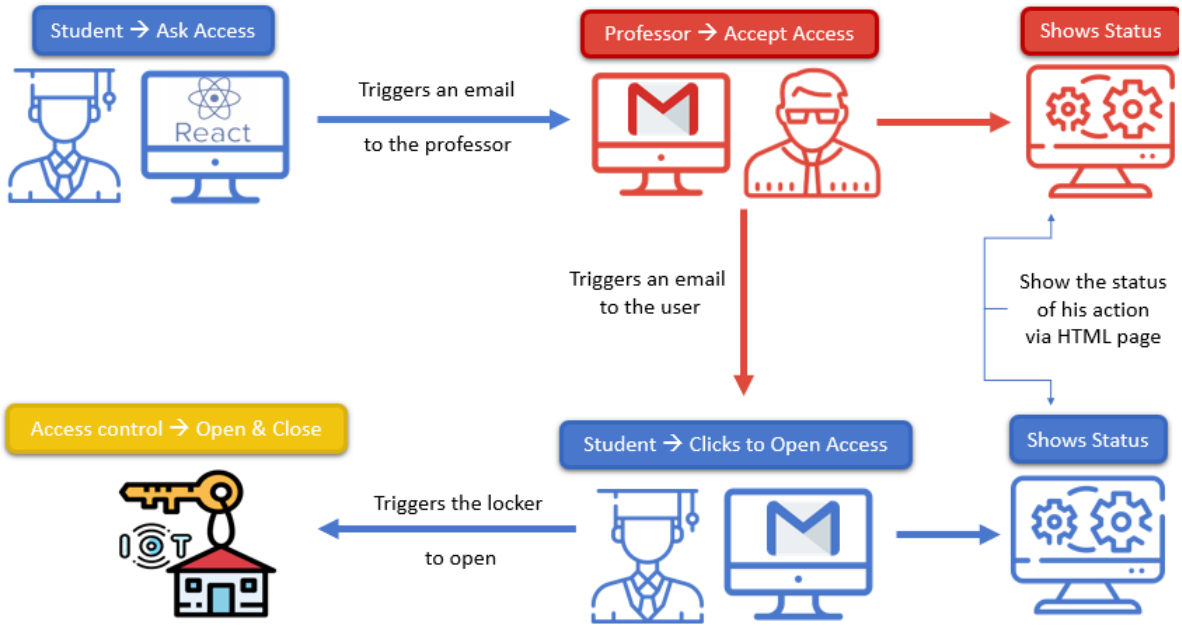


Figure 4.19: Data flow after student request.

Firstly, the user (student) requests the access in the website. Then, an email is triggered to the professor. This email contains the laboratory, student and request data needed for the professor to decide on the student's access (see example in Figure 4.20).

In the professor's email, Figure 4.20, there are 2 buttons to accept or deny the request. If the professor accepts the request, the student receives the email on the Figure 4.21.

Also, at the moment of professor's response, he is redirected to a simple *HTML* page where it shows if the access is still valid or not.

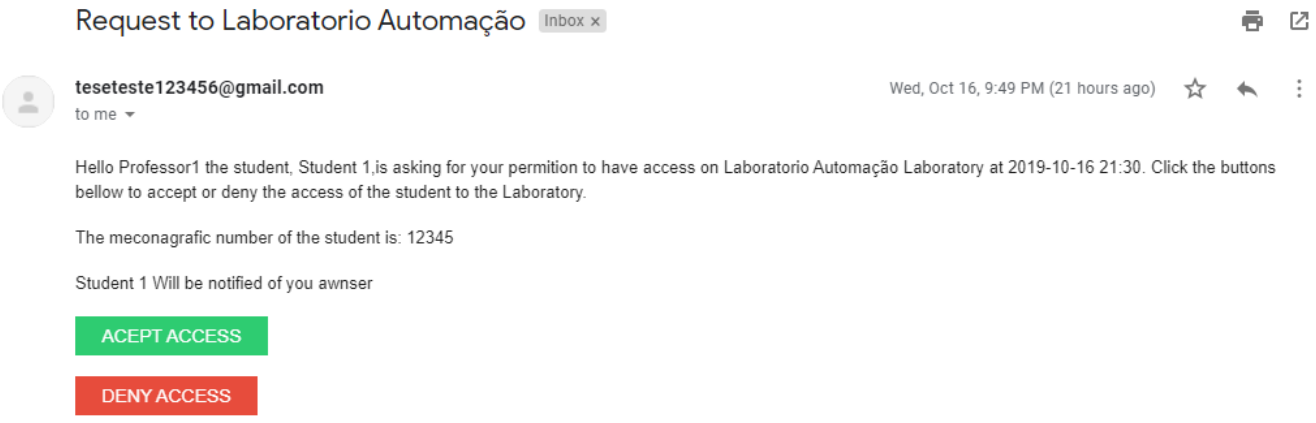


Figure 4.20: Example of a email received by a professor sent by the request of Student 1, asking access to "Laboratorio de Automação" at "2019-10-16 21:30".

Then, the student receives an email containing a button to open the door of the specific laboratory. The button can be clicked via computer, smartphone or any other

device. Of course, if the professor refuses the access the student just receives an text email saying he is not allowed.

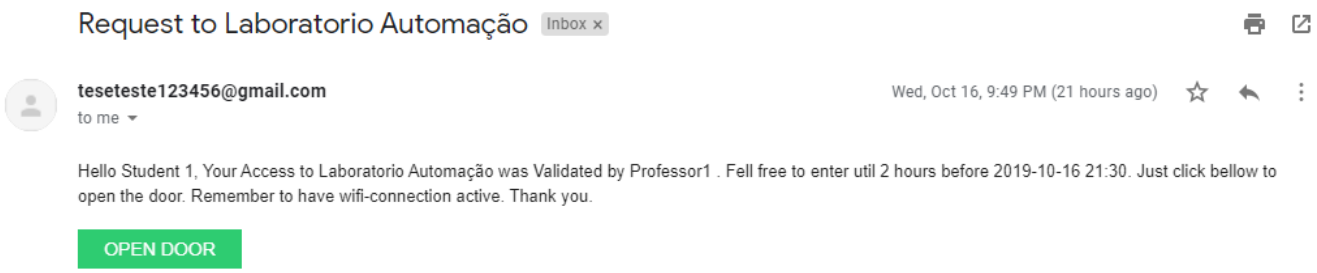


Figure 4.21: Filter information on the laboratory.

As well as in the email to the professor, when the student clicks on the button he is redirected a simple *HTML* page where it shows if the access is valid at the moment. The options are:

- The user tries to open the door before the requested time. In that case the Locker will not open the door, and the browser receives an *HTML* page with the time still missing until the requested date (in hours).
- The user tries to open the door after the 120 minutes of the required date. In that case the Locker will not open the door, and the browser receives an *HTML* page with a message with the delay time (in hours).
- The user tries to open the door until 120 minutes after the required date. In that case the Locker will open the door, and the browser receives an *HTML* page with a success message, with the time still valid to open the door(in minutes) and ensuring that the door is about to open.

4.3.3 Database MongoDB

The database used was MongoDB *No-SQL*. As explained in the section 4.2.2 there are multiple differences between *SQL* and *No-SQL* databases, but this section will focus on the data structure syntax differences and then will present how the database is configured to store all the needed data.

In *SQL* Databases the information is divided by tables, where each table contains multiple rows or records, each row contains an entry, and each column is associated with a specific propriety of that data-set. For example in the Figure 4.22, each row represents all the data for a specific user and each column an a propriety of the user.

In *No-SQL* is completely different, the information is stored in a array like structure instead a table like structure. Here, the information is divided by collections, where each collection have multiple documents and each document have all the information needed for that data-set.

In contrast with *SQL*, in the MongoDB document (equivalent to row in *SQL*) does not need to have the same fields (equivalent to columns in *SQL*) over and over again. Of course, is needed a Model for the collection of documents, where is specified the required

fields, their data type etc... But still it is a much more flexible data structure than *SQL* table, thus unorganised as well. The Figure 4.22 represents all this differences in a intuitive way.

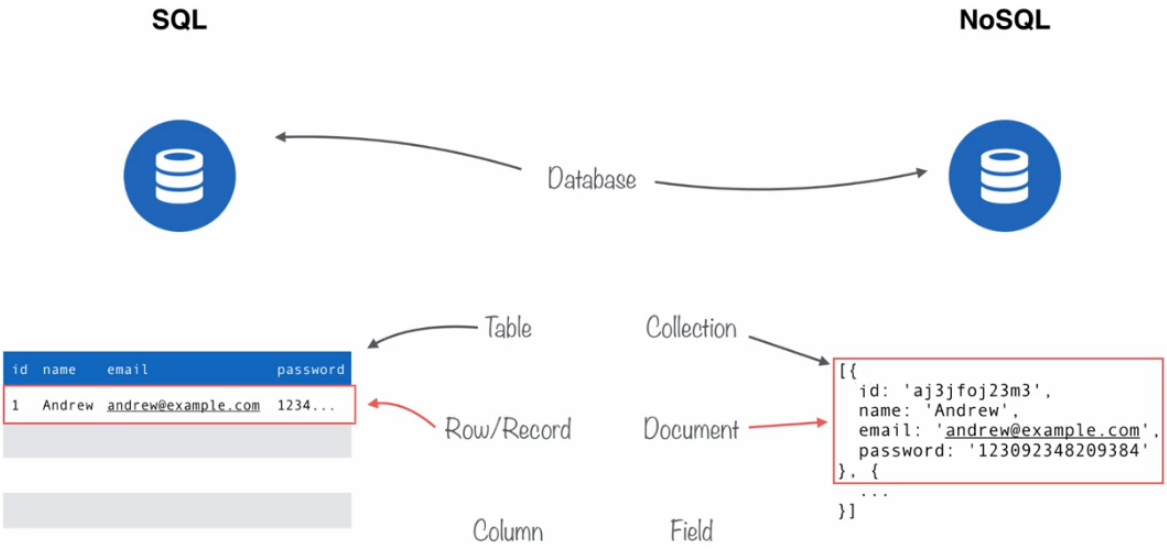
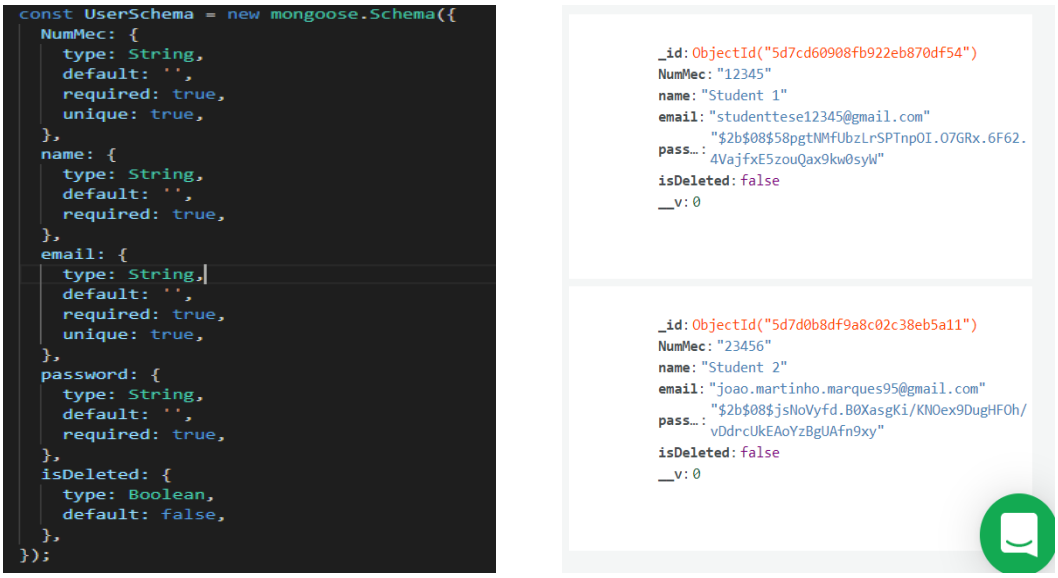


Figure 4.22: *SQL* vs *No-SQL* data storage.

For the *MVP* developed, four collections are used to store all the data needed for the system to work: The *User* collection (where is stored data relative to all users), the *Laboratory* collection (where is stored all the data relative to the laboratories), the *UserSession* collection (where is stored all the data about each login of each user, to save the most actual into a browser cookie) and the *Access* collection (where the data about each specific request is stored).

Firstly, the *User* collection have all the information relative to the user with the restrictions indicated by the model (see Figure 4.23). The *isDeleted* field only exists if the admin wants to delete the user in a easy way. The *password* field for security reasons is stored in a form of *hash*, (the 3^{th} party library *bcrypt* is used to create an equivalent *hash* of the chosen password by the user). Also, note that the MongoDB software creates automatically the *_id* field, this field is the primary key of the document.



```
const UserSchema = new mongoose.Schema({
  NumMec: {
    type: String,
    default: '',
    required: true,
    unique: true,
  },
  name: {
    type: String,
    default: '',
    required: true,
  },
  email: {
    type: String,
    default: '',
    required: true,
    unique: true,
  },
  password: {
    type: String,
    default: '',
    required: true,
  },
  isDeleted: {
    type: Boolean,
    default: false,
  },
});
```

(a) User MongoDB collection model.

```
_id: ObjectId("5d7cd60908fb922eb870df54")
NumMec: "12345"
name: "Student 1"
email: "studenttese12345@gmail.com"
pass…: "$2b$08$58pgtNMfUbzLrSPTnpOI.O7GRx.6F62.
        4VajfxE5zouQax9kw0syW"
isDeleted: false
__v: 0

_id: ObjectId("5d7d0b8df9a8c02c38eb5a11")
NumMec: "23456"
name: "Student 2"
email: "joao.martinho.marques95@gmail.com"
pass…: "$2b$08$jsNoVyfd.B0XasgKi/KNOex9DugHFOh/
        vDdrcUkEAoYzBgUAfn9xy"
isDeleted: false
__v: 0
```

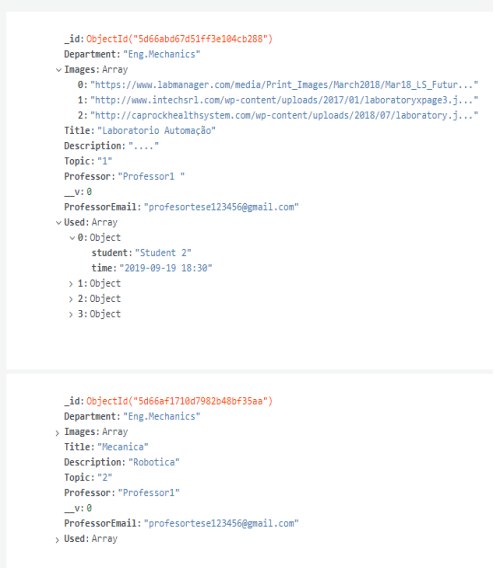
(b) The first 2 documents of the *User* collection.

Figure 4.23: Database *User* collection data structure.

Similarly to the *User* collection, the *Laboratory* collection have all all the information relative to each laboratory with the restrictions indicated by the model (see Figure 4.24). It contains the Name and email of the responsible professor, the department, the *MQTT* topic of the locker, all the information to show on the website (title, images and description) and also the information about the usage of the laboratory. Note that the *Images* and *Used* fields are arrays. In the *Image* filed is just needed to add the *URL* of the image to be automatically added to the laboratory carousel on the website. In the *Used* field appears by who and when that laboratory was used.

```
const LabSchema = new mongoose.Schema({
  Professor: {
    type: String, required: true,},
  ProfessorEmail: {
    type: String, required: true},
  Department: {
    type: String, required: true},
  Topic: {
    type: String, required: true,},
  Images: {
    type: Array, default: [],},
  Used: {
    type: Array, default: [],},
  Title: {
    type: String, default: '',},
  Description: {
    type: String,  default: '',},
});
```

(a) *Laboratory* MongoDB collection model.



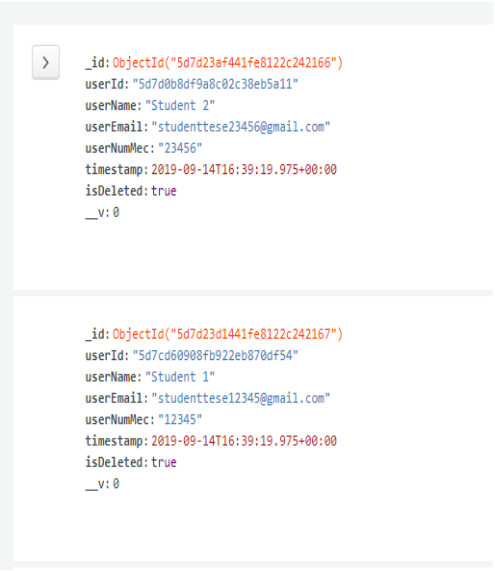
(b) The first 2 documents of the *Laboratory* collection.

Figure 4.24: Database *Laboratory* collection data structure.

The *UserSession* collection have all the information relative to each login of each user, to save the most recent login into a browser cookie with the restrictions indicated by the model (see Figure 4.25). It contains the information about the user (userId, username, email and the mecanograph number), the time of the login and if that login is still valid.

```
const UserSessionSchema = new mongoose.Schema({
  userId: {
    type: String,
    default: '',
  },
  userName: {
    type: String,
    default: '',
  },
  userEmail: {
    type: String,
    default: '',
  },
  userNumMec: {
    type: String,
    default: '',
  },
  timestamp: {
    type: Date,
    default: Date.now(),
  },
  isDeleted: {
    type: Boolean,
    default: false,
  },
});
```

(a) *UserSession* MongoDB collection model.



(b) The first 2 documents of the *UserSession* collection.

Figure 4.25: Database *UserSession* collection data structure.

Finally the *Access* collection, this collection have all the information relative each specific request with the restrictions indicated by the model (see Figure 4.26). It contains the date the user asked to open the laboratory (field *DataPedida*), the actual time in the moment of the request (field *DataActual*), the information of the laboratory, the information of the user(student), the information about the professor to be contacted, if the professor have already validated the access (*isValidated*) and if the student have already used the access to open the door (field *Used*).

For example in the first document of Figure 4.26 (b), the professor have validated the access and also the student have used it. In contrast in the second document only the professor have validated the access yet.

```
const AccessShema = new mongoose.Schema({
  // eslint-disable-next-line prettier/prettier
  DataPedida: { type: String, required: true },
  DataActual: { type: Date, required: true },
  LabTitle: { type: String, required: true },
  LabID: { type: String, required: true },
  Username: { type: String, required: true },
  UserId: { type: String, required: true },
  userNumMec: { type: String, required: true },
  userEmail: { type: String, required: true },
  Professor: { type: String, required: true },
  ProfessorEmail: { type: String, required: true },
  isValidated: { type: Boolean, default: false },
  Used: { type: Boolean, default: false },
});
```

(a) *Access* MongoDB collection model.

```
_id: ObjectId("5da7823f3f63ae3f806a5d04")
LabTitle: "Laboratorio Automação"
LabID: "5d66abd67d51ff3e104cb288"
Username: "Student 1"
UserId: "5d7cd60908fb922eb870df54"
userNumMec: "12345"
userEmail: "studenttese12345@gmail.com"
Professor: "Professor1 "
ProfessorEmail: "profesortese123456@gmail.com"
isValidated: true
Used: true
DataActual: 2019-10-16T20:49:02.934+00:00
DataPedida: "2019-10-16 21:30"
__v: 0

_id: ObjectId("5da9cb8d4a308228dceac948")
LabTitle: "Laboratorio Automação"
LabID: "5d66abd67d51ff3e104cb288"
Username: "Student 2"
UserId: "5d7d0b8df9a8c02c38eb5a11"
userNumMec: "23456"
userEmail: "studenttese23456@gmail.com"
Professor: "Professor1 "
ProfessorEmail: "profesortese123456@gmail.com"
isValidated: true
Used: false
DataActual: 2019-10-18T14:26:21.327+00:00
DataPedida: "2019-10-18 15:30"
__v: 0
```

(b) The first 2 documents of the *Access* collection.

Figure 4.26: Database *Access* collection data structure.

All data is stored into a online cloud MongoDB database service, called "MongoDB Atlas". By this platform is possible to give access to specific information to specific people, for example giving the hosts access to certain parts of the database.

4.3.4 Broker CloudMQTT

Due to its efficient and easy way to establish a communication between multiple devices, *MQTT* is the communication protocol used to communicate between the server and all the *IOT* lockers.

The center piece of any *MQTT* communication is the broker (see Figure 4.10), because its function is to to receive all the messages, filter it and distribute the information to all the devices. For that, the author decided to use an online cloud *MQTT* broker named *CloudMQTT* provided by amazon *AWS* services.

As represented in the Figure 4.27, the information flows from the server to broker and from the broker to the *IoT* lockers.

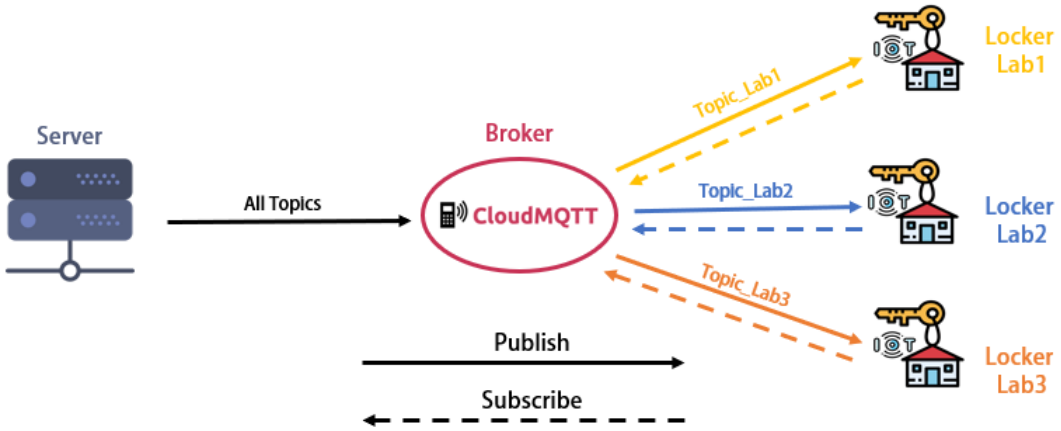


Figure 4.27: *MQTT* publish-subscribe model.

The server is the publisher to all topics, where the lockers are only subscribing to one topic, which are: their laboratory topic, presented in the field *Topic*(see Figure 4.24 (b)). By this simple system, the server can easily order any locker individually to open the laboratory door and all the information is processed in the server side.

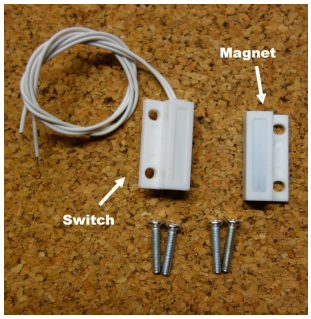
4.3.5 Hardware: *IoT* locker

Back to the Figure 4.2, the *IoT* lockers block is the one that proves most confusing, because the software presented in the last subsections do not manage only a locker, but have the ability to manage an infinite number of lockers (a locker per laboratory).

As defined in the sections 2.2.6 and 2.3, the only additional hardware needed is just a motor to trigger the opening of the previously installed deadbolt. The locker solution presented by this work is very simple: a step motor to turn the key and open the door.

For that was used the *NodeMCU 1.1* micro-controler to receive the *MQTT* data and give the orders to the rest of the system. The hole system is composed by: a magnetic sensor to know if the door is open or closed, a battery to power the system and a step motor to turn the key opening the door. Also, simple red and green LED's were also implemented (red when door closed, green when door open).

(a) *NodeMCU 1.1* micro-controller



(b) Magnetic sensor

(c) Servo motor

Figure 4.28: Hardware components.

The magnetic sensor works in very simple way: The electrical circuit is closed when a magnet is near the switch (less than 13 mm (0.5”) away) and is open when the magnet is far away from the switch (see Figure 4.33). In this way is easy to detect if the door is open or not, because when the door is closed the imam is near the switch and the opposite when the door is open.

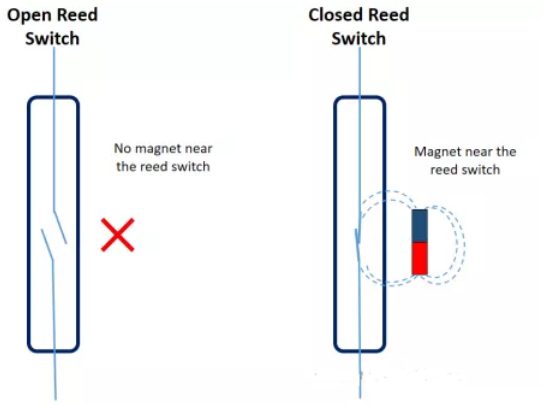


Figure 4.29: Magnetic sensor functionality.

To open the door the rules are simple, if the user clicks in the email button on time and with the access validated (Figure 4.21), the *NodeMCU* receives via *MQTT* the information to use the correct step motor to turn the key of the requested laboratory, opening the door. However, the *NodeMCU* will only give this order if the door is closed.

If everything is ok, the user will see via a green LED the period the door is opened and just have to push or pull the door.

4.3.6 Server Node.js

As already said in the section 4.2.2, the server is an essential part of the system being able to access files in the server, listen to *HTTP* requests, send data over *MQTT*, query database via *No-SQL* or *SQL* languages and all other functionalities that make the system possible.

To this product the server software chosen was Node.js. The description of Node on their on their website, give a clear picture of what this framework is : "Node.js is a JavaScript runtime built on Chrome’s V8 JavaScript engine. Node.js uses an event-driven, non-blocking I/O model that makes it lightweight and efficient. Node.js package ecosystem, npm, is the largest ecosystem of open source libraries in the world".

The first phrase indicates the most important feature, Node.js takes the *JavaScript* Chrome’s V8 engine and allow it to run on the command line of the developer’s computer.

Before Node.js, *JavaScript* was something that usually only run inside the browser engines, but now is possible to use an open source *JavaScript* engine (V8 chrome engine) to compile the code in the front-end and back-end simultaneously, making the compilation much faster and light-weight.

The second phrase indicates another advantage, "Node.js uses an event-driven, non-blocking I/O model", this means that Node.js does not read the code line-by-line. Instead, he

attach callbacks to the tasks that takes more time and perform the others in the mid-time, being able to reduce the computation time. For example if the server have to make an Database request that takes some time, while the server is waiting for a response is also performing other tasks, then returns back to the Database request when receives the response.

And finally the third phrase indicates another major advantage. Node.js contains the larger ecosystem of open source libraries in the world and is called *NPM* (Node Package Manager). The community is huge, therefore if you are trying to solve a generic problem or make generic configurations, already someone have done it and you can use it right away. Having so much different libraries to add all kinds of functionalities into the server means that you can focus much faster and efficiently in the infrastructure of your application.

In this way as the *JavaScript* engine is the same in the front-end and back-end, so *NPM* libraries can be also used in the front-end which is amazing and saves a lot of time on the front-end functionalities. Also, as Node was built to be non-blocking from the start all the libraries are non-blocking, by contrast with PHP or Phyton that many libraries are still developed in a Blocking fashion.

In practical matters, the Node server is the cornerstone of this product. The server makes the connection between all the fundamental blocks: exchanging information between both clients (React.js and *HTML* emails), between each client with the database and between the all the lockers with the database. This exchanges of data is exactly what makes the functionalities presented on this section possible and will be explained in detail in the next section.

4.4 Fluxes of information

The exchanges of data and interaction between the previously defined technological parts is exactly what performs the tasks the user needs to achieve his goal.

This communication is done by *HTTP* and *MQTT*, that were already previously explained.

This section is going to explain, what are exchanges of information that perform each task and ensure that the system works properly. These are the multiple functionalities performed by the system:

1. Login System
   (a) Sign Up (Figure 4.14)
   (b) Sign In (Figure 4.14)
   (c) Logout
   (d) Automatic login by cookie
2. Render dynamical information in the website
   (a) All laboratory data.
   (b) Update laboratory data, on user search (Figure 4.17).
3. Email client flux of information

(a) Ask request by student (Figure 4.16).

(b) Accept or refuse request by professor (Figure 4.20).

4. Open the door

(a) Student, triggering the opening of the door (Figure 4.21).

(b) Hardware response.

The next sub sections will explain each topic individually.

To understand the images presented in the next subsections, note that in the moment the server send the first message to the client the operation stops, because the server can only send one response to the client per operation.

Also notice that the server can only respond in two ways to the client: in *HTML* files and in *JSON* files that are documents made by strings able to update only the necessary variables on the already present *HTML* & *CSS* on the browser.

Finally, as said in previous chapters there are 2 ways of sending data from client to server: via query sting or by the body in *POST HTTP* request. It is recommended to use *POST* request to perform this job, however when there are just one or two variables to send is also viable to do it via Query String.

4.4.1 Login System

Sign Up

The following figure explains the information flow into the sign Up (register) process.

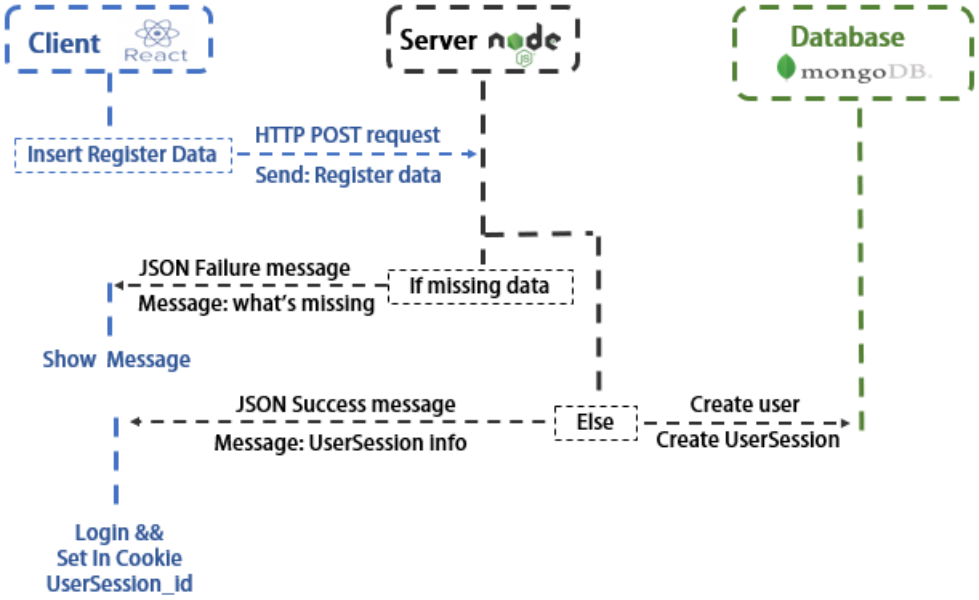


Figure 4.30: Sign Up information flow.

The action starts with the user inserting his register data. When the user submits it, the client makes a *POST* request to the server. Then, if there is any missing data

(for example the user did not put a password, email or if he inserts an invalid email) the website receives an *JSON* file to inform the user about what he is missing. If it is not the case, the server will create a *User* and a *UserSession* into the database, to therefore validate the login.

The login is validated by the *UserSession* data (Figure 4.25), that is why the server creates a *UserSession* document into the database and sends it via *JSON* to the website. The front-end uses it to validate the login and store it in the browser cookie to further authentications.

Sign In

The following figure explains the information flow into the sign-in (login) process.

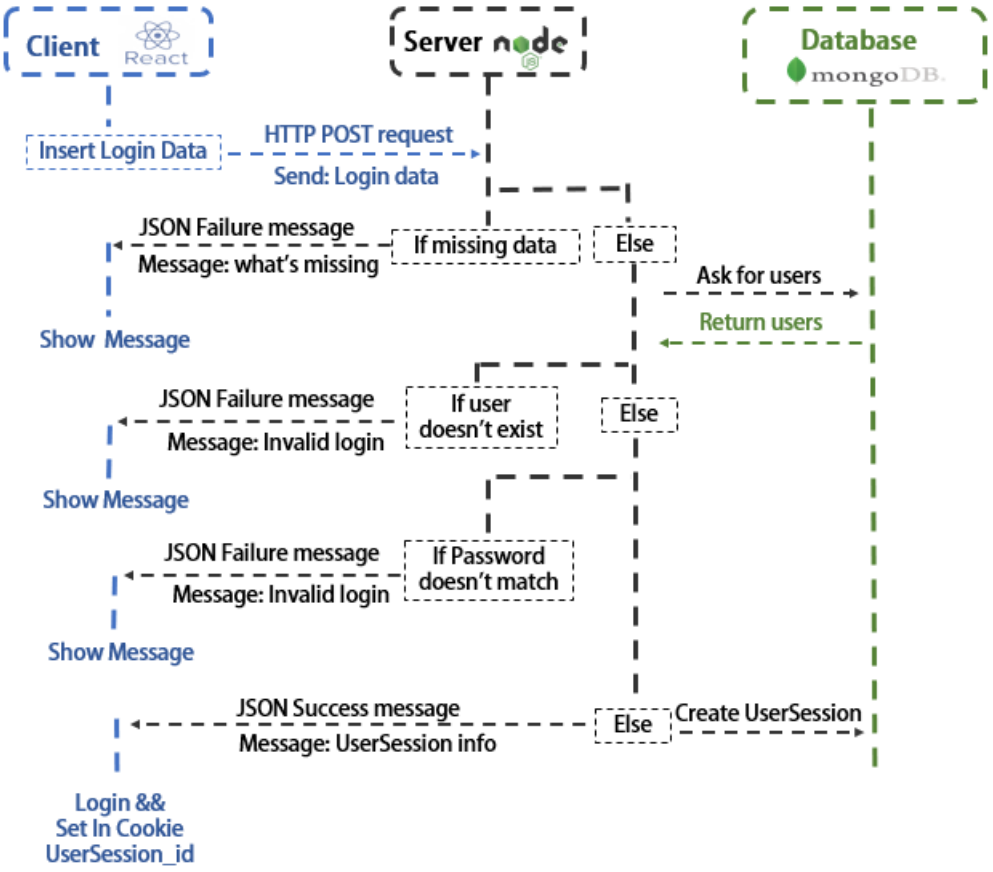


Figure 4.31: Sign In information flow.

The action starts with the user inserting his login data (Figure 4.14). Similarly to the sign Up process, when the user submits it, the client makes a *POST* request to the server. Then, if the there is any missing data (for example the user did not put a password, email, the email does not exists or the password does not match) the website render the respective failure messages. If that's not the case, the server will create new *UserSession* into the database and validate the login in the front-end.

In the same way as Sign Up, the new *UserSession* is stored into the cookie browser to further authentications.

Logout

The following figure explains the information flow into the logout process.

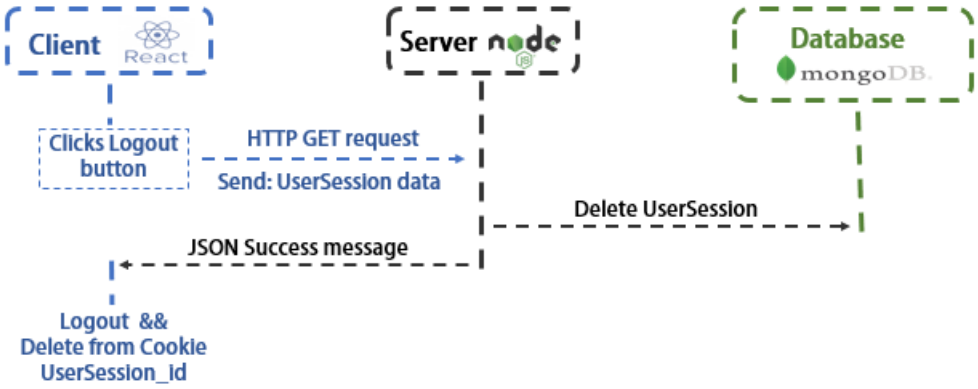


Figure 4.32: Logout information flow.

When the user clicks on the logout button, the front-end send a *GET* request to the server with the *UserSession* data. Then the server deletes that specific *UserSession* into the database and, via *JSON*, communicates with the website to perform the logout.

The logout is performed by resetting the user information in the website (client) and also in the cookie.

Automatic Login by cookie

The following figure explains the information flow into the automatic login process.

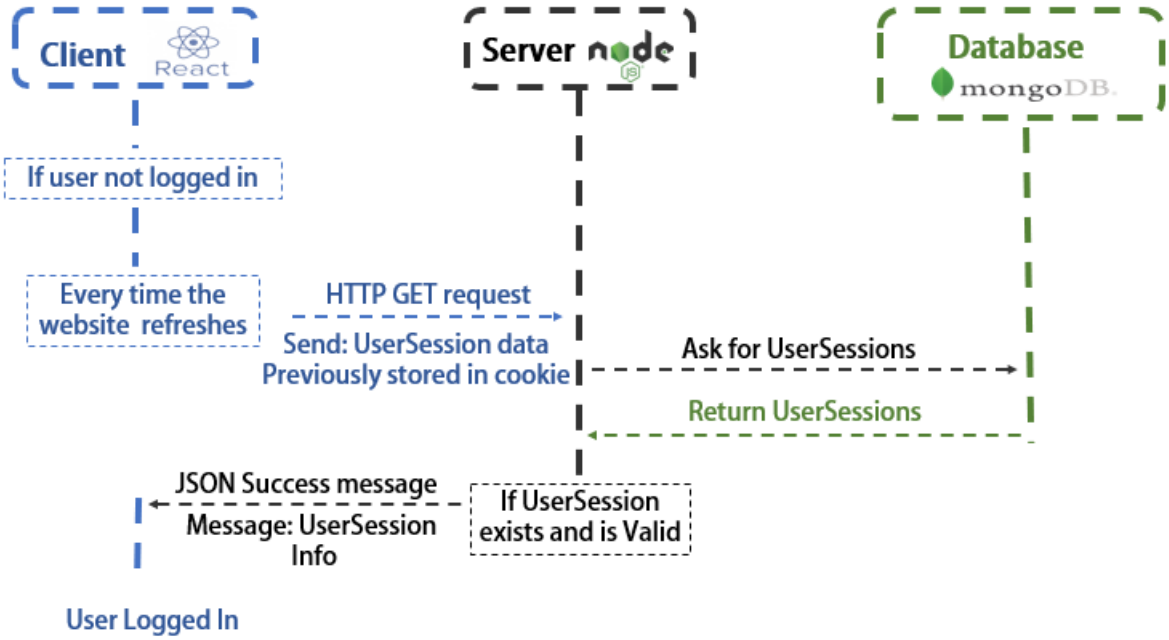


Figure 4.33: Automatic login process.

This occurs automatically every time the user is not logged in and refreshes the website. In these moments, the front-end send a *GET* request to the server with the *UserSession* data stored previously by the cookie. Then the server search in the database if that *UserSession* is still valid and perform automatically the login (via *JSON* message).

4.4.2 Dynamical information

Rendering laboratory information

The website have to dynamically render all laboratory information contained into the database. For that the laboratories are rendered automatically every time the website refreshes.

In this way, by rendering the laboratory information from the database, when the administrator want to add some laboratory or edit an existing one into the website, he only need to add or edit a document into the *Laboratory* collection (Figure 4.24).

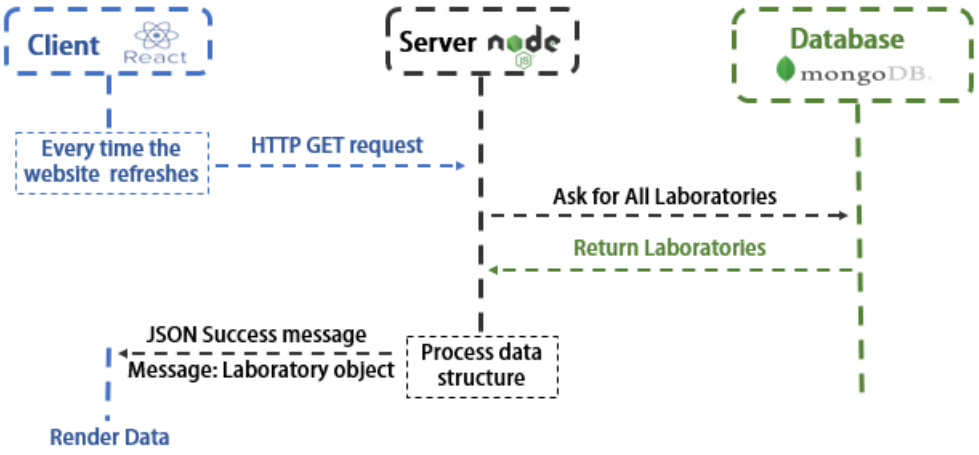


Figure 4.34: Initial render of the laboratories information flow.

The process on Figure 4.34, occurs automatically every time the website is refreshed. In these moments, the front-end send a *GET* request to the server. Then the server asks the database about all the laboratory information and organise it into a *JavaScript* Object. It also filters the laboratories that have non valid information fields.

Finally, the server sends this object to the front-end via a *JSON* file, knowing that it is optimised to read the information to display the laboratories in the carousel (Figure 4.16).

Updating laboratory information

Also important, the filter buttons presented in the Figure 4.17 allow the user to filter the laboratories by department and professor. The information flux to perform this action is presented by the Figure 4.35.

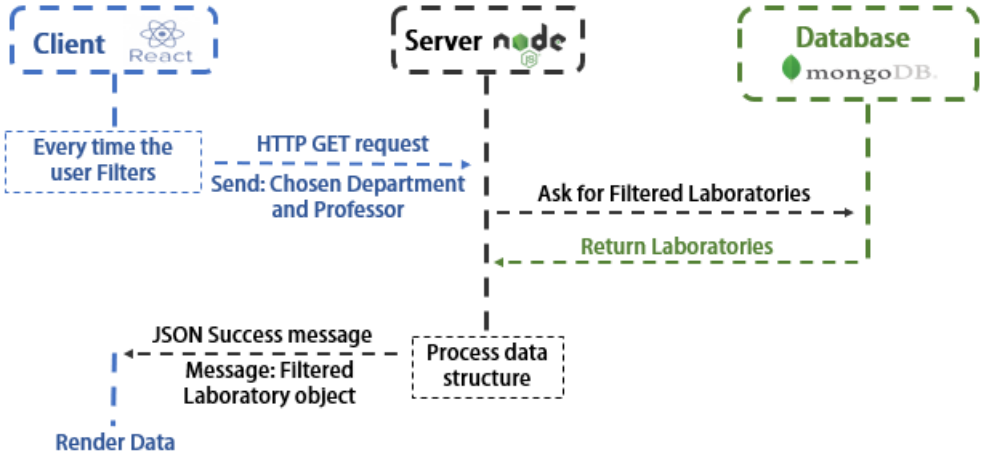


Figure 4.35: Update of laboratory display by filters information flow.

This occurs by, every time the user changes the filters, the front-end sends a *HTTP GET* request to the server with the Department and professor filters information (in

query string). Then, the server do the same process as in the Figure 4.34, with the difference that the *JavaScript* object is filtered to only the laboratories that meets the filters requirements.

4.4.3 Email flux of information

This subsection explains in detail how the information is transmitted from the student request until he opens the door. The steps of this process were already explained in the last section by the Figure 4.19.

Student request

Firstly the student request an access. This action generates a *HTTP POST* request that must send the *laboratory_id*, *User_id* and the check-in date to the server. Then to validate the request, the server does not only check if all data was received, but also asks the server about the users previous accesses to block and alert him if he have, in less than 30 minutes, asked a request to the same laboratory. In any of this situations a *JSON* file is sent to the browser to advise the user (see Figure 4.36).

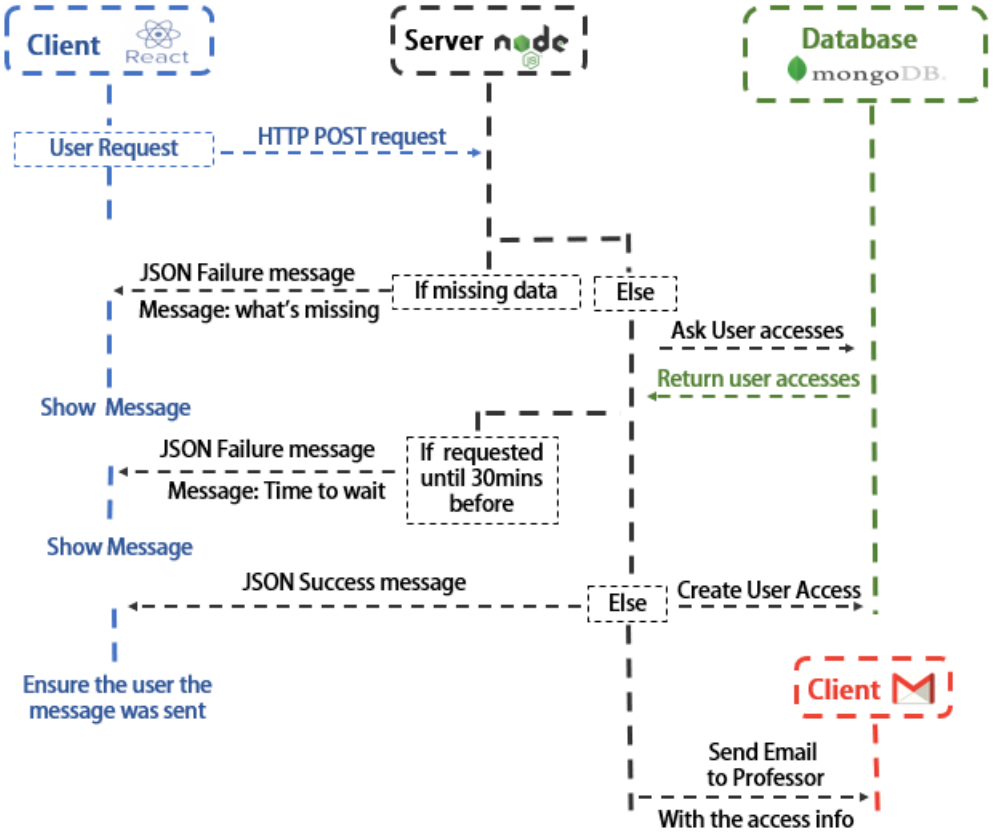


Figure 4.36: Ask request by student information flow.

Only after it, if everything proves right the server creates a new *Access* document into the database (see *Access* info on Figure 4.26), the user receives a message via *JSON* file

to ensure him that the access was sent, and finally the professor receives an personalised *HTML* email with all the necessary info to his decision (see email in Figure 4.20).

Professor response

The next step on the process (on Figure 4.19) is the professor response to the email received.

In case the professor accepts the student access (via button in the email, Figure 4.20), a *HTTP GET* request is sent to the server with the respective *access_id* in a query string. Then, the server, with the *access_id* consults the database to have all the information relative to the access. Then, the professor is redirected to an HTML page informing him of the situation.

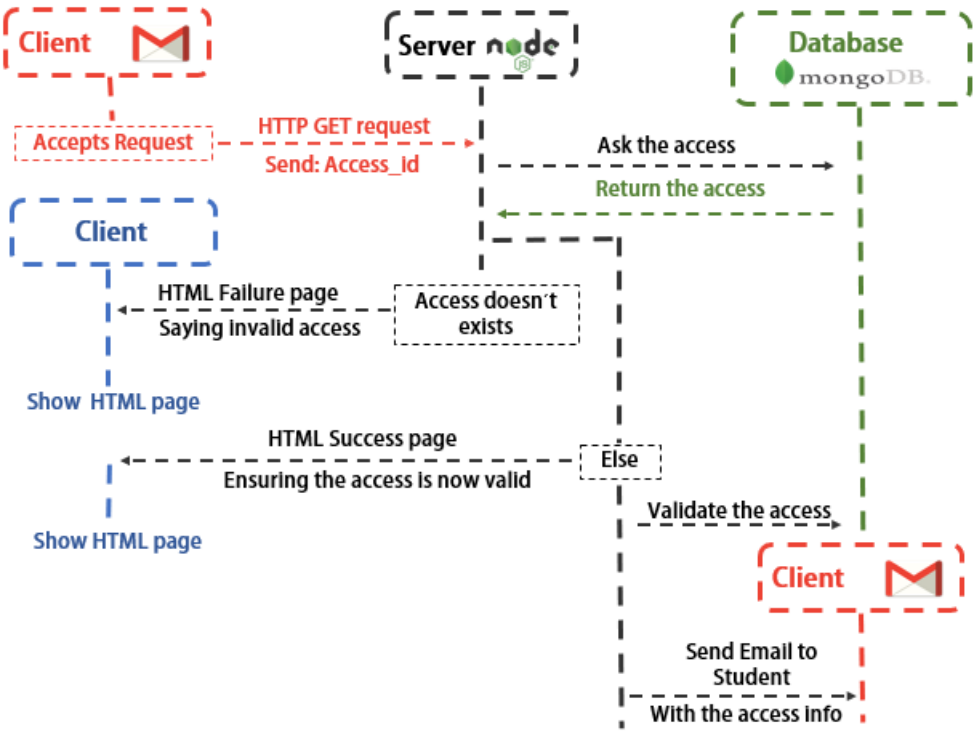


Figure 4.37: Professor accepts the student access, information flow.

If the *Access* still exists, the server validates the *Access* into the database and finally sends an email to the student with a button to open the requested laboratory (represented in Figure 4.21).

In case the professor denies the student access, all the process remains the same, with only two differences: the access remains not valid and the student receives an email saying that his access was denied (represented by the Figure 4.38).

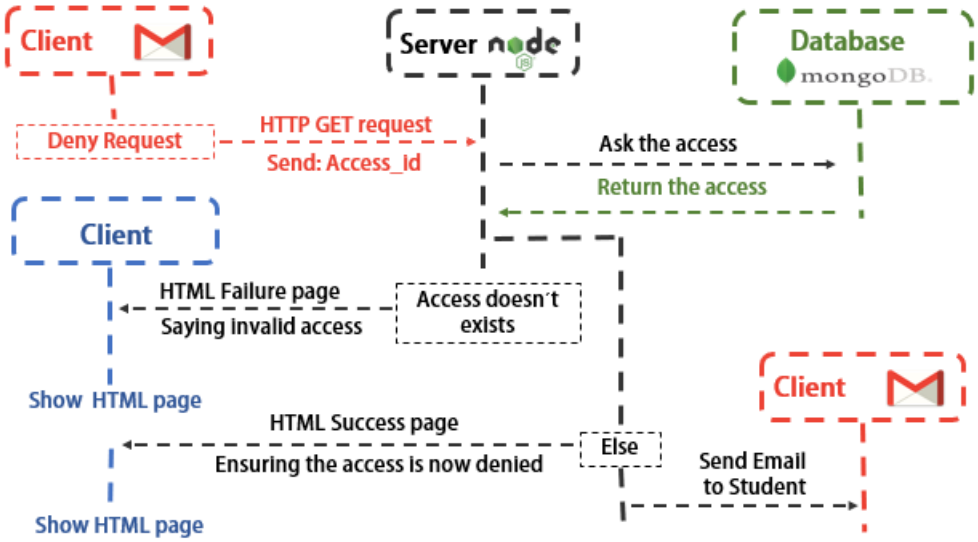


Figure 4.38: Professor denies the student access, information flow.

4.4.4 Open the door

If the professor have validated the request, now the student have received an email where he can trigger the process on the Figure 4.39 to open the door. Notice this is the last step of the system because is where the student achieves his goal and also the most complex one, because is here that the connection between software and hardware is established.

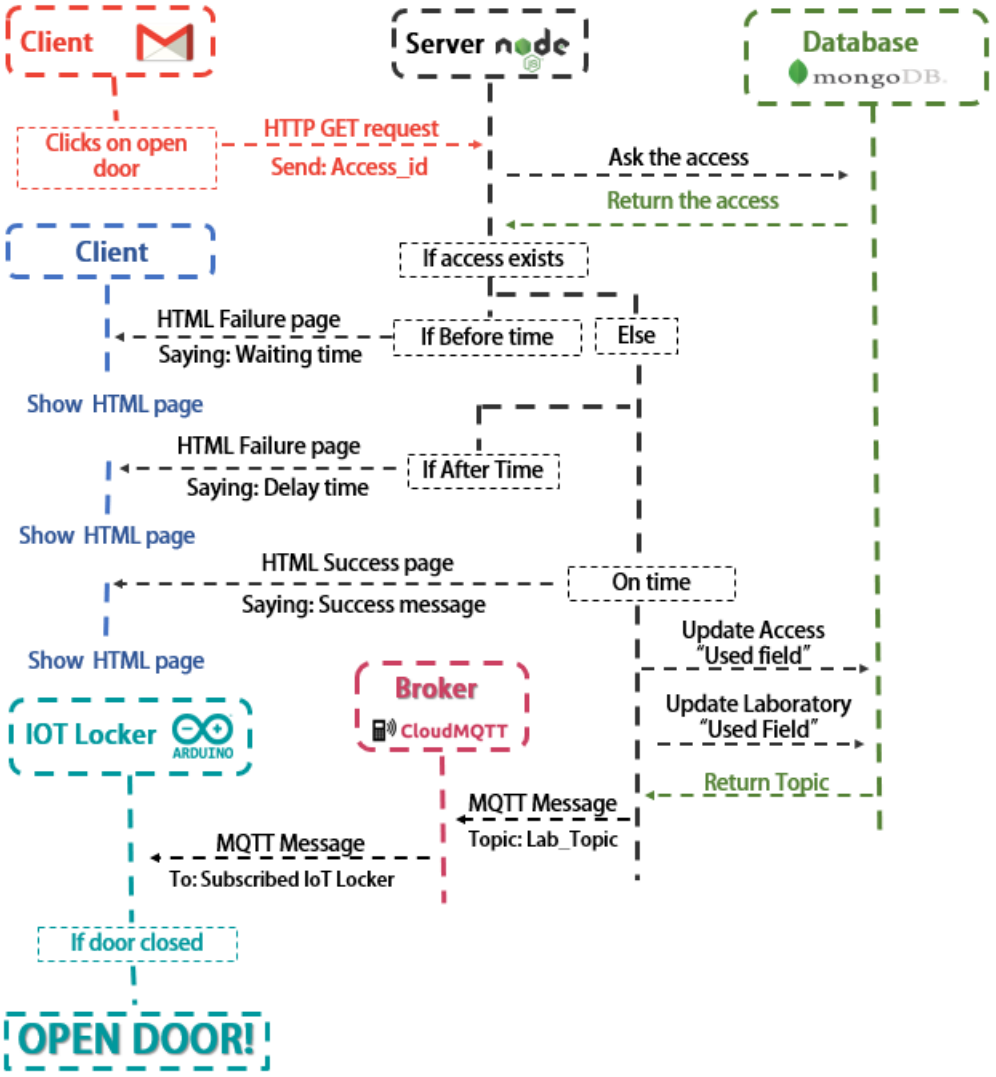


Figure 4.39: Student when opens the door, information flow.

The process follows this steps sequentially:

1. The student clicks on the button "Open Door" at the email received (represented on Figure 4.21).
2. It triggers an *HTTP GET* response to the server, sending the respective *Access_ id* via query string
3. The server with the *Access_ id* (unique key) asks the database all the data about this access.
4. If the access still exists and is validated by the professor, the process continues.
5. If the student tries to open the door before the requested time, the server sends an *HTML* failure page with the time still missing until the requested check-in time and ends the operation.

6. If the student tries to open the door after 120 minutes of the required date. The server sends an *HTML* failure page with the delay time, in hours from the requested check-in time and ends the operation.

7. If the student tries to open the door on time (until 120 minutes after the required date). The server sends an *HTML* success page to the user with the time still valid time and ensuring him that the door is about to open. In this case the operation continues to the next points

8. Then, the server updates into the database the *Access* Field *Used* to true (see *Access* collection Figure 4.26) and inserts into the *Laboratory* document filed *Used* the info of this access (see *Laboratory* collection Figure 4.24)

9. The database returns to the $MQTT$ topic of the required laboratory.

10. Using the *Laboratory* topic , the process gets out of the server domain, by the server publishing a $MQTT$ message to the broker.

11. The broker receives the message and publishes it to the specific respective IoT locker (locker subscribed with that topic and therefore to the correct laboratory).

12. The correct IoT locker receives a string message:"Open door". When the *NodeMCU* receives it, if the door is closed it commands the step motor to open the door, following the rules presented on section 4.3.5.

This section demonstrates the whole process where the user is able to create is own account, make his reservations and open the desired door at the desired check-in time. The professor can accept or deny the student's access. The admin is able to monitor all accesses used by whom ,where and when. Finally, the access control system will be able to connect to as many laboratories as we want to open correctly at the desired time.

Part V

Final Considerations

Chapter 5

Final Considerations

5.1 Overview

Over the document the author follows the methodologies, referenced in section 1.3. By the influence of the state gate technique the document had as goals the following topics:

1. Idea screening
2. Concept screening
3. Business analysis
4. Product prototyping
5. Analyzing the final result

Looking back on the document, it is possible to see that all points are fulfilled, with the exception of the last one. The first point was completed when the project was chosen, chapter 1. The concept, second point, was was created when the product got idealised, Chapter 3. The business analysis, third point, was completed through a state of the art (chapter 2) and Business Model (chapter 3). Finally the fourth point, was developed in the Chapter 4.

5.2 Analysing the final result

This topic will present the author opinion about the strengths and limitations of the work done. To facilitate the readability of this section, it will follow the same structure of the document, beginning with the introduction and and finishing with the prototyping.

5.2.1 Strengths

The initial introduction covers broadly the relationship between technology and tourism indicating the multiple opportunities that can be found in the this relationship. Additionally, it is mentioned why the problem this project tries to solve is important, its origins and what consequences it brings to society. Finally, presents the general characteristics of the solution and explains the methodology to be used to decide on product development.

The state of the art is split into three parts. It starts by understanding the target audience needs, characteristics and important factors, both for the tourist and the owner. After that, there is an explanation about the systems developed so far that can provide a solution to the problem. Finally, the author chose the most appropriate technology for the product to develop and presents multiple advantages about how the product could be adapted to the target audience needs.

With that information a better understanding of the product applicability's into the business world was developed by a business model, in the chapter 3. This chapter explains how the product developed could be profitable, generate value to society and present itself as an innovation.

Finally the *MVP* was done to be implemented in Aveiro Mechanical engineering laboratories, entering in the build-measure-learn feedback loop as quickly as possible (with the students). For that the *MVP* fulfils all minimum required functionalities that are important to demonstrate the system's concept and usefulness.

5.2.2 Limitations

For a better problem insight, there could have been contact with population experts, specially in the touristic & technology relationship. This would verify some possible assumptions the author is not aware.

In the Introduction, it would have been interesting to research data about the economic impact of the accommodation inside the touristic industry.

In the state of the art, regarding the target audience, it would have been interesting to interview a dozen of potential users to pick up natural behaviours they tend to do as well as better understanding and documenting their needs as users. Regarding the market research, buying the actual products in the market and put them to test with users, would help to better clarify and perhaps add to the pros and cons of the products.

In the business model, the the *MVP* presents one major limitation: It does not have potential to test the owner costumer segment. But quickly the developed MVP is adapted with an payment system and different layout of information to be tested inside the accommodation sector.

In the developed MVP, its implementation with user tests could have been done with the final prototype, to help identify errors and short comings of the concept.

5.3 Future work

It is important to look back on work done and understand what could be added and improved. This section will include a possible direction of work to build on this document, which the researches believes to be pertinent.

Interviewing users in order to develop a better idealisation of the product and using that information to adapt the concept would improve chances of future market acceptance. The same thing with testing the prototype. User testing should be done in an iterative fashion, in order to integrate the secondary functionalities and see which main characteristics the consumer value most.

User testing should be done in an iterative fashion, in order to integrate incremental improvements, changing configuration and technology according to the user needs.

Finally the product can be further implemented into the accommodation sector instead of only in the university environment, the hardware should be improved in the following ways:

- Step motor instead of servo motor to trigger the opening of the door.
- Development of an automatic calibration system to the step motor. Making the locker to adjust automatically to each door. This can be done by measuring the expenses of energy of the step motor by the analog pins of NodeMCU.
- Print an 3D model of the box to put all the locker hardware inside and fix-it into the door.

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