Product Design of Managed Services for a Connected Vehicles Startup

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To my dear Family and friends

Abstract

The age of IoT (Internet of Things) has already begun, but today's organizations have only scratched the surface when it comes to the full potential of such a technological revolution. Innovations are emerging at a very fast pace, and the proliferation of startups was a natural consequence of an accompanying soaring competition. The transportation sector was not left behind, as the connected vehicles paradigm is disrupting how people move, and what they carry out on the move.

Dealing with complex innovation, from a startup standpoint, comes with great challenges and limitations. However, when lean startup methodology is correctly applied, the right direction becomes clear and the speed of the journey amplified.

This project was conducted in a connected vehicle startup, which offers an innovative and future-ready connectivity solution for bus fleet operators. Three main goals were considered: designing a new captive portal feature to a customer from the ground up, developing service performance metrics and interviewing target customers with the purpose of testing a product-market fit hypothesis.

The product feature design was executed with a high customer involvement, starting from the customer needs and finishing with the operational feedback; the new captive portal survey was able to capture a sufficient number of answers in targeted buses only and help the customer make up a tactical decision.

The service was measured and monitored with the use of cross-deployment metrics. These were able to pinpoint issues such as a faulty variable calculation in the database or the impact on the user experience of having the whole customer network disconnected for a few minutes. The issues were subsequently mitigated through appropriate solutions.

Lastly, the fit between the startups' Mobile Wi-Fi solution and the bus fleet market was successfully assessed through customer interviews and deemed non-existent. This supports the assumption that the customer is the most important source of learning for an organization. Iterations in the product are suggested for the successive steps, as well as alternative target markets.

Desenho de Produto em Serviços Gerenciados para uma empresa emergente (*startup*) de veículos conectados

Resumo

A era da Internet das Coisas já começou, mas as organizações de hoje apenas rasparam a superfície no que toca ao total potencial desta revolução tecnológica. Inovações estão a emergir a um ritmo veloz e a proliferação das *startups* foi uma consequência natural de uma paralela e intensa competição. O segmento dos transportes não ficou para trás, sendo que o paradigma dos veículos conectados está a ter um efeito disruptivo na forma como as pessoas se movem e naquilo que elas executam em movimento.

Lidar com inovação complexa, do ponto de vista de uma *startup*, vem acompanhado de grandes desafios e limitações. No entanto, quando a metodologia *lean startup* é corretamente aplicada, a direção certa torna-se clara e a velocidade da travessia amplificada.

Este projeto foi realizado numa *startup* de veículos conectados, que oferece às operadoras de frotas de autocarros uma solução de conectividade inovadora e pronta para o futuro. Três objetivos principais foram considerados: desenho de uma nova funcionalidade de portal cativo para um cliente desde a sua génese, desenvolvimento de métricas de performance do serviço e entrevistas aos clientes alvo com o propósito de testar uma hipótese relacionada com o encaixe entre um produto e um mercado.

O desenho da funcionalidade de produto foi executado com grande envolvimento do cliente, começando pelas suas necessidades e terminando com comentários sobre a operação; o novo questionário de portal cativo foi capaz de capturar um número suficiente de respostas apenas nos autocarros alvo e ajudar o cliente a tomar uma decisão tática.

O serviço foi medido e monitorizado com o uso de métricas partilhadas pelos desdobramentos. Estas foram capazes de apontar problemas tais como o cálculo defeituoso de variáveis na base de dados ou o impacte na experiência do utilizador de ter toda a rede do cliente desconectada por alguns minutos. Os problemas foram de seguida mitigados através de soluções apropriadas.

Finalmente, o encaixe entre a solução de *Mobile Wi-Fi* da *startup* com o mercado de frotas de autocarros foi avaliado com sucesso através de entrevistas com clientes e foi considerado não existente. Tal suporta o pressuposto de que, para uma organização, o cliente é a fonte mais importante de aprendizagem. Iterações no produto são sugeridas nos passos sucessivos, assim como mercados alvo alternativos.

Acknowledgments

The first and greatest words of acknowledgement go to Veniam, for giving me the priceless opportunity to board their exciting mission. One of Veniam's ideals is that they strive for employing class A+ collaborators. This practice was noticeable from day one, as I felt surrounded by remarkable professionals from whom I had the chance to absorb a vast amount of knowledge. Yet, no one taught nor helped me more than the great product owner, my supervisor and mentor, Henrique Cruz, who I will certainly view as a role model for a long time coming. I would also like to thank Isabel Portugal for teaching me about all I know related to data analytics and for all the time and patience she dedicated to help me. To my team members and other overly helpful colleagues, Luis Carvalho, Diogo Figueiredo, Eduardo Carneiro, Dinis Areias, Joana Ribau and Marios Kyriakidis, thank you for always giving me a helping hand.

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Glossary

AP - Access Point

API – Application Programming Interface

CCTV – Closed-Circuit Television

DSRC – Dedicated Short-Range Communication

IoT – Internet of Things

MAC – Media Access Control

NPS - Net Promoter Score

OBU – On-Board Unit

OEM – Original Equipment Manufacturer

PDR – Packet Delivery Ratio

QoE – Quality of Experience

QoS - Quality of Service

ROI – Return On Investment

SSID - Service Set IDentifier

USP – Unique Sales Proposition

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1. Introduction

With a current size of 57 employees, Veniam is going through a stage that all growing startups must endure - *validation*. After proving its potential in different solutions for ports, smart cities and vehicle fleets, the startup narrowed their efforts into the segment of bus fleets, in which it aspires to achieve the absolutely necessary product-market fit. Figure 1 depicts the stages that a startup normally experiences before establishing itself as a mature company.

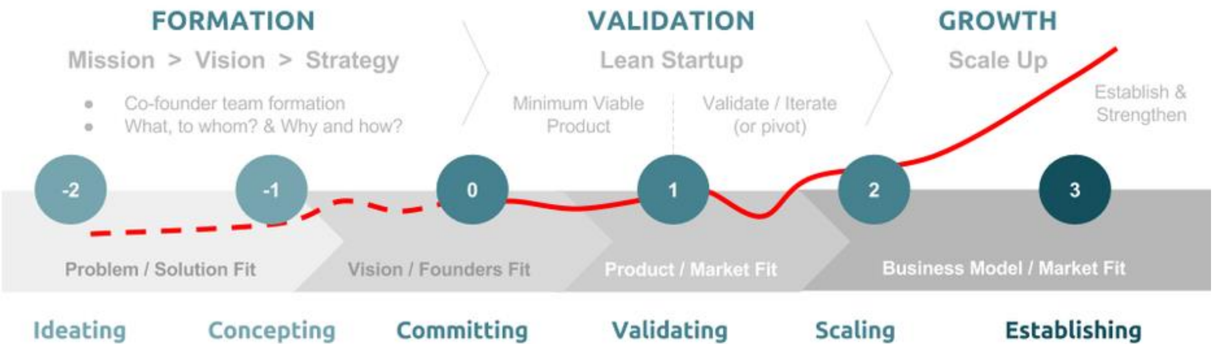

Figure 1 - Startup Development Phases. Source: www.startupcommons.org

Amid the *validation* phase, much of the startup's effort consists in testing and iterating on market experiments with its product. The main goal is to validate solutions by meeting customer growth and/or revenue. Since the company is still pursuing the sustainable solution that will enable it to scale and reach profitability, lean start up methodology comes in play as an important set of practises that guide the course of action efficiently towards the end objective.

The present dissertation explores the case of Veniam and focuses on three practical approaches that are consistent with lean startup and with pursuing the product-market fit: service usage monitoring and analysis, new product feature development and target customer interviews.

1.1. Veniam

Machine-to-machine networking, popularly known as IoT, is estimated to become a $19 trillion economic opportunity over the next decade. Some of its use cases include tracking railcars and their contents across their shipping routes to improve lead times; having connected medication bottles sending warning messages to a smartphone so that the patient doesn't forget to take them; placing sensors in jet engines to report gigabytes of operating data per flight with the purpose of optimizing maintenance and lowering costs (Bylund, 2017).

Connected vehicles consist of a crucial and valuable segment of IoT. By connecting the many electronic components of the vehicle to a centralized server, as well as installing specific IoT hardware, many services come into view. Active vehicle-to-vehicle (V2V) safety, data tracking, intelligent infotainment and Wi-Fi hotspots are only a few of the ones worth mentioning (Telefónica, 2015).

Veniam is a 5-year-old Portuguese startup that is focused on building the Internet of *Moving* Things™: with its own patented hardware, software and cloud services, Veniam turns vehicles into Wi-Fi hotspots, creates a mesh network that expands wireless coverage, collects terabytes of daily urban data and delivers managed services (CA Technologies, 2012) to intelligent transportation systems.
As a spin-off from the Instituto de Telecomunicações and from the Universities of Porto and Aveiro, Veniam takes advantage of Dedicated Short-Range Communication (DSRC), which is an open-source protocol for wireless communication specifically designed for automotive use. DSRC is used to connect vehicles to the Cloud, hence decreasing the need for cellular data transfers which are provided and charged by telecommunications companies. Traffic offload is also managed in a way that prevents networks from being congested, thus achieving high performance at a cheaper cost. Communication is made in V2V and vehicle-to-infrastructure (V2I) - which are collectively referred to as vehicle-to-everything (V2X) – and Veniam believes that the coming autonomous driving systems will depend on mastering this form of communication in order to become safe and reliable. Figure 2 gives an overview of Veniam's bus fleet network.

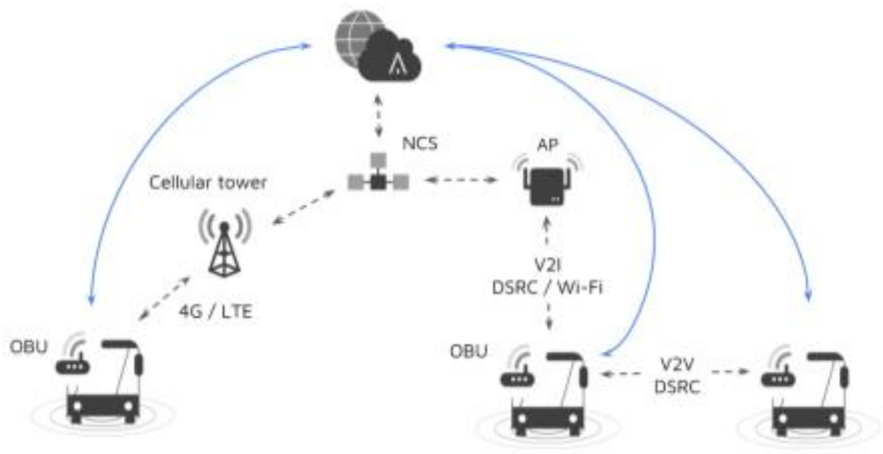

Figure 2 - Veniam's network components

The startup uses two main pieces of hardware. The on-board unit (OBU) for vehicles, also called NetRider™, comes in a metal or plastic casing and has several communication modules including Wi-Fi, cellular, DSRC and Bluetooth. It also has data storage up to 16GB so it can delay the transfer of non-urgent information while outside of the DSRC range and therefore minimizing the usage of cellular communication. This device, which can be seen on Figure 3, can transfer data between other OBUs alike, user devices such as smartphones or laptops and between Veniam's second main hardware device - the access point (AP). The APs can be found in fixed locations spread around the city and are connected to the fiber optic internet. Their purpose is to provide an internet connection through DSRC or Wi-Fi to the OBUs that move within their approximate 400-meter range of communication. The urban data generated by the passengers and the buses is transmitted to and from the Cloud and coordinated by a Network Controller System (NCS).

Figure 3 – Veniam NetRiders™ in metal and plastic casing

Veniam has built the world's largest connected vehicles network in Porto, which includes taxis, waste collection trucks and the entire major city bus fleet, STCP, offering free Wi-Fi to more than 500,000 active customers. It also has bus fleet deployments in Singapore and New York, as well as offices in these 3 locations.

The largest share of Veniam's personnel is based in Porto, comprising the efforts of Engineering, System Operations, Finance and Product Development. Abroad, teams of 5 collaborators are allocated to each office. The organizational chart can be found in Appendix A, Figure 27.

In February, 2016, Veniam was able to raise $22 million in series B funding by investors such as Cisco, Liberty Global, Orange, Verizon and Yamaha Motors. The startup has been recognized by several awards, including being ranked twice by the Consumer News and Business Channel (CNBC) as one of the top 50 most disruptive companies of 2016 and 2017 (CNBC, 2016).

1.2. Project

Veniam has created two customer-facing product teams, each consisting of 5 members, with the responsibility of guiding the organization's further development into useful and valuable services for the market. These teams are strongly business oriented, have high front-end development capabilities and use the data analysts' support to conduct lean startup practises.

One is managing the Network Operation Control (NOC) product, which is a cloud-based application for fleet and network management with smart visualisation. It includes a map where all the vehicles equipped with Veniam's OBUs are moving in real-time, information about the amount of data transferred by DSRC or cellular modes and other metrics and filters that grant fleet intelligence to its manager. Figure 4 gives a glance of its composition.

Figure 4 - NOC application

The other team manages the Mobile Wi-Fi product, which delivers high-quality mobile Wi-Fi to passengers while enabling new managed services for the operator through the captive portal. Captive portals consist of a web page that the users must see on their device - for instance, their smartphone - in order to connect to the Wi-Fi and are common in locations such as airports, trains, shopping malls, and more. They allow the fleet operator to establish a point of communication with the passengers, enabling the transmission of information, advertisement or other content, as well as capturing passenger data or opinion through surveys. Its most basic functionality is to impose the acceptance of its terms and conditions. Figure 5 presents Veniam's standard captive portal, that is, the unbranded one.

Figure 5 - Veniam standard captive portal with social media login

This project was mostly embedded in the Mobile Wi-Fi team, which felt the need to scale their operations. While offering Mobile Wi-Fi to bus fleets was the market experiment at hand, the team was employing the lean startup methodology to *build* the most appropriate product features, *measure* the current service usage and *learn* if the assumptions regarding this product and market were accurate. This consists a macro level build-measure-learn cycle (Ries, 2011).

Hence, this project aims at addressing the following three main goals:

A. **New product feature development -** Iterate on the product characteristics based on findings from the current STCP client, on a captive portal management market analysis and on Veniam's development capacity. This goal should lead to the development of a useful problem-solving feature with business value for the customer;
B. **Service usage monitoring and analysis -** Measure Veniam's current performance in terms of user (passenger) experience as well as understand the user's riding and Wi-Fi usage habits. This goal should lead to a dashboard with daily metrics that identify service improvement opportunities.
C. **Target customer interviews -** Validate Veniam's assumptions regarding the bus fleet market by conducting interviews with target customers. This goal should lead to a collection of interview reports as well as scorecards for each bus operator that assess their willingness to purchase our Mobile Wi-Fi solution. This task aimed at validating the product-market fit with passenger fleets.

For goal A, the following approach was executed:

1. Conduction of a deep competitive analysis of the captive portal industry, looking for best practises and categorizing the existing features as well as explaining them;
2. Creation of a table that describes the development state of these features in Veniam as well as an estimate for the effort of developing each feature;
3. Validation of 4 captive portal concept designs through meeting with STCP. These were based on customer needs that had been identified in previous meetings, on findings regarding the captive portal management analysis and on Veniam's development capacity;
4. Development of a fully functional feature and design of a short trial in a small number of buses;
5. Deployment of the trial and gathering of results.

For goal B, the following approach was executed:

1. Definition of metrics for daily assessment and time series creation based on data captured on Veniam's STCP and NUS fleet networks;
2. Calculation of the required formulas using the business intelligence software Tableau;
3. Dashboard creation on Tableau to be used by the whole company;
4. Monitoring of daily metrics and pattern analysis, aiming at identifying unexpected behaviours;
5. Research for possible root causes of a selected set of unexpected behaviours;
6. Identification of main cause and solution development.

For goal C, the following approach was executed:

1. Target customer prospecting (135 operators), limited to privately owned bus fleets in Europe, Singapore and the USA;

2. Definition of an interview script directed to gathering insights about the topics of Wi-Fi for passengers, passenger intelligence, rider engagement and connectivity hub.
3. First round of phone calls and emails aimed at gathering a relevant contact, assessing the existence of Wi-Fi in the fleet and the number of vehicles;
4. Second round of phone calls with an average duration of 30 minutes and with the use of the interview script. A document with notes is written for each phone call and shared within the whole company. This document also contains a score attributed to the interest of each operator in using the Mobile Wi-Fi solution for each of the 4 discussed contexts;
5. Designing of a matrix with all the operators and attributed scores;
6. Analysis of the quantitative results with graphs and of the qualitative results by summarizing the most prevalent responses and ideas.

1.3. Structure

The subsequent content of this dissertation is structured in 5 different chapters.

Chapter 2 addresses the literature review on the main themes presented along the project. The first review provides insights on the technological background of Veniam by briefly explaining the DSRC technology and its potential regarding mesh networking. The second review addresses the lean startup methodology, disclosing its five core principals, the MVP and the product-market fit. The Agile methodology and Scrum framework are reviewed next.

Chapter 3 describes the initial situation of the company when the present project began. The vision for the Mobile Wi-Fi product is presented, alongside with its current main hypothesis and assumptions. Company and team goals are clarified next, as well as the current deployments and its characteristics. Finally, the tasks at hand within the team are described.

Chapter 4 examines goal A (new product feature development), providing a detailed explanation of the adopted methodology and illustrating it with figures of the concept captive portals and of the final feature.

Chapter 5 explores goal B (service usage monitoring and analysis), presenting a table with the metrics that were developed, illustrating a few of the main patterns with graphics and describing the analyses that were conducted based on findings provided by the metrics.

Chapter 6 narrates the accomplishment of goal C (target customer interviews), accompanied by the main learnings that this execution allowed. In its closure, the results are scrutinized by the use of graphs.

The final conclusions are described in chapter 7, which summarize the overall product-market fit settlement and goes into detail regarding each project goal and respecting future work.

Ending the present dissertation, the references are presented, followed by the appendices that are referred along the whole work.

2. State of the Art

2.1. Technology

At its core, Veniam is an engineering focused startup. Many hardware, systems, software and cloud developments are performed continuously. Thus, many modern technology concepts are an inherent part of its business, providing both opportunities as well as limitations. The first part of this chapter intents to briefly explain the most relevant concepts that are mentioned along the thesis.

2.1.1 DSRC

Dedicated Short Range Communication (DSRC) is a 75MHz wide spectrum band located in the 5.9GHz spectrum and its use was made exclusively available for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication by the U.S. Federal Communication Commission (FCC, 2003). A similar band was allocated in Europe for the same purpose (Festag and Hess, 2009).

DSRC is characterised by having high reliability and low delay. Its data transmission rates are typically between 6 and 27 Mb/s (Dar *et al.*, 2010). Because of this, the primary motivation for DSRC was to support public safety applications that prevent vehicle collisions. These applications depend on the frequent broadcasting of data such as location, speed and acceleration over a range of about 1000 meters. Vehicles can send and receive "safety messages" from other DSRC-equipped vehicles and identify collision threats. As shown by Ahmed-Zaid and Carter (2009), examples of safety applications include:

- Forward collision warning (stopped car ahead);
- Emergency electronic brake lights (hard-braking vehicle ahead);
- Blind spot warning;
- Intersection movement assist;
- Do not pass warning;
- Control loss warning.

The U.S. FCC also explicitly allows for non-safety DSRC applications as a measure of stimulating the adoption of this technology (Chen *et al.*, 2009). Besides safety, several other intelligent transport systems (ITS) applications may benefit from DSRC, including traffic management, road monitoring, entertainment, contextual information and all their subcategories (Dar *et al.*, 2010).

2.1.2 VANETs

Vehicular Ad hoc NETworks (VANETs) make use of DSRC technology to make the dissemination of safety messages and other vehicle-related applications possible. Bai *et al.* (2006) presents a comprehensive classification of VANET applications with regards to their intrinsic network requirements. The list of applications includes real time audio/video communication, instant message exchange, coordinated movement of two or more vehicles and more. Boban *et al.* (2009) have demonstrated that VANET technology is capable of achieving satisfactory delay and jitter for most applications. Other important metrics for accessing QoS in vehicular communication include packet delivery ratio (PDR) and connection duration, which were shown to be highly dependent on vehicle density and the particular environment of the network (Boban *et al.*, 2009).

One important consideration is the positive economic impact of Internet access through vehicular DSRC networks, which has been estimated by Ligo *et al.* (2016). High density urban areas have an advantage in collecting the benefits of mesh networks, but as the load of Internet traffic and OBU penetration increase over time, benefits will exceed costs for ever less populated areas.

Deployment of the On-Board Units (OBUs) required for such vehicular networks is naturally a gradual process, with Bai and Krishnamachari (2010) estimating a 15 year period before all vehicles are equipped. To enable the safety messaging benefits of VANETs meanwhile the penetration rate is below 100%, Boban *et al.* (2012) propose a combination of standard wireless communication and visual cues, such as specific patterns of hazard warning lights, to increase the efficiency of transmitting safety messages.

Moreover, VANETs are spreading to contexts beyond road safety. A practical example of how flexible they can be was shown by Ameixieira *et al.* (2014) when seaport operations were leveraged by the deployment of a vehicular network. Wireless connectivity was given to the whole confined space of about $1km^2$ by making use of moving container trucks, cranes, tow boats and more.

2.1.3. Multi-hop

The DSRC technology can be leveraged to create a mesh network and extend connectivity by using multi-hop broadcasting. In Multi-Hop Wireless Networks (MHWN), a multitude of wireless nodes are able to communicate with each other via multiple wireless links (Wei *et al.*, 2017).

While in single-hop communication the OBUs connect directly to an access point or base station, in multi-hop the OBUs can use one another as intermediaries for the communication with the access point. Figure 6 illustrates both these scenarios.

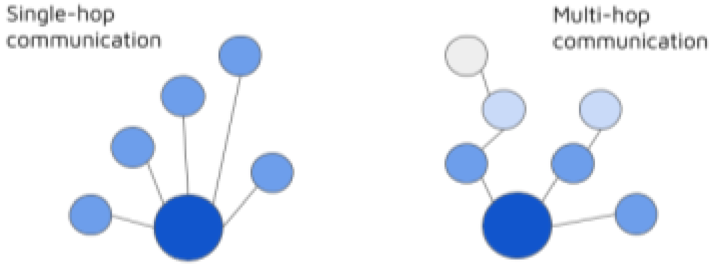

Figure 6 - Single-hop and multi-hop communication

Luong *et al.* (2014) have compared one-hop vs. multi-hop broadcast protocol for DSRC safety applications. Their results and observations show that multi-hop has a superior PDR than the single-hop, especially in vehicle densities below 75 vehicles/km and with a longer transmission range (between 130 and 200 meters).

There are several instances within the MHWN, each one suitable for a given scenario and circumstances. These include Wireless Ad Hoc Networks (WAHN), Wireless Sensor Networks (WSN), Wireless Mesh Networks (WMN) and more.

2.1.4. Bandwidth Aggregation

With ever increasing complexity in mobile applications, file size in photos and videos and smartphone penetration, the internet data demand of an urban population is increasing. Global mobile data traffic will grow at a CAGR of 46 percent between 2016 and 2021 (Cisco, 2017). To cope with such increasing data needs, bandwidth aggregation comes in play as a technique for using multiple communication modules simultaneously for an increased throughput. Bandwidth aggregation has been explored in different layers, with examples of protocols like Stream Control Transmission Protocol (Abd *et al.*, 2004) and Multipath TCP (Ford *et al.*, 2011) at the transport layer.

Kaspar *et al.* (2010) have assessed how startup latency (the waiting time before a video can begin) and large buffer overheads were amongst the most significant challenges in downloading over multiple aggregated channels.

More recently, Huang *et al.* (2016) have explored a cooperative streaming in the context of fleets, where multiple vehicles can allocate the free capacity of their radio modules to download video data. The requester can also make use of a multi-hop effect, reaching out to a greater number of peers.

2.2. Lean startup

The lean startup methodology (Ries, 2011) is a hypothesis-driven approach for launching a business and creating a product. It combines Toyota's lean manufacturing principles (Womack and Jones, 2010) with the concept of customer development (Blank, 2013) applied to new ventures. Lean principles aim at reducing waste as much as possible in the work environment and focusing on tasks that create value. Lean mind-set also includes immediate quality control: when a defect is encountered, the whole production line can be interrupted for the sake of understanding and fixing the problem as quick as possible (Ohno, 1988). In lean startup the same "quick learning" intention is applied to the context of software development and startups.

Waste in startup development is mitigated by the use of minimum viable products (MVPs) and quality control is assured by user feedback on MVPs. Customer feedback is usually measured by performance metrics, A/B testing, key metrics and prototyping (Ries, 2011).

Eric Ries conceptualized the lean startup methodology and with the help of professors like Steve Blank it became ubiquitous in modern startup culture. According to Ries, there are five principles in lean startup that will be explained next.

2.2.1. The five principles of lean startup

I. Entrepreneurs are everywhere

Entrepreneurs are not defined by the amount of resources that are available to them, whether they are monetary or human, but rather by the amount of risk that is involved in their efforts to launch a business. That means entrepreneurs can be found also in very large companies and are agnostic to markets or industries. Mature companies that seek product innovation in order to sustain their competitive advantage (Kuratko *et al.*, 2014) can rely on internal startups as a way to nurture innovation and entrepreneurship within their already established organization (Kuratko *et al.*, 2009). Internal startups consist in a setup in which a company launches a separate and (semi-)independently managed organization to pursue a new idea or innovation (Märijärvi *et al.*, 2016). Edison *et al.* (2016) even developed a model called "Lean startup-enabled new product development" which identifies the particular activities of software product innovation within internal software startups. The most important aspect of this lean startup principle, however, is the amount of risk that must be dealt with. If there was a known business model for a given idea, then success would be only related to its execution and not to the pursue of the right business model.

II. Entrepreneurship is management

Since a startup is an institution that operates in a specific context of risk and uncertainty, it requires a management style that differs from the one of a mature corporation (Blank and Dorf, 2012). Classic enterprise structure and managerial style are not appropriate for startups because they are typically rooted in the premise that if the plan is good enough then it will succeed. Thus, classic management do not rely on trials and errors, which are the pillars of the lean startup. In addition, the classical budget estimation is unnecessary and might even be hindering (Ries, 2010).

III. Validated learning

In a startup, the learning motive should be placed above product or profit. Learning how to build a sustainable business is the ultimate purpose of a startup. This validation can be done through scientific methods that consist in running experiments that test the vision-related hypothesis. Empirical evidence is sought and the main provider of knowledge is the potential customer. When compared to market forecasting, validated learning is more concrete, accurate and allows a faster progress towards success. It is also an iterative process that stimulates continuous innovation. After capturing intelligence on the many experiments that the startup must withstand, the lessons learned should be fed to innovation accounting (explained in section 2.2.5) in order to define the following hypothesis to be tested.

IV. Build-Measure-Learn

The foundation of a startup is to transform new ideas into products, measure customers will to use and buy the product and learn whether to pivot or persevere. When a pivot is done, the attention goes back to the ideas (hypothesis) and the cycle is repeated. A competitive startup is able to coordinate their team efforts into accelerating the feedback cycle, in order to learn quicker and reach product-market fit sooner. Figure 7 provides a clear view of this framework.

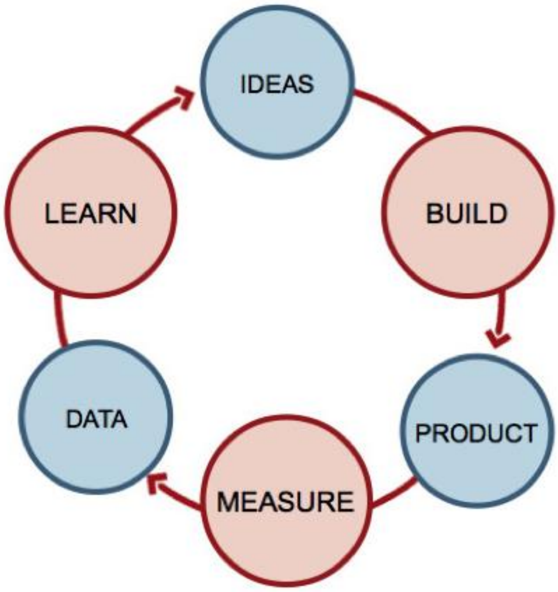

Figure 7 - Build-Measure-Learn cycle. Source: http://rajatgarg.net/post/13379561948/build-measure-learn, accessed 28-04-2017, 19:50

The "build" stage aims at delivering a MVP and can be performed with agile development methods. Abrahamsson *et al.* (2002) state that these methods are fundamentally simple and quick and focus firstly on the most urgent and important functions, delivering them fast, gathering feedback and quickly reacting to information updates. Popular agile methods include Extreme Programming (XP), Scrum, Feature Driven Development (FDD) and Crystal Method (Kumar and Bhatia, 2012).

The "measure" stage consists of defining metrics that can gather relevant data on the product and customer. According to Croll and Yoskovitz (2013), a good metric is comparative, understandable and in the ratio or rate form. A good metric should also influence the behaviour of the startup. A piece of data that doesn't drive the startup should be considered a vanity metric. As an example, "total signups" to a given website is a vanity metric because it is a number that can only increase over time. "Total active users" gives more information because it counts the number of signups that converted into loyal users. However, it is still a vanity metric because it will also increase over time, too, unless a serious mistake is done. A critical and actionable metric would be the "percent of users who are active" because it informs about the level of engagement of the users with the product. Positive changes to the product will make the percentage go up and vice-versa.

The "learning" stage simply compares the collected data with the original product hypothesis. Metrics and key learnings will inform if expectations were met or not. Importantly, there should be an understanding of why things happened the way they happened. This will contribute to the very important innovation accounting.

V. Innovation accounting

Innovation accounting consists on measuring progress, setting up milestones and prioritizing work. The focus is not placed on execution but rather on learning. The successive cycles of build-measure-learn will feed the knowledge banks of startups, informing further guidance and decisions.

One useful analysis tool for learning in lean startup is the five whys technique (Serrat, 2009).

It consists in a root cause analysis and is based on the ideas of Sakichi Toyoda of Toyota industries. In a chain of inputs, activities, outputs, outcomes and impact, it may be hard to link the extremities. To avoid blaming individuals or external factors when long chains of events occur, the five whys technique resorts to deep thinking through questioning the answer five times. Just like in the continuous improvement practises (Bessant and Caffyn, 1997), blame should not be directed to people but rather to a faulty process. Alternatives to the five whys technique that can also be used include barrier analysis, change analysis, causal factor tree analysis and the Ishikawa (or fishbone) diagram.

2.2.2. MVP

The minimum viable product is a version of the value proposition that results from the build-measure-learn cycle and is ready to go to market and be evaluated by the early adopters. It contains only the core features of the value proposition, the ones that actually solve the problem that the team is aiming to solve. The term MVP was defined by Robinson (2001) and propagated by Ries (2009) afterwards. This concept is continuously evolving and was defined by Eric Ries in 2001 (Ries, 2011) as "a version of a new product, which allows a team to collect the maximum amount of validated learning about customers with the least effort". Concurrently, the MVP is not always the simplest possible product if the problem at hand is not simple. Instead, the MVP should solve the main problems of the customer. Figure 8 is an adaptation of the featuritis curve (Sierra, 2007) and illustrates that an increase of functionality can bring an increase of customer resonance, but only to a certain extent before starting to decline. In this case, resonance refers to the amount of feedback attained from the customers.

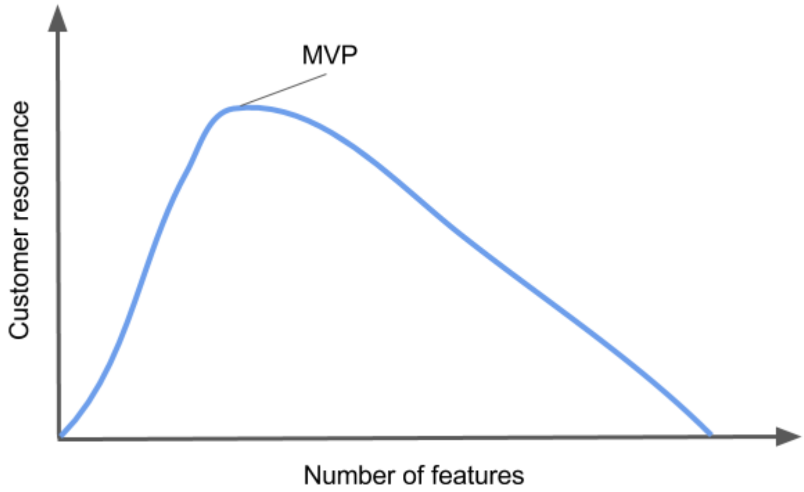

Figure 8 - MVP feature curve

2.2.3. Product-market fit

The product-market fit (Andreessen, 2007) occurs when the characteristics of the product match the needs of the targeted market. Its importance for the success of the startup is so prominent, that the world-renowned entrepreneur and Netscape co-founder, Marc Andreessen is often quoted by the following statement: "*the only thing that matters is getting to product-market fit*".

By applying the 5 principles of the lean startup method, this stage is achieved with several informed changes through iterations and with minimum waste of resources. It's important to mention that the iterations are not limited to changes in the product, but also to validating who the right customer is. Andreessen (2007) explains that when a great market is found, the market itself "pulls" product out of the startup. Contrarily, in an awful market, the best product and an outstanding team will not prevent failure.

A subsequential framework by Olsen (2015) called the product-market fit pyramid – Figure 9 - suggests that attention should be given to the following five components: target customer, underserved needs, value proposition, feature set and user experience (UX). User experience is the "real-world manifestation of software products that customers see and use". Product-market fit is therefore the measure of how well the product (top three layers of the pyramid) satisfies the market (bottom two layers of the pyramid).

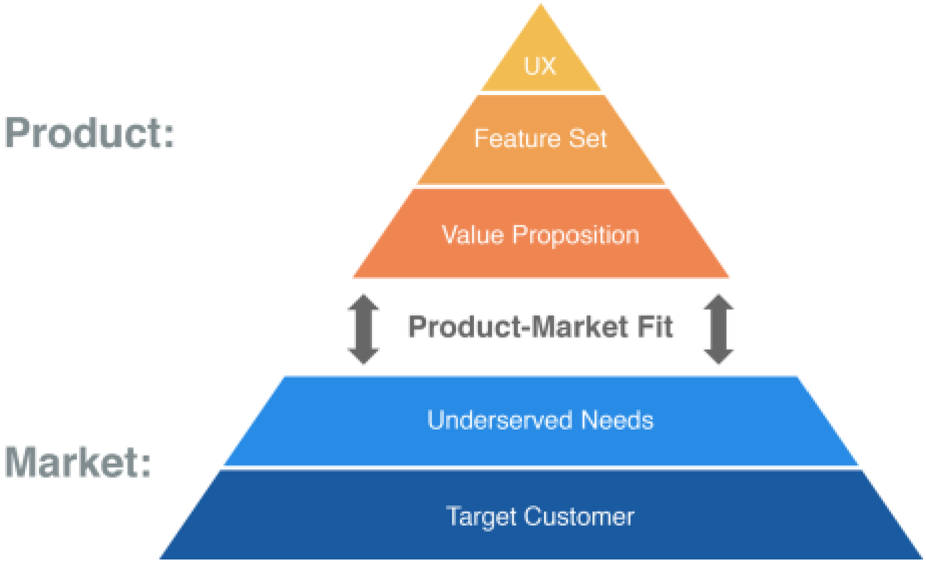

Figure 9 - Product-Market Fit Pyramid; Source: Olsen (2015)

2.2.4. Product development vs. startup failure

Failures in sales and marketing are commonly identified. However, the reason why software product startups fail might be related with product development issues, as Crowne (2002) explores. Different issues occur in different stages. As an example, in early stage startups, symptoms like lack of objectives and goals for product development are frequent and can cause important decisions to be made on an ad-hoc basis, regardless of a prevalent strategic plan. Establishing a strategic plan from the start can help guide the product development (McGrath and MacMillan, 2000), even if the plan suffers several changes due to changes in the market and company. The next example comes from startups that have done their first sale(s) and face too many new feature requests from existing customers as well as from the sale team. The pointed solution is the use of a business process in order to gather new requirements, prioritize them and finally evaluating their feasibility and value before adding them into the development record or not. This process is managed by the product owner. Recognizing such issues in an early stage can increase the odds of success for a startup.

2.3. Agile

Agile software development (ASD) is a very different approach compared to the traditional software development approach (Moe *et al.*, 2012). In ASD, planning is shortened and decision making is done in compressed iterations, resulting in anticipated and more frequent result deliveries. Teams collaborate actively in each critical decision, thus increasing the individual responsibility in the success or failure of a project (Drury *et al.*, 2012). Furthermore, ASD involves more interaction with customers throughout the project, such as regular meetings and consultation for increased feedback and client involvement in development decisions (Moe *et al.*, 2012).

Fitriani *et al.* (2016) studied the main challenges in ASD and concluded that team management and distributed team (geographically disperse) are the most significant, followed by requirement prioritization and documentation. These and other challenges should be taken into account before starting an ASD project.

To mitigate the growing challenge of working with distributed teams, Khmelevsky *et al.* (2017) propose several recommendations, including: acknowledging cultural differences in approaching a problem, using "rich" communication channels and high speed and quality video conference to simulate face-to-face meetings and avoiding agile variations that exclude basic practises of the framework.

2.3.1. Scrum

Scrum is an iterative and incremental agile software development framework for managing product development (Alliance, [20—]).

One important principle of Scrum is the a priori recognition that customers shift their understanding regarding their demands or needs during the design or development phase (often called requirements volatility (Henry and Henry, 1993)) and that there will be unpredictable challenges - for which a predictive or planned approach is not suited. As such, Scrum focuses on how to maximize the team's ability to deliver quickly, to respond to emerging requirements, and to adapt to evolving technologies and changes in market conditions (Hirotaka and Ikujiro, 1986).

The workflow in the Scrum framework is organized in sprints, which are the basic units of development. The sprint is a time boxed effort; that is, it is restricted to a specific duration (Gangji and Hartman, 2010). The duration is fixed in advance for each sprint and is normally between one week and one month (Schwaber, 2004).

Each sprint starts with a spring planning event, where items that were previously defined in the backlog are assigned to the team members. The sprint backlog is the list of items that the team must address during the next sprint (Martinelli and Milosevic, 2016). These consist of features, bug fixes, non-functional requirements, etc. - whatever must be done to successfully deliver a viable product. The product owner (commonly a lead user, marketing executive or product manager (Mountain Goat Software, [20—])) sorts the product backlog items based on risk, business value, dependencies and due date. Every item has an estimation of effort so that the team members commit to a realistic amount of work for the sprint. In the end, there is a sprint retrospective, which is a meeting with all the team members aiming at reviewing the progress and identifying lessons and improvements for the next sprints (Sutherland, 2004).

Items should be written in the user story format, which, according to O'hEocha and Conboy (2010), is the most common way of doing so, in Scrum. Their goal is to capture requirements in the simplest way in order to facilitate a common understanding among team members. As suggested by Cohn (2004), each story should be written in the following format: "I as a (role) want (function) so that (business value)".

3. Mobile Wi-Fi initial situation

Mobile Wi-Fi is Veniam's solution to provide Wi-Fi connectivity for passengers of a moving vehicle. It makes use of Veniam's innovative mesh networking technology and vehicle-to-vehicle communication to offer reliable connectivity to fleets of moving vehicles, captive portal management for rider engagement and analytics on the service, on the riders and more.

This solution started as a company vision, which aligned the learnings from the market with the technology developed up to date. However, this innovative solution was not fully developed as it required a step-by-step validation of the market, in order to be sure that the developing efforts would result in usefulness and return on investment for the customers. But validating an innovative solution can be challenging when outcomes are not easily foreseen and when experiments are expensive. Also, the market is many times unaware of the characteristics and potential of the new technologies, thus requiring some educational expenditure. For that reason, Veniam tries to write case studies regarding successful deployments, like a common tactic applied by Veniam's sales team is to suggest a free trial with only a few NetRiders to the potential customer. The trials are usually defined for a period of 3 months and up to 10 OBUs. No Access Points are mounted in the city, meaning that the fleet runs only on cellular communication in order to provide Wi-Fi to passengers. Although the bandwidth and service quality are not as good as Veniams' full potential, it's enough to demonstrate the value of the solution and allow the fleet owner to understand if there is interest in purchasing a large-scale deployment.

As a starting point for the startup, a broad definition of success was established for Veniam Mobile Wi-Fi:

- Fleet owner sees the value in the Wi-Fi service;
- Riders are pleased with the service;
- Fleet owners are pleased to share their story with Veniam in the form of case studies.

As for how to measure this success, the following metrics would be required:

- Number of vehicles installed with Mobile Wi-Fi;
- NPS[1] of riders;
- Percentage of data offload done with DSRC (as opposed to cellular);
- Percentage of projects that convert from trial to deployment.

[1] NPS stands for Net Promoter Score and is a management tool that can be used to gauge the loyalty of a firm's customer relationships. It serves as an alternative to traditional customer satisfaction research and claims to be correlated with revenue growth (Bergevin *et al.*, 2010).

3.1. Main hypothesis

Ensuing the lean startup methodology, a product team has the role of formulating hypotheses based on product/market assumptions and then testing these hypotheses. The result strives to uncover the truth about the previous assumptions, turning them into knowledge and subsequently using the knowledge to reach new assumptions and formulate the next hypothesis.

At the start of the project, the main hypothesis that would be tested had grown into the following question: "Is there a fit for an after-market solution to offer Mobile Wi-Fi and captive portal management as a managed service to bus fleets in the US, Europe and Singapore?"

The after-market specification is related to the fact that the product is directed to already operating fleets and the customer is the fleet owner or manager.

The main assumptions that define the hypothesis above were that bus fleets valued the following items in such a way that they would be willing to purchase Veniam's current Mobile Wi-Fi offering or even cooperate and invest in a more sophisticated solution built from it.

- Providing Wi-Fi to passengers – with the purpose of improving the riding experience, complying with the transit authority, differentiate from the competition or following the already established trend for having Wi-Fi in the buses of the region;
- Passenger intelligence – with the purpose of using the data associated to the Wi-Fi sessions, such as passenger demographics and bus riding habits, for enabling the fleet operations or marketing manager to learn about the passengers and improve the service accordingly;
- Passenger engagement – use captive portal management to establish a two-way communication with the passengers, collecting feedback and sending relevant information in real-time;
- Connectivity hub – connecting all devices of the bus, managing all the data and media in one centralized platform and offloading big amounts of data through Wi-Fi and DSRC.

As for the bus fleet market, its size has been accessed in regards to three factors: the regions where Veniam is currently operating (USA, Europe and Singapore), to the ownership of the fleets (public vs. private) and to the number of vehicles comprised in the fleet. The number of buses was based on governmental statistics. Ownership was considered a relevant factor because, based on Veniam's learnings, public fleet's sales cycles amount to an average of around two years. Since that period is too long for a startup to test their hypothesis, the private segment of the bus fleet market was sized, providing a reference for the market that can be targeted within the first two years. Such sizing as based both on governmental reports as well as on a sample of fleets for each region. As for the size, fleets with over 200 vehicles were considered a priority, not only because of the higher revenue that they would bring, but also because one of Veniam's hypothesis was that a large fleet would have a larger benefit while using the Mobile Wi-Fi solution. Its size was also attained thanks to the assessment of a sample of fleets for each region.

Below, Figure 10 illustrates the number of buses within Veniam's three operating regions, as well as the proportions of state vs. private fleets and large (more than 200 buses) versus small fleets. Finally, the total addressable markets (TAM) for large fleets and for private fleets were accessed separately, since there was no way found to confidently estimate the intersection of both markets. It was based on a rough pricing estimative of $1000 per vehicle per year.

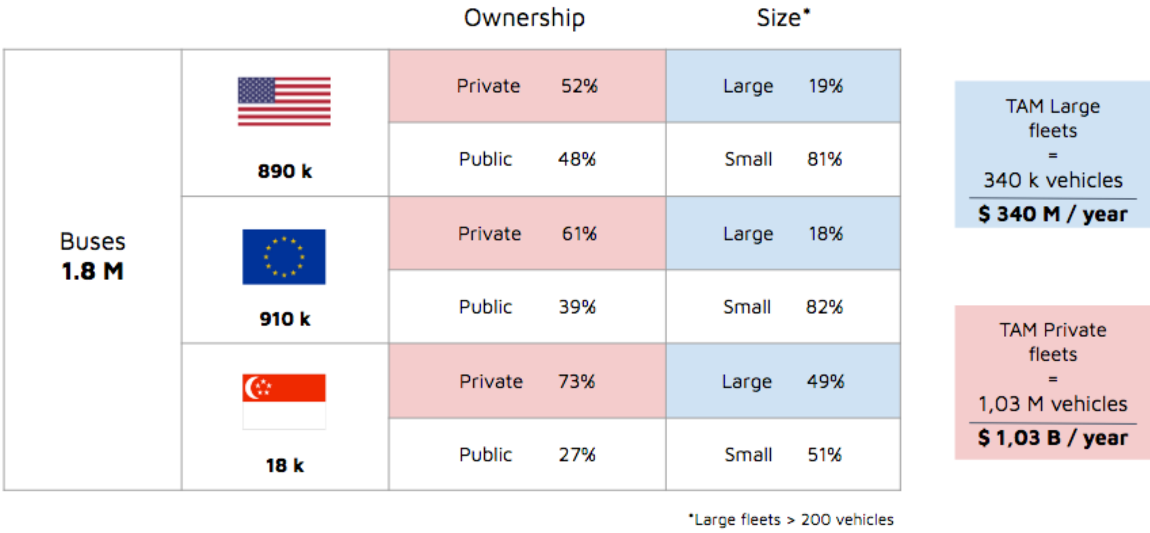

Figure 10 - Bus fleet market sizing and total addressable markets

3.2. Deployments

In regards to the passenger bus fleets market, where Veniam had attained its minimum viable product, there were three deployments at the date of start of this project: STCP in Porto, NUS in Singapore and DTA in New York. Each fleet has different characteristics and needs, which translated into different specifications. First, the three deployments will be shown in table 1 table and afterwards a short description of each will be presented.

Table 1 - Veniam's bus fleet deployments

Fleet	STCP	NUS	DTA
City	Porto	Singapore	New York City
Start	September 2013	May 2016	October 2016
Nº of OBUs	410	38	7
Nº of APs	52	12	4
Unique Wi-Fi users	657,000+	155,000+	8100+
Internet sessions	7 million +	10 million +	130 thousand +
Internet traffic / month	9 TB	2 TB	60 GB

3.2.1. STCP

STCP (Sociedade de Transportes Colectivos do Porto) is the public transport company that runs the bus and tram service in Grande Porto, Portugal. It is a public company controlled by a board which responds to the central government. It has 74 lines (including 3 tram lines) and a fleet composed by articulated, double decker, mini and standard (12-meter-long) buses. An average of 250 thousand passengers are transported daily.

This was Veniam's first client project which started in September 2013 and grew steadily until reaching around 400 OBUs. It had the support of the Porto Municipality, Porto Digital and Vodafone. Many experiments were put in practise with STCP buses and the good relationship with this operator was crucial for all the risk taken, for allowing many mistakes and errors and for paving way to the stable and complex network that exists today. In 2015, the service was limited to the centre of Porto, where the density of routes and Access Points is higher. For that reason, 70% of the data was transferred by DSRC. In September 2016, all the 410 buses were equipped with the NetRider v4 and the service was expanded to the whole scope of operation.

This bus fleet has the captive portal enabled with the main goal of strengthening the relationship between the operator and the passenger. It establishes a bidirectional communication channel between both parts. However, at the time that the project started, the only feature that was enabled was the branded captive portal and the acceptance of the terms and conditions to use the free Wi-Fi connection.

3.2.2. NUS

NUS (National University of Singapore) hosts over 38 thousand students and has an internal shuttle bus serving the whole academic community, but mainly focused in transporting students to and from classes. There are 12 different lines across the campus, which are actually operated by the multi-national transport company ComfortDelGro (NUS, 2015).

This deployment was made in May of 2016 thanks to a partnership with StarHub, one of the three major telecommunication operators in the Republic of Singapore. StarHub was already supplying the university with Wi-Fi in fixed locations indoors and around the campus. Alongside with this 39-bus deployment was the perspective of deploying over 6,000 buses in the city of Singapore under StarHub's umbrella.

Due to the growing worldwide adoption of "eduroam-like" networks in academic sphere (Meyer, 2017), this network is free of a captive portal. User with valid academic account are automatically authenticated to the Wi-Fi even if they don't use their devices whilst in the bus ride. This explains why the number of sessions in the NUS network has surpassed that of STCP despite having a lower number of buses, unique users and being considerably younger.

3.2.3. DTA

DTA (Downtown Alliance) manages the downtown-lower Manhattan business improvement district. The company collects data on commercial, hotel, retail, residential, and tourist markets in lower Manhattan. DTA offers neighbourhood services in the areas of downtown connection bus operation, public safety, sanitation, social services and more.

In cooperation with Sky Packets and Downtown Alliance, Veniam is providing free Wi-Fi at the Downtown Connection buses in Lower Manhattan. The smaller fleet with only 7 buses started with the goal of showcasing Veniam's technology in the United States and to attract potential customers in the continent. The main particularity of the DTA fleet is that the buses are equipped with LCD screens that display relevant information to the passengers. Through Veniam's network, the displayed content is remotely manageable and coordinated with the captive portal content.

3.3. Company and team goals

With three functional deployments in different geographical areas, the company had proven that its technology was not limited to a single location. This achievement was especially important for financing purposes. Following this milestone, Veniam had most of the efforts directed to establishing a good fit between the current products and the passenger fleet market. There was still a substantial amount of learnings to be done with this market, as well as customer needs to be fulfilled. At the same time, however, strategic partnerships and other opportunities were always being evaluated in regards to the autonomous vehicles space, smart cities, non-passenger fleets, ports and more.

The startup had defined the objectives and key results (OKRs) for the first annual semester, which unfolded into team OKRs. The most relevant that concerned the Mobile Wi-Fi team can be seen on Table 2. These consist of qualitative goals, designed to push the organization towards a desired direction, as well as quantitative achievements that measure the fulfilment of the related goal (Niven and Lamorte, 2016).

Table 2 – Mobile Wi-Fi objectives and key results (OKR) for the 1st semester

Objectives	**Key results**
1. Deliver Wi-Fi MVP to 3 customers	a) Do deep market research of 5 Wi-Fi and captive portal management solutions
	b) Have 2 design sprints with customer validation
	c) Ensure 80% of backlog items are associated to at least one key business value for the customer: • Reduce operating costs • Increase revenue • Improve available internet bandwidth • Improve customer/user experience • Increase competitive advantage
2. Validate product-market fit with bus fleets	d) Engage in 25 target customer interviews
	e) Participate in 3 passenger fleet related events
	f) Identify the top 500 fleets around the world
3. Have reliable and stable Wi-Fi service	g) Define Wi-Fi funnel of experience and measurement points
	h) Assess QoE in STCP quantitatively and qualitatively; define measures of improvement
	i) Achieve positive NPS on NUS and STCP

Objective 1 consists in a good example of the lean startup methodology. Enlarging the product offering to the same or to new customers would increase the topics for feedback and validated learning. Thus, the related key results are set to make use of the Scrum capabilities in terms of delivering MVPs efficiently as well as learning from the market. Key result a) is related to market analysis; result b) puts the focus on designing a new functionality that appeals to the customer; c) reinforces the idea of customer-oriented development.

Objective 2 puts a deadline on the assessment of the particular product-market fit of the bus fleets, meaning that in the end of the semester it is possible that the startup directs its attention to a different market and/or different product. Key result d) is very related to goal C of this project and indicates 25 as a feasible number and hopefully large enough to reach a solid conclusion; result e) is again related to goal C and hopes not only to achieve interviews but also to advance sales, have conversations related to fields such as autonomous vehicles and pursue meaningful partnerships; f) gives more knowledge regarding the bus fleet market, adding to the already familiar number of buses in Veniam's regions.

Objective 3 is the "measure" focused goal. To access the quality of the product, the fit with the clients' needs, the user experience and so on, the three formulated key results target important tasks that have not yet been fulfilled in the startup. Result g) consists of a funnel with all the different steps that take place in a Wi-Fi session, from the first package sent by the OBU to the in-range device until the end of the session; the intention of the funnel is to know which percentage of users is not experiencing a full session and where exactly does it fail; h) regards quality of experience and can be done with metrics and surveys; i) consists in performing an NPS survey through the captive portal, collecting the answers and having more promoters than detractors for each population.

3.4. Team management and Scrum

During the sprint that preceded the project, the most substantial tasks that the team tackled were the following:

- *As a Veniam project manager/sales person, I want to have a standard Veniam captive portal so I can use it during demos to customers, and during visits to non-customer sites.*

As an example, in Singapore the NUS deployment did not have a captive portal, therefore there was no practical way to show the captive portal in action. Terms and conditions for the standard captive portal were developed as well.

- *As a Wi-Fi user, I want to see meaningful error pages whenever the service is not available so that I am aware of what is happening with the service.*

Firstly, the different occasions in which an error page is required were stated and described. Secondly, the error pages were designed to give a thoughtful message to the user who couldn't meet the need of using the Wi-Fi. Before these error pages were uploaded, the users would see an unfriendly and displeasing page with Veniam brand overly prominent.

- *As a marketer/fleet manager, I want to have access to a simple dashboard where I can have an overview of who is using the Wi-Fi service.*

Like the previous item, this story also proposed the design of a low-fidelity prototype. The rider intelligence was defined as a web page for the administrator to view the aggregated data that is captured about the Wi-Fi service users. This includes breakdowns based on demographic variables like age, gender and country of origin/language, top websites and apps visited by the riders, visualization of a heat map that highlights where riders are logging in and logging out of the Wi-Fi and ability to filter the previous aggregated data by vehicle, geographical fence and vehicle route.

- *As a marketer/fleet manager, I want to have access to a simple dashboard where I can have an overview of the Wi-Fi service usage.*

Again, this story also proposed the design of a low-fidelity prototype. The service usage was defined as a web page for the administrator to view the aggregated data that was captured on the Wi-Fi sessions. This includes breakdowns over a defined time period that show the total number of Wi-Fi sessions, the proportion of new and returning users, the frequency of usage (distributions of number of sessions per user), session duration, session traffic, top routes with more sessions or more traffic, as well as other filters like specific vehicles, routes and geographical fences. The resulting low-fidelity prototype can be seen in Figure 11.

Figure 11 - Low fidelity prototype for service usage analytics using *Marvelapp.* Source: internal document, all rights reserved to Diogo Figueiredo

The last three items were finished employing the web tool *Marvelapp*, which is used by designers and front-end developers for the purpose of developing low and high-fidelity prototypes for apps and websites. The tool also enables a guided demonstration of the prototype, where certain actionable items get highlighted so that the viewer knows where to move the mouse or click.

3.5. Summary

Understanding the foundation and initial vision of the Mobile Wi-Fi product was an important starting point for the project. Simultaneously, having a good knowledge regarding the startups technology - including hardware, software and cloud services – alongside with focusing in the main hypothesis and assumptions, was critical in leading to a successful work.

The composition of the bus fleet market was only briefly addressed in the present dissertation, but in fact it was of great importance to have a broad assimilation of the different segments, offered services, stakeholders, and other particularities. A previously done competitive analysis was also studied in order to provide greater insights for the coming project.

The profiles of the current customers allowed to have a better understanding of who the product is serving and what are the similarities and differences between them.

The company and team goals were also of great importance to set the right direction for the project. Having them in mind throughout the complete internship was essential for assuring useful outcomes, as strategic goals have the imperative of guiding all teams and functions of the startup into a common direction.

Lastly, analysing the initial sprint developments granted insights on the team’s capabilities, organisation and needs, which contributed for an accurate definition of the project tasks.

Following this initial internal and external assessment, the three goals and their respective steps were followed virtually in parallel.

4. Development of a new product feature

For this goal, and due to the previously described need for a deeper market analysis, a research focused on the leaders within the captive portal management market would be executed in order for the team to know what options are available for tackling the customer's needs and requirements.

4.1. Captive Portal Management

Before commencing with the analysis, a brief explanation about what is being considered as the captive portal management (CPM) market will take place. In this market, there are several players providing Software as a Service (SaaS) for the owners of locations that possess Wi-Fi broadcast. While having an internet connection is increasingly important for more and more people, several users look for a free Wi-Fi connection whenever they are in public spaces, restaurants, stores, public transport, etc. This need drove many businesses that hold a location to provide such a connection for their clients, as it became a differentiating factor against their competition. Some business owners started to disclose their Wi-Fi credentials while others charged for its access. With CPM tools, the owner is able to provide a Wi-Fi connection in both ways (out of charged and paid) while at the same time engaging and capturing relevant information about the customer. In small organizations, the Owner can assume two different personas when using CPM: the Marketer and the Network Manager; whereas in big organizations there is usually a person or a team dedicated to each function. Figure 12 portrays their relationship. In this analysis, mostly the Marketer role will be considered.

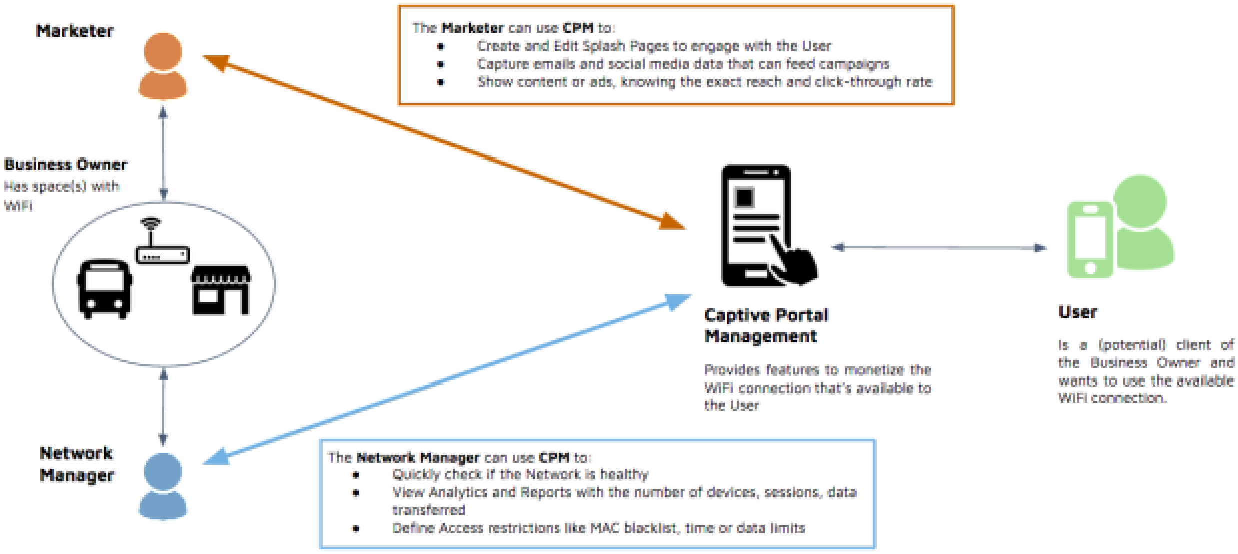

Figure 12 - Captive portal management actors

4.2. Best practises and detailed feature set for captive portal management

Based on a google search with keywords such as “captive portal management”, “captive portal cloud-based software”, “hotspot management” and “social login”, a list of seven commercial solutions was compiled. These emerged as market leaders and up-to-date solutions because they offered major features like the social media authentication or advertisement on the captive portal, as well as recent activity on their Facebook pages or appearances on news articles (not older than 2 months). The following companies were analysed:

- Purple - http://purple.ai/
- Tanaza - https://www.tanaza.com/
- Colony Networks - http://colonynetworks.com/
- Wavespot - http://www.wavespot.net/
- Muft Wi-Fi - http://muftwifi.com/
- Cucumber Wi-Fi - https://cucumberwifi.io/
- Globalreach - https://www.globalreachtech.com/

In the Appendix B, Figure 28 illustrates a table that compares the selected organizations regarding certain general company information.

Based on each company’s product description on their website, online documentation and also 30-60 minute live demonstrations and respective recording with Tanaza, Colony Networks, Cucumber Wi-Fi and Globalreach, it was possible to compare a few different approaches to execute the same feature. Some of the most interesting approaches were:

- Purple’s survey editor with three answer types: rating, multiple choice and text box (Appendix B, Figure 29);
- Purple’s user analytics dashboard (Appendix B, figure 30);
- Cucumber’s integration with PayPal for paid access to internet through the captive portal.

The above examples and more were saved in a document that was shared with the Mobile Wi-Fi team and with the whole startup as well. The team would use it as a reference upon deciding to develop the same features.

As for the more detailed feature set, three categories were used group them, which will be briefly described:

Authentication process - when the user provides his/her email address to access the Wi-Fi, for example - can be done in multiple ways and capture different sets of information. This information is then usually presented in a CPM dashboard, where different metrics and statistics can be visualized. The data can, in some cases, be extracted to external tools that deal with CRM, helpdesk, advertising campaigns, and more. The authentication processes include: click through, email, phone, code, coupon/voucher, SMS, form, social media, combinations of the previous methods, “remember me” and Hotspot 2.0. Furthermore, the authentication may be free or paid. Coupons or vouchers are normally used for this matter with either an implemented captive portal paying method or an “over the counter” payment.

Access Policies - enable the administrator to regulate variables like the time limit of the session, the bandwidth or different captive portal pages appearing in different moments or different wireless access points. These features restrict the access according to this type of variables.

Content - there are two groups: captive portal content and session content filtering. The former is related to the content that the administrator can choose to make the user see when authenticating. This can be images, videos, text boxes or social actions. On the other hand, session content filtering is related to the addresses that the user browses within a session. This can be a previous filter that blocks inappropriate or illegal content such as pornography, child abuse, hate or similar, as well as blocking access to malicious websites and preventing malware downloads. There are various types of filters, but the 3rd party DNS is the most used by the CPM companies.

The following table lists all the identified authentication methods, access policies and content related features. A minimum description for each is shown. The effort column was filled by the front-end and back-end developers. Since it was agreed that it was not important to have a very detailed and accurate estimation, the T-Shirt Sizing analysis was used - an Agile tool for the relative estimation of effort (Schmietendorf *et al.*, 2008). The table aims at understanding which of the features are already available for a deployment and to what extent. It is being updated by Veniam as work progresses. Table 3 portraits the situation at the time when it was first introduced in the startup.

Table 3 - Captive portal management features

Authentication Methods	**Description**	**Available in Veniam**	**Effort**
Click-through	Click of a button to login (usually accepting T&C). No user data captured.	Yes	-
Code	One code per SSID for all users	No	S
Email	Requires user to provide email address. There can be an email verification process providing a link or code for authentication.	Yes (email not verified)	XL
Phone (SMS)	Requires user to provide phone number and receive an SMS with a code for authentication.	No	XL
Form	Captures specific information. Nationality, age or education can be requested.	No	M
Survey	Requires user to answer one or more questions. This can be made with multiple choice, starts, circles or text box for written answer.	Yes	M
Social media	Users can use 3rd party authentication with the credentials of a social media platform. Rich data sets about the user can be captured.	Yes (Facebook, Google and other oAuth providers)	-
Voucher	Vouchers are usually used for paid Wi-Fi usage. A voucher is normally linked to a set of access policies (i.e. 2 hours of Wi-Fi service).	No	XL
Voucher w/ payment	Like Vouchers, but payment is done in the captive portal through a payment gateway (i.e. PayPal).	No	XXL

“Remember me”	After the first authentication with a given method, the user can authenticate again without seeing the captive portal.	No	L
Hotspot 2.0	User will be able to authenticate instantly (without seeing a captive portal) in every network that is compliant with the Hotspot 2.0 (or IEEE 802.11u) standard.	No	XXL
Access policies	**Description**	**Available in Veniam**	**Effort**
Periodic access	Defines a period in which the captive portal is accessible. Outside of that period the SSID is not shown.	No	M
Time limit	Defines the time length of the access for a given session and per MAC address.	No	S
Data limit	Defines the amount of data that can be transferred (download and upload) in a given session and per MAC address	No	M
Bandwidth limit	Defines the maximum speed of data transferring (download or upload) per MAC address.	No	XL
Idle timeout	Defines the time length that a user can be idle (not using the internet) until being automatically disconnected.	Yes	-
Number of users	Defines the maximum number of users that can connect at the same time to a single SSID.	No	S
MAC addresses	Enables a determined list of MAC addresses to either become blacklisted or whitelisted. The former means they won’t be able to access the internet while the latter means they will be able to bypass the captive portal.	No	M
Content	**Description**	**Available in Veniam**	**Effort**
Media and text	Display of videos, photos and text on the captive portal. User may be forced to wait a certain amount of time before being able to authenticate and while the content is showing.	Yes (but no timed content)	-
Widgets	Display a widget (small application with limited functionality) on the captive portal.	No	M
Social action	Option for the user to do a social action in a social widget (i.e. a “like” on Facebook or a “follow” on Twitter). These actions are then captured so the administrator can see who did what, and when.	No	L
Content filter	Integrating a 3rd party DNS filter.	No	S

4.3. Design sprints

Following the collection and Effort analysis of the multiple features for the captive portal, it was accessed how the easier items could fit to real customer problems and needs. Since only STCP had the captive portal enabled, it was the only candidate for a captive portal feature design at the moment.

STCP's needs and goals could be grouped in two: the operations lens and the marketing optic. Meetings with both departments had been done and requirements were gathered. However, the marketing needs were more closely related to the captive portal experience, therefore only these were considered.

The marketing role at STCP was essentially focused on QoS, demand and profitability. Some of the most relevant needs and desires include:

1. The ability to send real time information to the bus, i.e. when there are unexpected changes on the routes;
2. Detecting the exit of passengers and their overall patterns;
3. Preventing buses from going to "empty" bus stops using, for example, a service for the passengers to "call" the bus;
4. Combining information from ridership with social media data and customer preferences;
5. Improving and measuring the quality of the riding experience.

They were then linked to the features that would potentially solve them or add value based on them.

Customer need 1, regarding real time information, was linked with content features of **media and text** and **widgets**. Social media apps like Facebook or Twitter could be used as widgets to show last publications. STCP had a Twitter account that was used to post bus line related information in real-time. There was also a wish to increase the number of Twitter followers. Since there was still no dashboard for Veniam's customer to manage and introduce media and text autonomously, a widget would be a good and more accessible way of establishing a real-time communication channel.

To access the second customer need about entry and exit patterns, the simple start and finish of the sessions could to a certain extent be used to infer this. By using the geographical position of the bus when these two moments occur, a map visualization would give insights about were most people possibly hop-in and hop-off the buses. Regarding a captive portal feature, it was proposed that the user could be prompted an optional question regarding where he/she would leave the bus. Data from the answers could be then compared with the geographical position of the session ending, with the purpose of analysing which percent of times the users finished a session where they said they would leave.

Customer desire 3 was in fact in the lines of a demand-responsive transit system. These have shown to offer equal or better service in situations of low demand density, such as rural areas or during night time, with maintaining comparable agency costs (Li *et al.*, 2007). For such a service, two main possibilities were thought of. The first included a mobile application that would enable the user to call the bus to a certain bus stop, by, for example, tapping the desired stop in a map with all the stops. To mitigate the wrongdoing of having users calling buses to stops in which they are not really positioned, there could exist a GPS verification of the passengers' location related to the stop. Regarding the mobile application, it would have to be developed from the very beginning, and its development is too far away from Veniam's core business. Also, there are no significant synergies with Veniam's technology. The second possibility was to provide Wi-Fi coverage to the bus stops by installing a smaller access point. By doing so, users could access the Wi-Fi not before seeing the captive portal and having the option of "summoning" the bus by interacting with a widget or a few buttons. Despite being an innovative solution, there were many challenges to surpass. Difficulties in providing optic fibre internet to this bus stop access point would also arise. But the biggest challenge would be to make sure every bus rider used the system correctly so that the bus wouldn't miss stops with people waiting. In this sense, having a mobile application system would exclude people that do not carry a compatible device from being picked up. For all the reasons stated above, it was concluded that this need could not be satisfied by Veniam in the near future.

Customer desire number 4 required two main steps: step one was to capture the intended social media data and customer preferences; step two was to integrate that data with STCP database. The first step could be indeed performed by the captive portal and the appropriate features would be the **form**, **survey**, and **social media** authentication. The social media authentication is able to capture user data from Facebook, Google, Twitter and many other oAuth compatible networks. These may include: first name, last name, email, city where user lives, gender, birthday, profile picture, MAC address, browser and its version and device operating system and its version. As for the form and survey, they could both be used to enquire the user about his/her preferences. The form consists of text boxes where the user has to do the writing, which can be more time consuming and therefore contributing to a worse experience. The survey, however, allows to have flexibility in the types of questions to be done, as it can have multiple choice, starts, circles and also text boxes for written answer. Specific questions can be asked, with a limited number of answers that would facilitate the analysis. For this reason, the survey seems more adequate in capturing customer preferences about the bus trips, the Wi-Fi service or others.

The fifth customer desire about improving and measuring the quality of the riding experience could also be accessed interesting content of **media and text**, **widgets** and **surveys**. The former two could, for instance, display news articles from an online newspaper or have a map showing where the bus is riding and so the passenger can see the names of the streets, nearby restaurants or more. The latter could ask questions like "how often do you find it difficult to get a seat?", "how often are the buses late?" or "how would you rate, from 1 to 5, the normal hygiene of the buses?"

Based on the conclusions of the previous exercise, a quick brainstorming was done by the whole team and resulted in around 15 different ideas to use widgets, media, surveys and social media. The top 4 ideas were selected and the front-end developer executed the design of all the concept captive portals. These are briefly explained below and shown in Figures 13 and 14.

- **Twitter widget** for STCP to share real-time information and with the possibility for passengers to start following the Twitter page. This didn't represent additional work for STCP, since they were already using Twitter for the same purpose. Three moments are represented in Figure x, which includes the first display, the display after clicking the "Mais Tweets" (More Tweets) button and finally the display after clicking an individual tweet, which shows the user comments related to it.

- **Embedded newsfeed** integrated with the top online newspaper read in Porto. The user could click on the articles to read the full version while on the captive portal. This feature contributes to improving the riding experience.
- **Embedded estimated time of arrival (ETA)** for the current bus line that the passenger is using. The network would identify the possible lines where the passenger could be riding based on geographical location of the OBU. It would then prompt the user to choose the correct line and see the next stops, accompanied by the ETA for each one. There can also be an option for the passenger to select the stop that he/she is riding to and even get a notification when the ETA is just 2 minutes. This way, the feature would not only improve the riding experience but also capture a number of riding habits regarding where they actually leave the stops, as the disconnect from the Wi-Fi session alone is not perfect in detecting this action.
- **Survey for NPS,** which is a test to measure customer satisfaction and the potential of user growth. This concept contained one of the strategic key results for the quarter, which was to conduct an NPS analysis and have a positive result. Along with this survey example, the variety of other possible surveys would be explained to the customer. The expectation for the meeting was that if STCP liked this idea and provided a question or set of questions to be submitted to the network, then we would develop a survey accordingly. If not, then Veniam would insist in conducting the NPS survey.

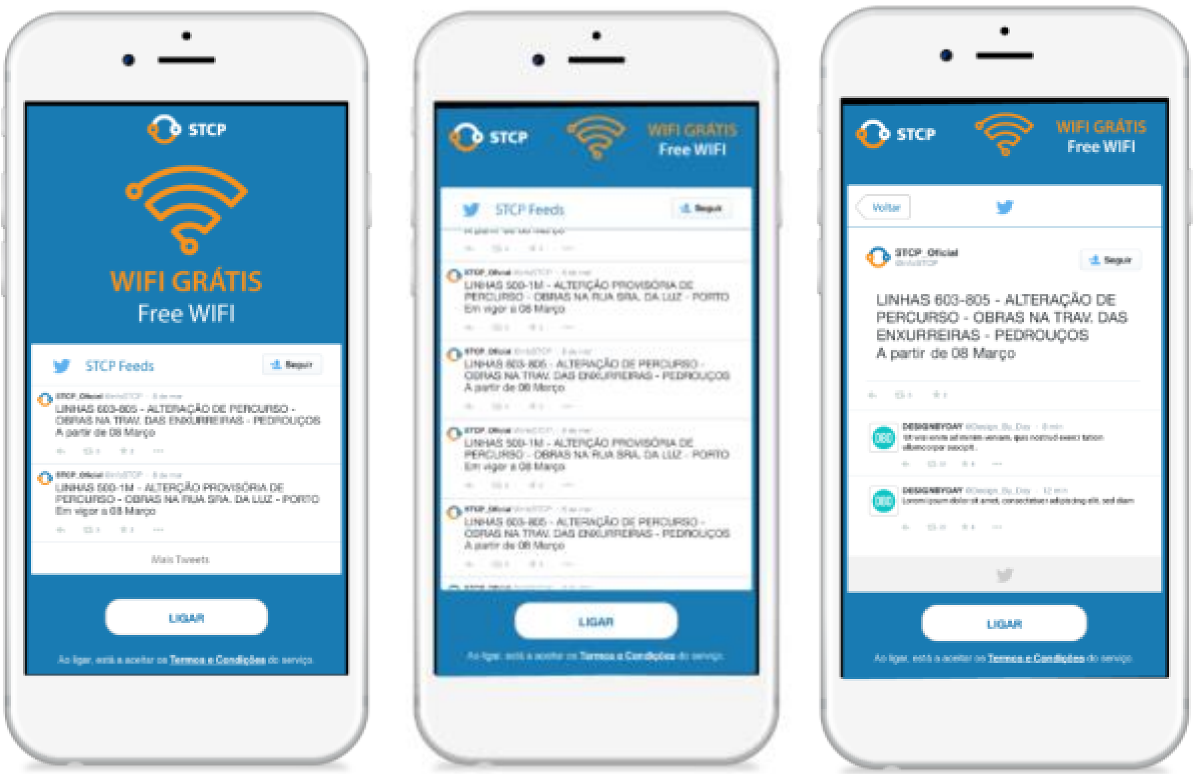

Figure 13 – Design of concept captive portal for Twitter widget, 3 different moments. Source: internal document, all rights reserved to Diogo Figueiredo

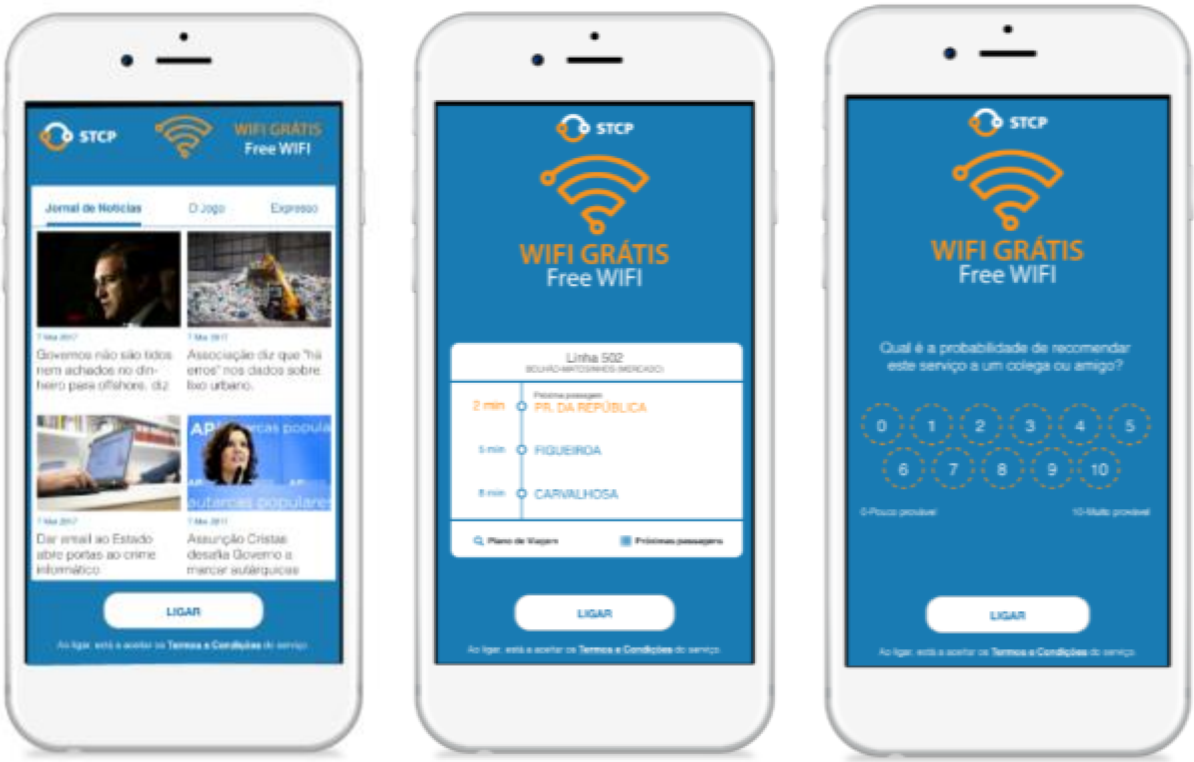

Figure 14 - Design of concept captive portals for newsfeed, ETA and NPS. Source: internal document, all rights reserved to Diogo Figueiredo

4.4. Customer feedback

After developing the 3 concepts, a meeting was set to present them to STCP and to access if they would meet the previously gathered needs. The feedback resulted in a good appreciation of the Twitter widget, the ETA and all its further ideas and also the surveys. The newsfeed was said to be interesting, but not as much as the other 3, which were said to be better at improving the experience of the passengers and also engaging with them. Yet, it was the survey functionality that was most discussed during the meeting, because STCP had prepared an idea that could be achieved with it. The fleet operator was trying to decide if it should extend two particular bus lines to a new destination. Thus, collecting input from the passengers of such lines could help drive the decision. The multiple-choice survey was raised as the most suitable tool to do so, and the sentences and phrasing were quickly decided during the meeting. They were as follows:

“If this line would take you to [destination] in less than 30 minutes, how often would you use it?”

- Several times a week;
- At least once a week;
- At least once a month;
- At least once a year;
- Never.

4.5. Execution and results

As the front-end developer worked in the design of the survey for internal approval, the back-end developments performed in the direction of making the survey generic and therefore of use in other contexts and for different customers. A couple of rules were defined for the surveys: it could either be mandatory or optional to answer the survey in order to access the Wi-Fi; the same MAC address would display the survey every time it connected, only once or only until the survey was answered. For the case of the STCP survey, it was defined as optional to answer, but passengers would see it until they answered. The final design can be found below on Figure 15.

Figure 15 - Captive portal survey for STCP. Source: internal document, all rights reserved to Diogo Figueiredo

In STCP, buses change routes on a daily basis. This means that a bus holding a given OBU will possibly do many different routes in a week's period. At the present moment, Veniam does not have direct access to the bus schedule, therefore STCP exceptionally kept the same buses doing the two respectful routes during the period of the survey. This way it was easier to define which OBUs would present the survey.

In the previous week, STCP informed which buses would do the 2 routes by providing their bus identifier, which are linked to each OBU identifier in Veniam's database. There were 6 OBUs and 3 substitutes allocated to one line and another 9 and 5 substitutes were allocated to the other. The period of the survey was 6 complete days, starting at mid-night. The results can be found in Figure 16.

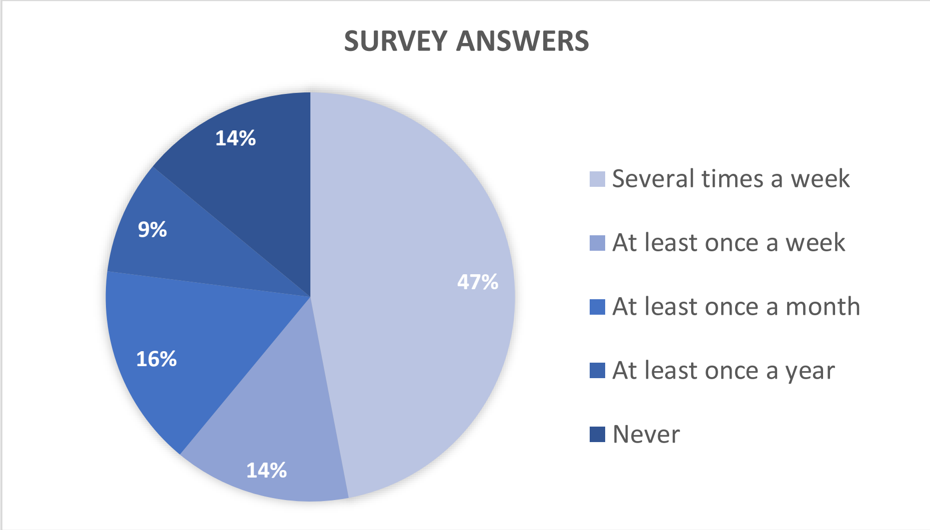

Figure 16 - STCP survey results

The total number of answers cannot be disclosed, but it was large enough to make this statistic relevant. We can appreciate a substantial advantage of the answer “several times a week” with 47% of the answers, and if we group the top two answers in terms of frequency of riding the bus line, 61% say that will use it at least once a week.

STCP commented that the survey was helpful in accessing their decision of extending the bus lines, which served as validation of the usefulness of a captive portal survey for taking tactical decisions.

5. Measuring service performance

Prior to the beginning of the Project, service monitoring was mostly done via *ad hoc* analyses. Performance measurements were at the core of Veniam's operations from an early stage.

The most important indicator for characterizing the volume of service is the number of sessions. This value reflected the number of people using the Wi-Fi service, the frequency of usage, the availability of the service (problems in the network may render the service unavailable, this less sessions can be made). Figure 17 shows an increase of the number of sessions over time for the STCP deployment. From March 2016 to March 2017, the volume of sessions has nearly doubled. Low peaks in the months of August are observable too.

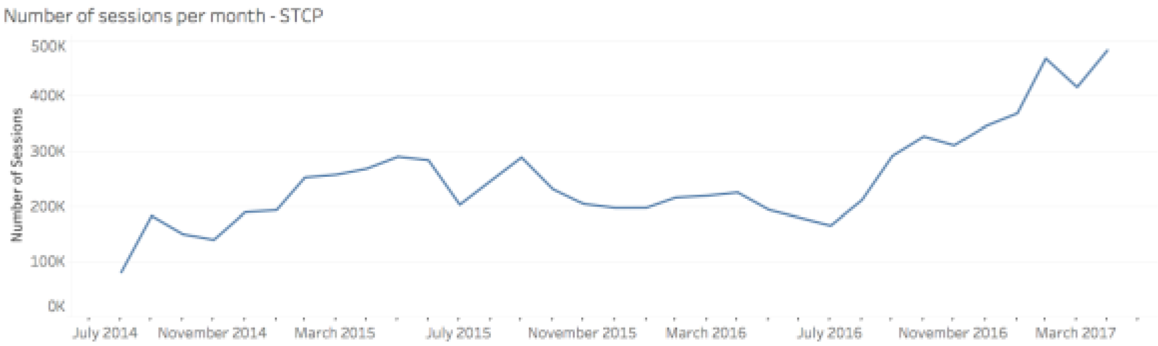

Figure 17 - Number of Wi-Fi sessions per month in STCP

However, the startup intended to start implementation of daily metrics and scale its alarmistic processes. In the case of the Mobile Wi-Fi product, it was important to understand how the normal service looked like for different fleets, how stable was the network, how network problems affected the users of the service and eventually detect patterns and improvement opportunities.

Having these goals in mind, a group brainstorming was conducted. Every member wrote down a number of metrics which, in the end, were assessed in terms of feasibility and usefulness. Feasibility was conditioned by the data that was stored in the database. As an example, the metric "average time spent on captive portal" was not feasible because such session information was not captured. Regarding usefulness, it was important to have metrics that could be related to one another or to the team member's perception of reality. Also, metrics should not have redundant information. For example, having already the number of sessions and the number of unique devices that connected, the average number of sessions per device would not add much information as it rather redundant.

As an attempt to guide and improve the brainstorming, a small variation was introduced. Occasionally, a question was asked out loud, prompting the brainstorming of ideas to select a metric to answer it. As an example, question "How do I know and measure if all the sessions were successful?" induced the metric "Login to 1st byte", which assesses the percentage of sessions that made at least 1 byte of traffic. Sessions that don't reach this value cannot be considered successful as the captive portal alone accounts for 4.9KB, thus were considered sessions when they should have not.

As section 2.2.1 of this dissertation regarding the "measure" step of the build-measure-learn cycle explains, relative metrics (percentages and median values) were a priority, but only when absolute values were not considered more important. Median values were favoured over average values because of the existence of outliers.

5.1. List of metrics and definitions

Two groups of metrics were pursued: the first was on a higher level and portrayed the whole population of users for that fleet – fleet level; the second was on a lower level and portrayed the individual user – user level. Type a) metrics were applied to both STCP and NUS, while type b) metrics were only applied to STCP. All the metrics accounted for a day's period of data. Below, Table 4 presents the final metrics, their classification and definition.

Table 4 - Metrics for service usage

Type	Fleet level	Definition
a)	Sessions	Number of Wi-Fi sessions made across the whole fleet network. In the presence of the captive portal, a session starts when a user consciously clicks the "login" button and successfully connects to the Wi-Fi. In its absence, a session starts when a device that has permission to authenticate gets inside the range of communication of an OBU for a few seconds, not requiring any action by its user
	Devices	Number of unique devices that made Wi-Fi sessions. These are mostly smartphones, tables and computers. The distinction of devices is based on the unique MAC addresses
	OBUs w/ sessions	Number of OBUs that had at least one session
	Traffic (Gb)	Total amount of data that was downloaded and uploaded by every device that made sessions
	Median Devices per OBU	Median number of unique devices that connected to an OBU
	Median Activity per OBU	Median number of hours that each OBU was turned on (indicating that the bus was also turned on)
	Perc (95) Activity per OBU	95th percentile of the activity per OBU, in hours
b)	OBUs w/ connection attempts	Number of OBUs that had at least one login attempt. A login attempt can be failed or successful and is defined as a conscious or unconscious attempt to connect to the Wi-Fi, from the user's perspective. A connection attempt starts at the moment when the OBU receives the first data package from a Wi-Fi enabled device that enters its range
	Failed connection attempts	Number of connection attempts that fail to convert into a Wi-Fi session
	Nº OBUs affected	Number of OBUs that have at least one failed connection attempt

	User level	Definition
a)	Median Traffic	Median amount of data that was downloaded and uploaded per device
	Median Duration (min)	Median duration of a Wi-Fi session, in minutes. The duration is accounted from the session begins until the moment it ends. There are 4 ways a session can end: 1) conscious logout made by the user; 2) inactivity by the user; 3) device gets out of OBU's range; 4) lack of internet (affects all devices that are connected to the OBU)
	Perc (95) Duration (min)	95h percentile of the Wi-Fi session durations
	Sessions (<10 s)	Percentage of sessions with a duration smaller than 10 seconds
	Sessions (>1 h)	Percentage of sessions with a duration larger than 1 hour
	Login to 1st byte	Percentage of sessions that download at least one byte

5.2. Calculations

The above metrics were executed in Tableau and the data source used was MySQL. The metrics were calculated for STCP and NUS only, since DTA was not yet capturing several required data. Most variables were contained in a table with session-related data. One additional table was required to measure the OBU's activity, which stores every OBU's pings that are generated minute by minute, as well as their GPS coordinates generated every second. An additional table was required for calculating STCP's *Failed connection attempts* (FCAs).

SQL queries were used only to filter the scope of dates considered for the metrics, as practically all variables were required and simple "Select *" (select all instances) queries were sufficient. Only the last month of data was analysed.

A dashboard with the tables was created and programmed to be sent by e-mail every morning using Tableau online. Tables with 8-days' worth of metrics for STCP and NUS can be found in Appendix B. Also on Appendix B, a different dashboard was sent once a week, containing the weekly time series of the previous week and the one before that for comparison.

5.3. Monitoring and learnings

After one month of monitoring the metrics, most of them were relatively stable and their normal values could be understood. There was a clear seasonality within the week, where the working days showed a different behaviour than the weekends in both fleets. In STCP, the number of daily sessions was found to have an average of 17984 thousand and a standard deviation of 3119 for the weekdays; as for the weekends, the average Saturday had 6813 sessions and the average Sunday only 4949. Figure 18 portrays the time series for the number of STCP sessions in every week. Week one had a low peak on Tuesday that was originated by a system update. This caused the service to be unavailable for around 8 hours during peak time in the afternoon. Other metrics were affected as well.

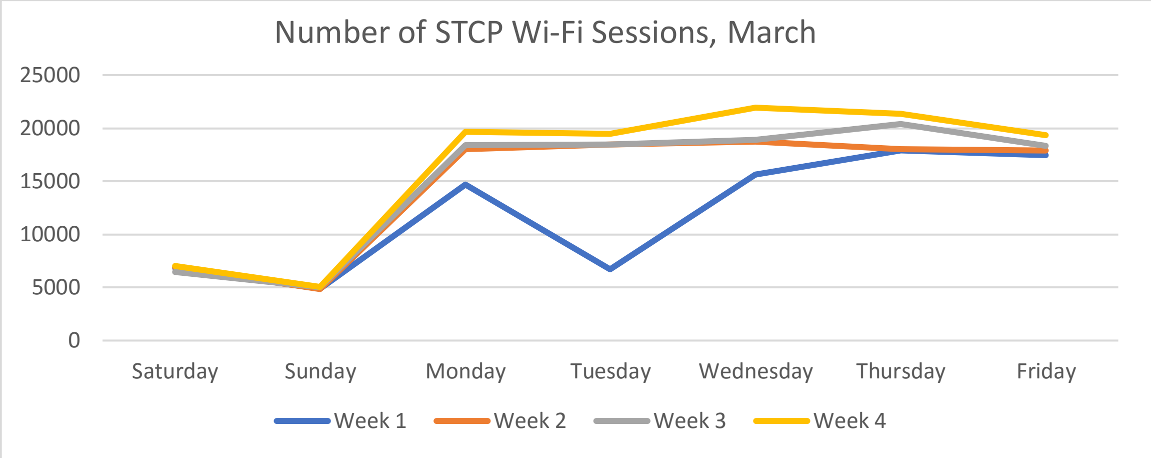

Figure 18 - Weekly comparison of the number of daily Wi-Fi sessions for STCP

In NUS, the case was different: the average number of sessions during working days was 57487, with a standard deviation of 8230. Saturdays had around 3,5 times more sessions than Sundays, with an average of 23827 for the former and 6863 for the latter.

As explained before, the absence of a captive portal in NUS is the main responsible factor for the higher number of sessions compared to STCP, even though the latter has roughly 10 times more buses. The definition of "session" can be considered different for the two fleets, as in STCP the user is forced to consciously authenticate himself and in NUS the authentication is done automatically for users of the network.

In Appendix C, Figures 33 and 34, the maximum and minimum values for a two-week period are labelled. It is worth mentioning that the durations are not well calculated in STCP, as a 10-minute period is being added to most session durations. The reason why is due to a "timeout" period in which the session may remain if the connection is lost or terminated in between. In other words, if the user disconnects, he/she has 10 minutes to connect again and not see the captive portal or account for an extra session. Notwithstanding, the session duration should not include the 10-minute period of inactivity, which is currently inflating the distribution. Many sessions with 0-second duration are also observable. This matter will be addressed in section 5.4.1.

In order to assess if some OBUs were more prone to having FCAs, a distribution that assesses the number of *Session attempts* versus the number of *Sessions* was made for the week. In Figure 19, OBUs that did not cause FCAs are situated in the quadrant bisector (x = y) and OBUs that have a higher number of FCAs are located on the right if this line.

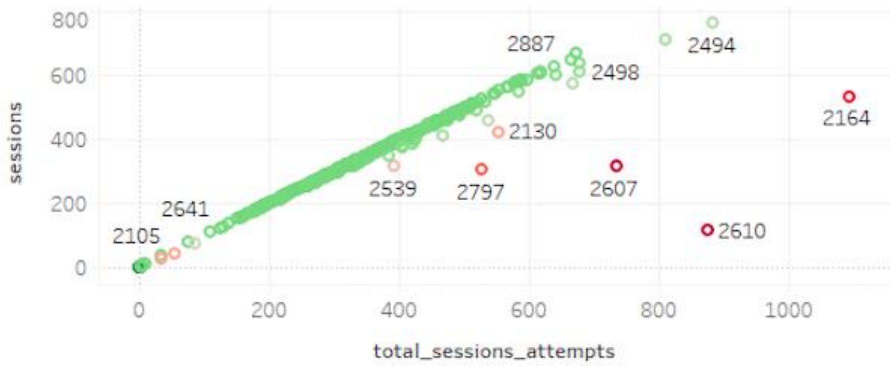

Figure 19 - Session attempts vs. sessions per OBU

5.4. Further analysis

The FCAs, *Nº OBUs affected*, *Sessions (<10 s)*, and *Login to 1^{st} byte* metrics were especially directed at understanding if the service had undesirable or irregular behaviours. In NUS, a higher number of *Sessions (<10 s)* was acceptable, due to the fact that many devices connect to the bus while it moves along its route. In all other cases, these metrics should be as low as possible. By simply using common sense, certain values were hard to explain. Two were selected for additional research, having been formulated into small research questions. These were then accessed mainly with data analysis and sometimes with conversations with other teams.

5.4.1. <10 second sessions

"Why were there around 3,5% of sessions with less than 10 seconds of duration in STCP?" was the question that emerged.

The *Sessions (<10 s)* metric exhibited a relatively stable value of around 3,5% in STCP. The value of 10 seconds was not randomly selected for the metric, but rather chosen as a time length that would be inferior to most small Wi-Fi session (reading one email or text message). Therefore, the team's intuition sensed that 3,5% was not a fair representation of reality or at least felt the need to have other supporting information.

Tableau was used for a first quick analysis: all sessions with more than 10 seconds in a full day period were excluded. Of the 3,7% sessions of the randomly selected day that were left, it was observable that almost all of these sessions had a value of zero seconds in the *Duration* table. However, most of these sessions had traffic, meaning that the duration value was miscalculated.

The calculation of these values in the database was looked at. The database captured a *timestamp* (date variable) for the moments that a session begins and ends, and the duration is the difference between these timestamps, except when the *end timestamp* was *null*. In the latter case, the *duration* exhibits the value of zero. It was then found that for a one month sample, around 3,5% of *end timestamps* were not being received, causing this value and the duration for the respectful session to be zero. A next step used a query to select all sessions of a full day, except the ones with more than 10 seconds and with exactly zero seconds. The percentage of all daily sessions that were left was 0,5%, which is an acceptable value.

After understanding the cause of the problem, a solution was pursued. The database collected an additional *timestamp* called the *update timestamp*. Every minute this variable updated its date value while the session was ongoing, thus the *update timestamp* was equal to the last, most recent date received. A new rule was created for the calculation of the *duration,* setting that, in case the *end timestamp* was lost, the *duration* would be equal to the *update timestamp* minus the *start timestamp*. This quick fix turned the metric of *Sessions (<10 s)* into low, stable and expected values.

5.4.2. FCAs peaks

"Why where there peaks in the FCAs and *Nº OBUs affected* metrics on the 14^{th} and 16^{th} of March in STCP?" was the second question that surfaced.

The FCAs metric was the least stable, indicating network instability and potential bad user experiences, as a portion of them occurred while the user was consciously trying to connect to the service. In spite of this, the 14^{th} and 16^{th} of March recorded really high values. When excluding both days, the average for the FCA during the month of March was equal to 568 and the standard deviation was 306 (54% of the average). But in the 14^{th} of March this value reached 1785 and two days later it was 1644. The *Nº OBUs affected* averaged 142 for the whole month and totalled 230 on the 14^{th} of March. This indicated that the problem was probably systemic and not caused by a single malfunctioning OBU.

While seeking an answer, it was first ruled out the possibility of a programmed update or a physical intervention in an Access Point.

Next, a visual analysis of the FCA's distribution by GPS coordinates was done, to access if the cause was related to the internet module – DSRC is prevalent in the city centre, while cellular data is more used in the outer parts of the city (Appendix C, Figure 36). The graph exhibited a geographically disperse distribution of occurrences, meaning that it was not originated by one model in particular.

Then, the distribution of FCA's over time was analysed. Figure 37 in Appendix C shows the hourly number of FCA's from the 12^{th} to the 19^{th} of March. A peak of 653 FCA in one hour is visible, standing out from the second highest peak of 358 FCA in March 16^{th}. Figure 38 in Appendix B shows the same distribution, only from 12 am to 10 pm of March 14^{th}. This last picture clearly identifies the 6 pm hour as the one with the 643 occurrences. The even more granular Figure 20 shows the number of FCA per minute. An 80-occurrence peak can be found at 6.50 pm, which was known to be peak service time for STCP and for Wi-Fi usage.

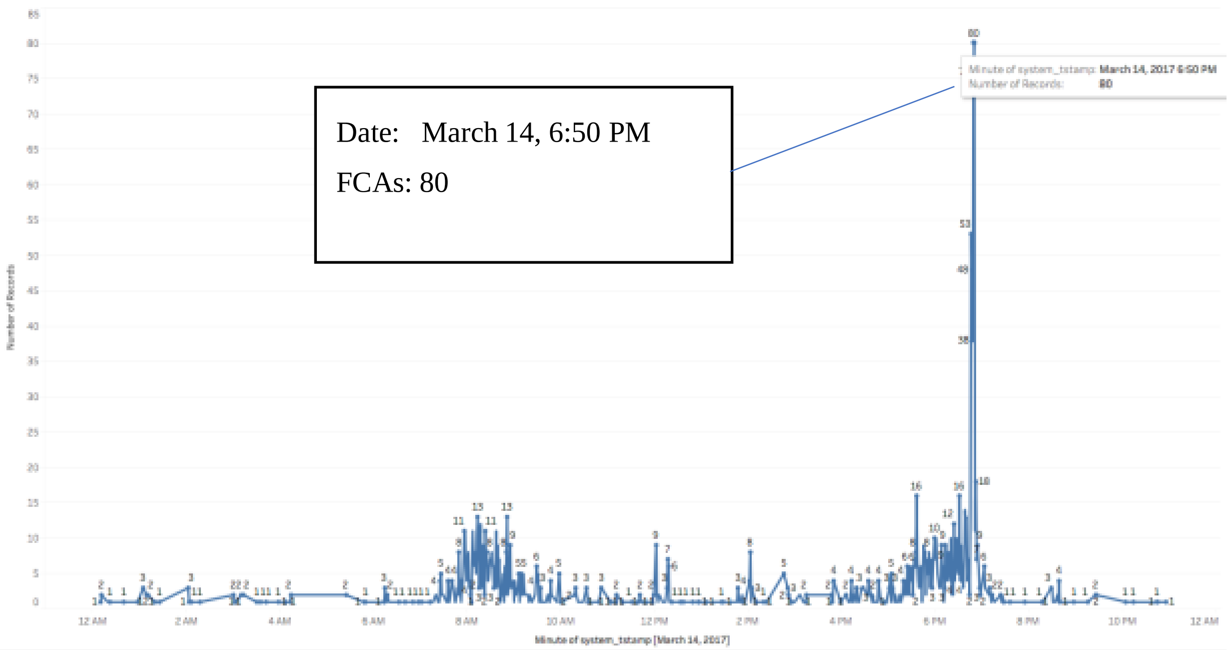

Figure 20 - *Failed connection attempts* (minute by minute) on March 14^{th} from 12am to 12 am in STCP

To identify the cause, other components of the network were analysed in the particular minute of 6:50 pm. The captive portal server could have been responsible, but there were no CPU, memory nor throughput peaks to be found. The Network Controller System (NCS) was then looked at and found to have been disconnected at 18:44, taking around 5 minutes to become operational again. The NCS are responsible for coordinating which AP provides internet to a given OBU. While they were down, there was no internet service for the all the APs and

OBUs that were connected to them. The NCS was down in other moments of the day and also on March 16^{th}, according to Nagios, the systems monitoring tool used by Veniam. The systems team was already aware of the situation because they used their own alarmistic. However, the Nagios alerts were not used by most teams, including the Product's.

As a prophylactic measure, there was a fix under development to make the communication switch to cellular automatically whenever the NCS was down, preventing internet loss and FCAs. Also, Nagios alarmistic was made more accessible to the whole organization, so that future peaks in metrics or other unusual behaviours can be quickly ruled out by the NCS performance or by other systems events.

6. Target customer interviews

This chapter will explore how the Mobile Wi-Fi team conducted interviews with target customers to validate the hypothesis for the product-market fit between its product and bus fleets. First, the bus fleet market was segmented, then sales prospecting – making outbound calls and sending outbound emails in hopes of creating opportunities for interviews and for sales accounting (ringDNA, [20—]) - was executed and, following that process, 11 semi-structured interviews with fleet operators were done on the phone or through Skype. Reports were filled and scores were given on 4 distinct categories, rating the willingness to purchase the Mobile Wi-Fi product and managed services. Alongside, face-to-face conversations in events were conducted, following the same purpose of the phone interviews and rating process.

The central question that was being accessed with the interviewing process was the following: "Is there a fit for an after-market solution to offer Mobile Wi-Fi and captive portal management as a managed service to bus fleets in the US, Europe and Singapore?"

6.1. Remote customer interviews

As stated before in chapter 3, there are approximately 1.8 million buses in the three targeted regions, of which around 340 thousand belong to fleets with over 200 buses and nearly 1.03 million are owned by private companies. Yet, another relevant factor that was not considered in the market sizing for lack of sufficient data but was still considered during the customer interviews was the type of service offered by the fleet operators. After an exploration of studies such as the north American *Motorcoach Census* (Dunham and Associates, 2016) and the *Comprehensive Study on Passenger Transport by Coach in Europe* (Dunmore, 2016), the following list of segments was considered:

- Airport shuttles;
- City sightseeing;
- Public service urban routes;
- Intercity;
- Private service;
- Mixed (providing two or more of the above services).

For each segment, a number of bus fleet operators was searched on the internet. To guarantee a certain amount of diversity, the list held operators based on 8 different European countries plus Singapore and USA, and operating in about 20 countries altogether. The previously cited studies from Dunmore (2016) and Dunham and Associates (2016) were helpful in identifying some of the market's players. The *Union Internationale des Transports Publics* (UITP) was also used, as it is composed of 1400 member companies across 96 worldwide countries and a big portion consists of fleet operators. The goal for the prospecting list was of 100 fleets, but in the end 135 relevant organizations were identified.

In order to avoid having meaningless interviews, it was important to identify and target the people within the operators who would be fit to answer our questions and provide the largest amount of insights and knowledge. Since the 4 topics of the interview would be the same as the product's assumptions described in chapter 3 (Wi-Fi for passengers, passenger intelligence, passenger engagement and connectivity hub), the focus was directed at the collaborators responsible for Information Technology, Marketing and Operations. In certain cases, the companies used different labels to name these roles, so a certain flexibility was required when looking for the most suited contacts. In other cases – usually when companies were smaller – the CEO on general director was searched for.

While searching for the companies, the best contact that could be found publicly online was captured. This included LinkedIn profiles, that were used many times to identify the key people that were targeted for the interviews. When the contacts of the intended roles were not found in the public domain, the contact of the headquarters was searched. In some cases, only the customer service contact was found, which was considered the last resource.

After identifying 135 relevant organizations and the respectful contacts, phone calls to the whole list were made. The goal of the first round of calls was to attain basic information, which included the number of buses, type of ownership, variety of services offered and if any buses had Wi-Fi for passengers already installed. Furthermore, a phone or email contact of a relevant person to perform the interview was requested.

Results of the first round of contacts were very diversified, ranging from nonexistent phone number to achieving the right contact to follow-up. In certain cases, the companies were found to no longer operate or to have been merged into different organizations Out of the 135 operators, 80 were reached and only 56 provided a new contact for a follow-up. These were mostly constituted by the email contact of the relevant person. Despite this contact being provided by an employee of the target organization, there was no guarantee that it would be replied. In fact, from the 56 follow-up emails sent - which in some cases were sent three times over the course of three weeks and yet there was no answer – the number of interviews achieved was 11, thus corresponding to an 8% conversion rate from first contact gathered to interview. Figure 21 depicts the number of contacts that advanced to the subsequent phases. The interview script can be found in appendix D.

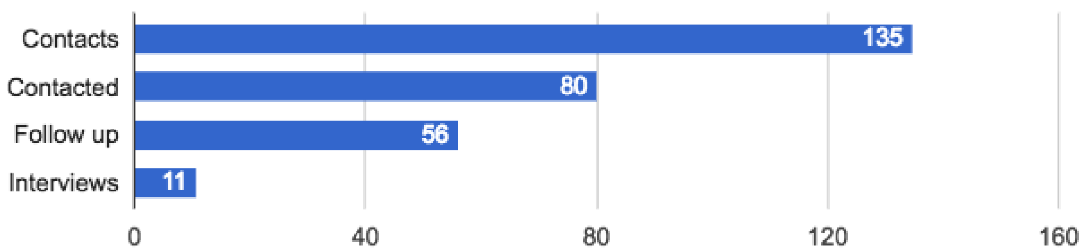

Figure 21 - Prospecting to interview conversion

6.2. Face-to-face interviews

Although the phone and skype interviews required very limited resources, it was a slow and low conversion rate process. The 11 interviews were possible over the course of one month and a half, but they did not satisfy the team goal of achieving 25.

Guest *et al.* (2006) propose that the number of participants relays on reaching the saturation point – no new major concepts emerging in the last interviews or observations. For homogeneous groups, it often occurs around 12 participants. The group of 11 participants represented different companies, types of bus service, company roles and nationalities, thus not being particularly homogeneous. Saturation point was not yet reached, as new interesting concepts were being mentioned at last every other interview. Besides the discussion of concepts, the diversity in the ratings was also considered, in the sense that it was desired not to have a very divergent set of ratings.

To accelerate the process of interviewing and also fulfil the semester OKR described in section 3.3, the team participated in three bus industry events:

- Bus2Bus Congress and Exhibition, 25-26 of April, Berlin, Germany;
- UITP Global Public Transport Summit, 15-17 of May, Montréal, Canada;
- Next.mov Smart Region Summit, 18-19 of May, Portimão, Portugal.

These industry events attract several stakeholders including operators, transit authorities, associations, manufacturers, technology providers, consultors, and more. Before each event, the list of participants was collected and emails or LinkedIn *InMail* messages were sent to the relevant people that could be identified, with the goal of booking a conversation in the agenda. This process was not efficient when contacting companies for the first time, as only around one out of ten people replied. During the events, Veniam was represented with a branded booth, where people would engage while passing by. This process was also not very efficient in producing interviews, as most people that engaged were not within the target. Alternatively, a proactive scan for interesting companies around the fair was done by walking by their booths. This approach resulted in the highest number of interviews.

During the three events, 11 interviews were accomplished, adding up to a total of 22 interviews with target customers.

6.3. Results

The rating scale was from 1 to 5 and only integer numbers. The score of 1 means “no interest for a solution”, score 3 means “the need exists, but it is not mission critical/happy with incumbent solution and not pressed for change” and score 5 means “genuine need for the solution; can close a deal in the next 3 months”. The four categories were rated. Interviewees were not asked to do their own appreciation, but rather the interviewer would meet with at least one team member and discuss the right score for each category.

Figure 22 shows the final scores that resulted from the 22 interviews.

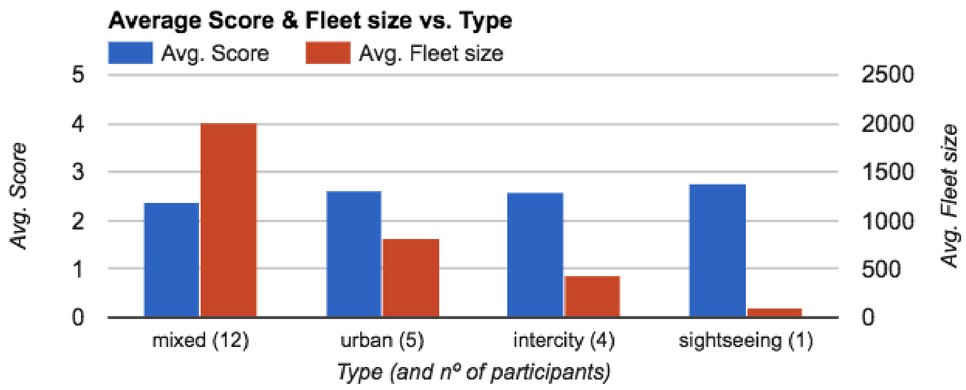

Figure 22 - Interview results: Average score & Fleet size vs. Type

The average scores represented by the blue bars consist in the average of the four categories and of all the participants included in each type of operator. The values range from 2.39 in the mixed type to 2.75 in the sightseeing type. Whereas in terms of fleet size, there's a clear trend for the bigger fleets to offer mixed types of services. Operators dedicated to airport shuttle and private services did not participate in the interviews. Nonetheless, these services were provided by 3 operators belonging to the mixed type.

When the 4 categories are assessed independently, the average scores are as seen on Table 5:

Table 5 - Ranking of the four Mobile Wi-Fi categories by average score

Category Rank	**Average Score**
Wi-Fi for passengers	2.95
Passenger engagement	2.60
Connectivity hub	2.50
Passenger intelligence	2.40

Next, each category's score distribution was assessed. Also, the most prevalent answers and ideas were selected for each category, giving a general description of the target customer's panorama.

6.3.1. Wi-Fi for passengers

Regarding Wi-Fi for passengers, there is already a high penetration of solutions on private fleets, especially in Europe. The Pricing for existent 4G/LTE solutions is typically between 15 and 25 euros per vehicle and per month and these solutions are generally satisfactory. On the other hand, most solutions lack captive portal management features. Figure 23 presents the scores regarding Wi-F for passengers.

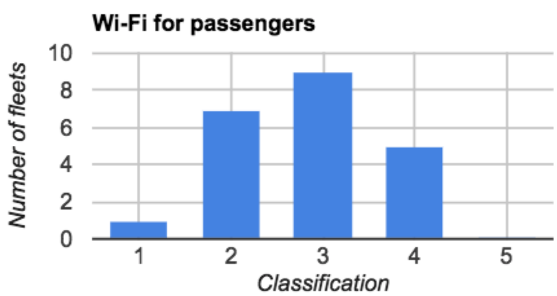

Figure 23 - Customer interview results regarding Wi-Fi for passengers

6.3.2. Passenger engagement

Passenger engagement is seen by most operators as an added benefit, but not as the sole reason to invest in a new technological solution. One large fleet stated that it spends €100,000 per year in manual surveys to engage with passengers. When it comes to the captive portal, operators rarely use it for advertisement, surveys or relevant information, but rather to collect basic information, i.e. email and nationality. Figure 24 illustrates the passenger engagement results.

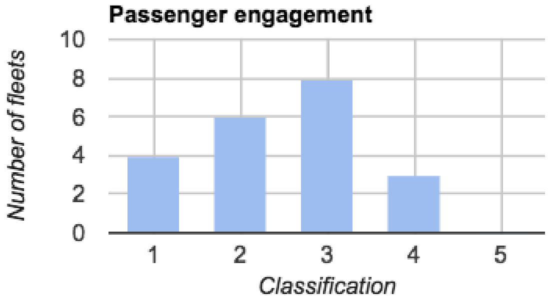

Figure 24 - Customer interview results regarding passenger engagement

6.3.3. Connectivity hub

Most operators pointed an existing inconvenience in managing multiple systems within the infrastructure. The main high-bandwidth service used is the CCTV, although not enabled by most fleets. One important aspect concerns CCTV regulation since it varies between geographies and restrains its use in at least Austria and Germany. Moreover, operators foresee an increasing need for transferring large volumes of data with the cloud. Figure 25 portrays the Connectivity hub results.

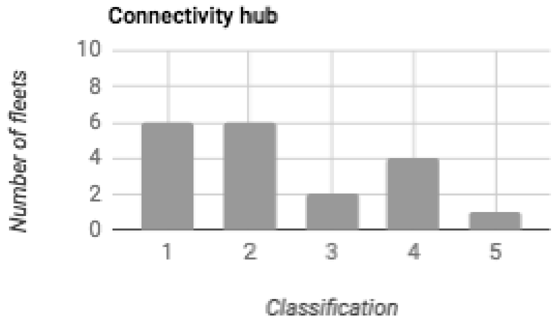

Figure 25 - Customer interview results regarding connectivity hub

6.3.4. Passenger intelligence

On passenger intelligence, fleets operating urban routes are generally interested in better understanding the passenger flow and patterns. Intercity fleets already collect ridership information based on ticketing, which includes start and end of trip. However, their routes change only sporadically, therefore using passenger intelligence to map intercity bus routes was never mentioned as something interesting. Regarding automatic passenger counters, it was found out that they are not yet widespread. Figure 26 describes the Passenger intelligence score distribution.

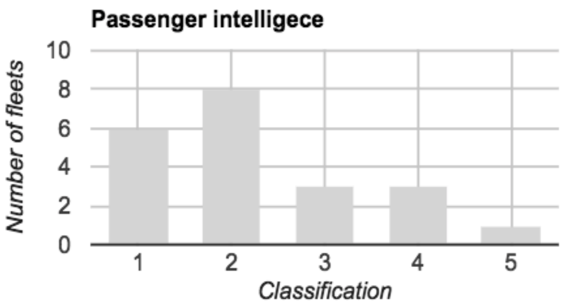

Figure 26 - Customer interview results regarding passenger intelligence

7. Conclusions and future work

Working in a startup requires a particular mind-set, one that holds a weave of optimism and pragmatism concerning new ideas and innovation. Because entrepreneurship involves experimentation activities, in which it is much more likely to fail than it is to succeed, failure must be embraced and must, above all, drive the coming trials to reach a sustainable business. As cofounder of Waze, Uri Levine once said: “Fall in love with the problem not the solution, and the rest will follow.” All in all, it is utterly important to maintain the ambition to succeed, as much as it is important to acknowledge that certain products or markets will not fulfil that mission.

7.1. Main results

All three goals of the present dissertation were able to satisfy their desired outcomes and drive a positive impact on Veniam’s progression.

Goal A – the development of a new product feature – demonstrated how the lean startup methodology can be a powerful tool in the efficient development of useful features. With the captive portal survey, a sufficient number of answers was gathered in under one week. These survey results were then used by STCP for conducting the tactical decision of extending two particular bus lines. Compared to the traditional method of surveying passengers personally – which one of the interviewees in chapter 6 said to cost around 100 thousand euros per year – the captive portal survey is much more efficient and cost-effective.

The four concept captive portal prototypes that resulted from this development were stored in the form of innovation accounting, as they had been validated through customer feedback. These prototypes are ready to be used for gathering more feedback or for sales purposes with other customers.

Additionally, the concern of creating generic and flexible features is important for preventing *ad hoc* developments that are unable to scale to different customers. Inevitably, certain developments would not be useful in alternative contexts, such as the ETA prototype which would not be fit for bus operators outside the fixed-route, multi-stop passenger transportation framework. This should also be regarded when selecting between desired features for a customer.

Goal B exemplified how metrics enable a company to have a better understanding of the service that it offers. Average values became clearer, seasonality within the week was visible as well as differences between deployments. The goal resulted in metrics that answer many of the previous internal questions about the different fleets’ networks and their monitoring is still ongoing and useful. The metrics were also intended for additional fleet deployments and in alternative contexts, as none of the metrics was restricted to the bus fleet paradigm.

Furthermore, two primary examples were used to demonstrate how metrics and their monitoring may identify improvement opportunities. This required a competent understanding of how the relevant data was being calculated and also of user experience. Only then could the metrics be examined to look for irregular values. The use of data analysis is also appreciable in finding root causes to problems. Solutions were then successfully implemented in the startup, mitigating future issues.

The developed metrics also allowed to recognize a few limitations regarding the current service and network. Certain desired metrics were not viable due to the lack of data. For instance, the number of conscious failed connection attempts (the user clicks the “login” button but is not able to connect to the Wi-Fi) is not known and its calculation would require the recording of an additional timestamp.

Also, not all issues detected as a result of the metrics were solved. When addressing the 3,5% session rate with duration below 10 seconds in STCP, a small number of sessions with negative duration was found. This behaviour can only be explained as a code “bug” in the backend of the captive portal, that was yet to be found. Since the number of occurrences was only about 0,3% of all daily sessions, decoding it was not considered a priority.

Metrics were also blind to certain anomalies that were detected by other means. The NUS client reported occurrences of a device having multiple sessions in different OBUs simultaneously. Such situation was analysed and found to be very insignificant (only 3 cases throughout one day). Notwithstanding, it is possible that a variety of agents is causing similar quasi-insignificant effects that become meaningful as a whole. This should be used as a motivation for further data analytics and metrics.

Finally, goal C exhibits the importance of customer input for testing the main hypothesis and validating product-market fit. It was particularly interesting to verify how the number of interviews increased dramatically by participating in industry events and also how useful that was. This corroborates Steve Blank’s most recurring statement regarding startup work, which is that entrepreneurs must “get out of the building” and talk to customers (Blank, 2013).

Since the average score was below 3 in the 1-to-5 scale for every category of Mobile Wi-Fi as well as for every type of bus service, it was concluded that Mobile Wi-Fi was considered a “nice to have” service for the bus operator, instead of an intended “must have” attitude. For this reason, it was decided that there is no strong indicator of product-market fit between Veniam’s Mobile Wi-Fi solution and bus fleet operators and therefore the startup will move its focus to different markets and products.

Nevertheless, a few opportunities are still being evaluated by the international sales teams, which are working not only with NUS and DTA but also with the partners that led to these customers. In Singapore, for example, StarhHub and ConfortDelGro have interesting needs that are being appraised by Veniam and might result in appealing developments for Mobile Wi-Fi.

Also, two iterations are suggested. The first one consists in shifting channels to the OEM market, as opposed to the after-market channel for Mobile Wi-Fi. Bus manufacturers could, for instance, include the Veniam OBUs in the new buses as an add-on for buyers, or as a standard equipment which requires activation of certain managed services. A new set of assumptions would have to be generated for the use in a new target customer interview process.

On the other hand, the pivot can consist in pursuing partnerships with technology providers in order to do joint sales. Combining or "bundling" Mobile Wi-Fi with electronic passenger counting systems or CCTV could take advantage of mature providers and their valuable relationship with our customers in common.

Furthermore, the entire customer interview process and product-market fit evaluation was documented, internally shared and presented to the startup. The product team has a great responsibility and influence on all the collaborators' progress, therefore it is of great importance to communicate the findings clearly and in the right moment. Having alternatives that are supported by good reasoning or by innovation accounting is also very important and must be transmitted with confidence, as new relevant hypotheses may materialize from them.

7.2. Further developments

Regarding goal A, the present dissertation may be seen as a contribution to a case study, in which the benefits of the survey feature for a bus operator could be demonstrated. This would require a better comprehension of such benefits, made through an additional meeting with STCP and supplementary data analysis. The latter would gauge the impact of a survey on the Wi-Fi habits, assessing, for example, if passengers are more or less likely to use the Wi-Fi service when captive portal surveys are presented to them. With such a case study, other fleet operators could more easily see the value of the Mobile Wi-Fi and have more confidence in a high ROI.

In chapter 5, some metrics still depicted an ongoing suboptimal service. One of the most conspicuous is the FCAs metric, as it should be practically eliminated. This achievement however is not straightforward, as the occurrences are systemic (spread across many OBUs) and may be linked to complicated problems that will probably remain unsolvable in the next year or longer. For instance, it is known that certain locations have weak cellular coverage, thus being the cause of internet failures and resulting in FCAs. Veniam could provide DSRC coverage by installing access points, but upgrades of this nature are costly. So far, the need to do so has not matched the required effort. Hence, FCAs must be analysed so that the many causes are listed alongside with their share in inducing the failures. Only then could solutions be drafted. Moreover, the same metrics development procedure should be conducted in order to extend the scope of data monitoring, as well as data analysis based on metrics.

As for an alternative product-market fit assessment, the customer-facing product teams started focusing on two separate markets for the short term (autonomous vehicles are constantly targeted for the long-haul). One is the confined space market, which includes ports, airports, mines and more industries where there is a considerable physical area of operation that can be leveraged by Veniam's unique connectivity services. In this context, the Wi-Fi network is normally restricted to the area of operations and intended for a professional use and not by non-staff individuals. The second is the automotive industry, which has growing segments in the connected car space, as well as in shared mobility services. It is expected to have over 33 million connected cars worldwide by 2018 (Stamford, 2016) and the V2V communication market size was estimated at over 15 billion USD in 2015, with an estimated CAGR of more than 5% up to 2023 (Global Market Insights, 2015).

The ports market is a particularly interesting one, as international world trade of goods accounted for 16 trillion USD of which 30% correspond to sea freight transport (World Trade Organization, 2017). Veniam’s deployment in the Leixões harbour is active since 2014 with very little issues or needed interventions compared to the bus fleet deployments. Further work includes a better understanding of how the Leixões harbour deployment leveraged its many stakeholders’ operations, including port authority, cargo operators, logistics companies, security, cleaning and more. Before being able to conduct the same customer interview approach, additional work must be done in order to develop an informed and validated value proposition and MVP.

References

Abd, Ahmed, Tarek Saadawi, and Myung Lee. 2004. "LS-SCTP: a bandwidth aggregation technique for stream control transmission protocol." *Computer Communications* 27 (10):1012-1024.

Abrahamsson, Pekka, Outi Salo, Jussi Ronkainen, and Juhani Warsta. 2002. Agile software development methods: Review and analysis. VTT Finland.

Ahmed-Zaid, F, and A Carter. 2009. Vehicle Safety Communications-Applications VSC-A. First Annual Report December 7, 2006 through December 31, 2007.

Alliance, Scrum. [20—]. "What is Scrum? An Agile Framework for Completing Complex Projects." accessed 17/06/2017. https://www.scrumalliance.org/why-scrum.

Ameixieira, Carlos, André Cardote, Filipe Neves, Rui Meireles, Susana Sargento, Luís Coelho, Joao Afonso, Bruno Areias, Eduardo Mota, and Rui Costa. 2014. "Harbornet: a real-world testbed for vehicular networks." *IEEE Communications Magazine* 52 (9):108-114.

Andreessen, Marc. 2007. "Part 4: The only thing that matters." Pmarchive, accessed 30/05/2017. http://pmarchive.com/guide_to_startups_part4.html.

Bai, Fan, Tamer Elbatt, Gavin Hollan, Hariharan Krishnan, and Varsha Sadekar. 2006. "Towards characterizing and classifying communication-based automotive applications from a wireless networking perspective." Proceedings of IEEE Workshop on Automotive Networking and Applications (AutoNet).

Bai, Fan, and Bhaskar Krishnamachari. 2010. "Exploiting the wisdom of the crowd: localized, distributed information-centric VANETs [Topics in Automotive Networking]." *IEEE Communications Magazine* 48 (5).

Bergevin, Real, Afshan Kinder, Winston Siegel, and Bruce Simpson. 2010. *Call Centers for Dummies*: For Dummies.

Bessant, John, and Sarah Caffyn. 1997. "High-involvement innovation through continuous improvement." *International Journal of Technology Management* 14 (1):7-28.

Blank, Steve. 2013. *The four steps to the epiphany: successful strategies for products that win*: BookBaby.

Blank, Steve, and Bob Dorf. 2012. The Startup Owner's Manual: The Step-by-Step Guide for Building a Great Company. Vol. 1. Pescadero, CA: K&S Ranch. Inc.

Boban, Mate, Ozan K Tonguz, and João Barros. 2009. "Unicast communication in vehicular ad hoc networks: a reality check." *IEEE Communications Letters* 13 (12):995-997.

Boban, Mate, Tiago TV Vinhoza, Ozan K Tonguz, and Joao Barros. 2012. "Seeing is Believing—Enhancing Message Dissemination in Vehicular Networks Through Visual Cues." *IEEE Communications Letters* 16 (2):238-241.

Bylund, Anders. 2017. "9 Facts You Didn't Know About the Internet of Things." accessed 13/06/2017. https://www.fool.com/investing/2017/05/04/9-facts-you-didnt-know-about-the-internet-of-thing.aspx.

Chen, Qi, Daniel Jiang, and Luca Delgrossi. 2009. "IEEE 1609.4 DSRC multi-channel operations and its implications on vehicle safety communications." Vehicular Networking Conference (VNC), 2009 IEEE.

Cisco. 2017. "The Zettabyte Era: Trends and Analysis." VNI.

CNBC. 2016. "Disruptor 50 list." accessed 04/05/2017. http://www.cnbc.com/2016/06/07/2016-cnbcs-disruptor-50.html.

Cohn, Mike. 2004. *User stories applied: For agile software development*: Addison-Wesley Professional.

Croll, Alistair, and Benjamin Yoskovitz. 2013. *Lean analytics: Use data to build a better startup faster*: " O'Reilly Media, Inc.".

Crowne, Mark. 2002. "Why software product startups fail and what to do about it. Evolution of software product development in startup companies." Engineering Management Conference, 2002. IEMC'02. 2002 IEEE International.

Dar, Kashif, Mohamed Bakhouya, Jaafar Gaber, Maxime Wack, and Pascal Lorenz. 2010. "Wireless communication technologies for ITS applications [Topics in Automotive Networking]." *IEEE Communications Magazine* 48 (5):156-162.

Drury, Meghann, Kieran Conboy, and Ken Power. 2012. "Obstacles to decision making in Agile software development teams." *Journal of Systems and Software* 85 (6):1239-1254.

Dunham, John, and Associates. 2016. Motorcoach Census - A Study of the Size and Activity of the Motorcoach Industry in the United States and Canada in 2014.

Dunmore, Dick. 2016. Comprehensive Study on Passenger Transport by Coach in Europe.

Edison, Henry, Xiaofeng Wang, and Pekka Abrahamsson. 2016. "Product innovation through internal startup in large software companies: a case study." Software Engineering and Advanced Applications (SEAA), 2016 42th Euromicro Conference on.

FCC, U.S. Federal Communication Commission. 2003. FCC Report and Order 03-324: Amendment of the Commission's Rules Regarding Dedicated Short-Range Communication Services in the 5.850-5.925 GHz Band.

Festag, Andreas, and Soeren Hess. 2009. "ETSI technical committee ITS: news from european standardization for intelligent transport systems (ITS)-[global communications newsletter]." *IEEE Communications Magazine* 47 (6):1-4.

Fishbein, Mike. 2014. "The Ultimate List of Customer Development Questions." accessed 11/04/2017. http://mfishbein.com/the-ultimate-list-of-customer-development-questions/.

Fitriani, Widia Resti, Puji Rahayu, and Dana Indra Sensuse. 2016. "Challenges in agile software development: A systematic literature review." Advanced Computer Science and Information Systems (ICACSIS), 2016 International Conference on.

Ford, Alan, Costin Raiciu, Mark Handley, Sebastien Barre, and Janardhan Iyengar. 2011. Architectural guidelines for multipath TCP development.

Gangji, Arif, and Bob Hartman. 2010. "Agile SCRUM for Denver Web Development." Neon Rain Interactive, accessed 23/05/2017. https://www.neonrain.com/agile-scrum-web-development/.

Guest, Greg, Arwen Bunce, and Laura Johnson. 2006. "How many interviews are enough? An experiment with data saturation and variability." *Field methods* 18 (1):59-82.

Henry, Joel, and Sallie Henry. 1993. "Quantitative assessment of the software maintenance process and requirements volatility." Proceedings of the 1993 ACM conference on Computer science.

Hirotaka, Takeuchi, and Nonaka Ikujiro. 1986. "The new new product development game." *Harvard Business Review* 64 (1):137-146.

Huang, Chung-Ming, Chia-Ching Yang, and Yu-Cheng Lin. 2016. "An adaptive video streaming system over a cooperative fleet of vehicles using the mobile bandwidth aggregation approach." *IEEE Systems Journal* 10 (2):568-579.

Insights, Global Market. 2015. Vehicle to vehicle (V2V) Communication Market Size, Industry

Outlook Report.

Kaspar, Dominik, Kristian Evensen, Paal Engelstad, Audun F Hansen, På l Halvorsen, and Carsten Griwodz. 2010. "Enhancing video-on-demand playout over multiple heterogeneous access networks." Consumer Communications and Networking Conference (CCNC), 2010 7th IEEE.

Khmelevsky, Youry, Xitong Li, and Stuart Madnick. 2017. "Software development using agile and scrum in distributed teams." Systems Conference (SysCon), 2017 Annual IEEE International.

Kumar, Gaurav, and Pradeep Kumar Bhatia. 2012. "Impact of Agile methodology on software development process." *International Journal of Computer Technology and Electronics Engineering (IJCTEE)* 2 (4).

Kuratko, Donald F, Jeffrey G Covin, and Robert P Garrett. 2009. "Corporate venturing: Insights from actual performance." *Business Horizons* 52 (5):459-467.

Kuratko, Donald F, Jeffrey S Hornsby, and Jeffrey G Covin. 2014. "Diagnosing a firm's internal environment for corporate entrepreneurship." *Business Horizons* 57 (1):37-47.

Li, Yuwei, Jessica Wang, Justin Chen, and Michael Cassidy. 2007. Design of a demand-responsive transit system.

Ligo, Alexandre K, Jon M Peha, and João Barros. 2016. "Throughput and Cost-Effectiveness of Vehicular Mesh Networks for Internet Access." To appear in IEEE Vehicular Technology Conference (VTC).

Luong, Hien P, Suong H Nguyen, Hai L Vu, and Bao Quoc Vo. 2014. "One-hop vs. multi-hop broadcast protocol for DSRC safety applications." A World of Wireless, Mobile and Multimedia Networks (WoWMoM), 2014 IEEE 15th International Symposium on.

Märijärvi, Jukka, Laura Hokkanen, Marko Komssi, Harri Kiljander, Yueqiang Xu, Mikko Raatikainen, Pertti Seppänen, Jari Heininen, Mervi Koivulahti-Ojala, and Marko Helenius. 2016. "The cookbook for successful internal startups." *DIGILE and N4S*.

Martinelli, Russ J, and Dragan Z Milosevic. 2016. *Project management toolbox: tools and techniques for the practicing project manager*: John Wiley & Sons.

McGrath, Rita Gunther, and Ian C MacMillan. 2000. *The entrepreneurial mindset: Strategies for continuously creating opportunity in an age of uncertainty*. Vol. 284: Harvard Business Press.

Meyer, Karl. 2017. Eduroam continues to grow in 2016.

Moe, Nils Brede, Aybüke Aurum, and Tore Dybå. 2012. "Challenges of shared decision-making: A multiple case study of agile software development." *Information and Software Technology* 54 (8):853-865.

Niven, Paul R, and Ben Lamorte. 2016. *Objectives and Key Results: Driving Focus, Alignment, and Engagement with OKRs*: John Wiley & Sons.

NUS. 2015. "Bus Frequency & Route 2015." accessed 17/06/2017. http://www.nus.edu.sg/oca/doc/Bus Frequency & Route (2015).pdf.

O'hEocha, Colm, and Kieran Conboy. 2010. "The role of the user story agile practice in innovation." In *Lean enterprise software and systems*, 20-30. Springer.

Ohno, Taiichi. 1988. *Toyota production system: beyond large-scale production*: crc Press.

Olsen, Dan. 2015. *The Lean Product Playbook: How to Innovate with Minimum Viable Products and Rapid Customer Feedback*: John Wiley & Sons.

Organization, World Trade. 2017. World Trade Statistical Review.

Ries, Eric. 2009. Venture Hacks interview:" What is the minimum viable product?". URl: http://www.startuplessonslearned.com/2009/03/minimum-viable-product.html (visited on 17/06/2017).

Ries, Eric. 2010. "Is Entrepreneurship a Management Science?". Harvard Business Review, accessed 28/05/2017. https://hbr.org/2010/01/is-entrepreneurship-a-manageme.

Ries, Eric. 2011. *The lean startup: How today's entrepreneurs use continuous innovation to create radically successful businesses*: Crown Business.

ringDNA. [20—]. "What is sales prospecting?", accessed 16/06/2017. http://www.ringdna.com/inside-sales-glossary/inside-sales-glossaryinside-sales-glossarywhat-is-sales-prospecting-2.

Robinson, F. 2001. "A proven methodology to maximize return on risk." *Retrieved February* 24:2016.

Schmietendorf, Andreas, Martin Kunz, and Reiner Dumke. 2008. "Effort estimation for agile software development projects." 5th Software Measurement European Forum.

Schwaber, Ken. 2004. *Agile project management with Scrum*: Microsoft press.

Serrat, Olivier. 2009. "The Five Whys Technique." *Cornell University ILR School*.

Sierra, Kathy. 2007. "Featuritis vs. the Happy User Peak." accessed 17/06/2017. http://headrush.typepad.com/.

Software, Mountain Goat. [20—]. "Product Owner." accessed 17/06/2017. https://www.mountaingoatsoftware.com/agile/scrum/roles/product-owner.

Stamford, Conn. 2016. Gartner Says Connected Car Production to Grow Rapidly Over Next Five Years. edited by Gartner.

Sutherland, Jeff. 2004. "Agile development: Lessons learned from the first scrum." *Cutter Agile Project Management Advisory Service: Executive Update* 5 (20):1-4.

Technologies, CA. 2012. "Introduction to Managed Services."

Telefónica. 2015. "The 5 best and most demanded Connected Car features." 15/06/2017. https://iot.telefonica.com/blog/the-5-best-and-most-demanded-connected-car-features.

Tunguz, Tomasz. 2015. "8 Customer Discovery Questions to Validate Product Market Fit For Your Startup." accessed 11/04/2017. http://tomtunguz.com/anatomy-of-a-customer-reference/.

Wei, Xianglin, Qiping Wang, Tongxiang Wang, and Jianhua Fan. 2017. "Jammer Localization in Multi-Hop Wireless Network: A Comprehensive Survey." *IEEE Communications Surveys & Tutorials*.

Womack, James P, and Daniel T Jones. 2010. *Lean thinking: banish waste and create wealth in your corporation*: Simon and Schuster.

Appendix A: Veniam's organizational chart

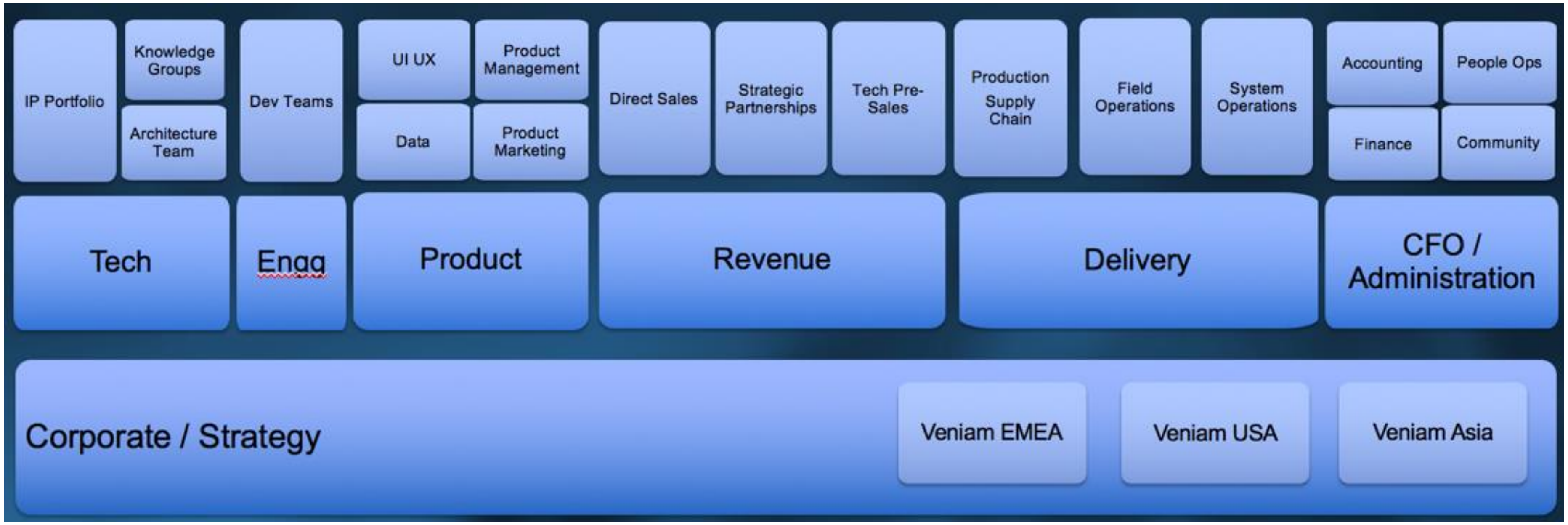

Figure 27 - Veniam's organizational chart. Source: internal document

Appendix B: New product feature development

Company	Founded in...	Office Locations	Size (employees)	Total Funding
purplewifi	2012	UK, USA, Spain, Australia, Singapore, Chile	+100	$15.92 m (last: $3.9 m in September 2016)
Tanaza	2010	Italy	+23	<$200 k (February 2014)
Colony	-	Canada	11-50	-
cucumber	2014	UK	7	-
globalreach	2009	UK, USA, Malaysia, Australia	11-50	$5 m (March 2016)
wavespot	2011	USA	11-50	-
मुफ्त इंटरनेट Muft WiFi	2014	India	-	$62 k (2014)

Figure 28 - General information on captive portal management companies

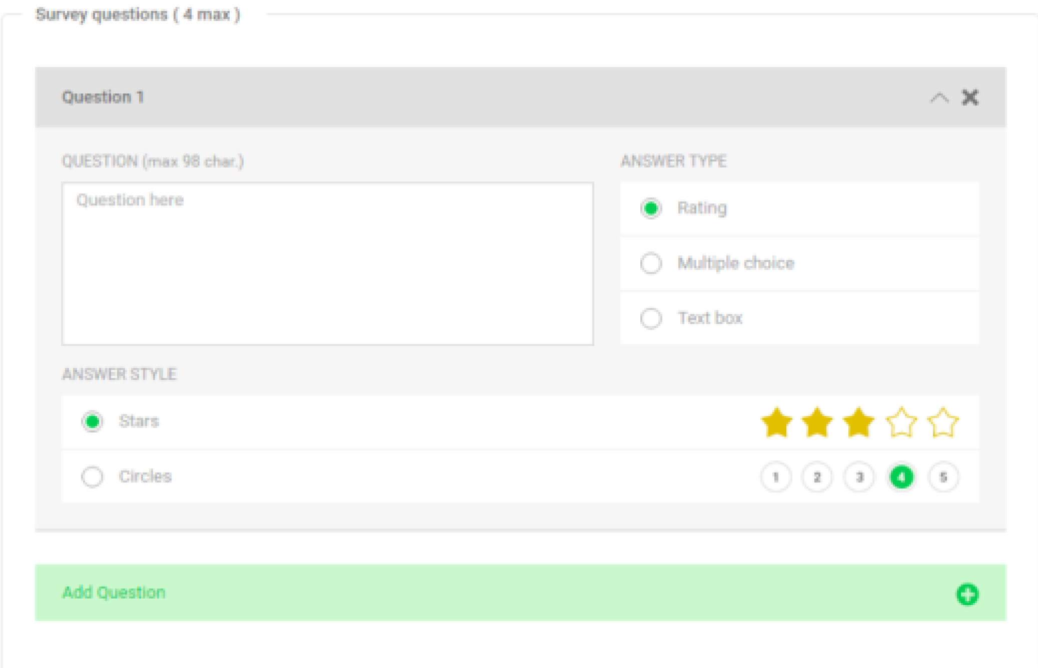

Figure 29 - Purple's survey editor with three answer types: rating, multiple choice and text box. In: https://s3-eu-west-1.amazonaws.com/portal-guides/Customer+Portal+-+Marketing.pdf , accessed 19-06-2017, 23:15

Figure 30 - Purple's user analytics dashboard. In: https://s3-eu-west-1.amazonaws.com/portal-guides/Customer+Portal+-+Reports.pdf , accessed 19-06-2017, 23:17

Appendix C: Service metrics and analysis

STCP

	March 14, 2017 Tuesday	March 15, 2017 Wednesday	March 16, 2017 Thursday	March 17, 2017 Friday	March 18, 2017 Saturday	March 19, 2017 Sunday	March 20, 2017 Monday	March 21, 2017 Tuesday
Sessions	17,882	18,069	18,413	18,667	8,759	5,759	18,830	19,445
Devices	11,453	11,385	11,656	11,984	5,815	3,986	11,850	12,202
OBUs w/ sessions	393	394	389	394	263	216	391	389
Traffic (Gb)	298.96	310.16	313.45	330.99	156.24	104.27	314.65	337.71
Median Devices	41	43	45	46	27	23	45	45
Median Traffic	7.88	8.07	8.15	8.44	7.98	8.47	8.30	8.37
Median Duration (min)	23.2	24.1	23.4	24.0	23.4	23.6	24.0	23.8
Perc(95) Duration (min)	48.5	49.6	49.5	53.0	48.3	49.6	49.5	49.5
Sessions (< 10 sec)	6.69%	3.54%	6.57%	5.18%	2.73%	2.41%	3.11%	4.63%
Sessions (> 1 hour)	1.95%	2.13%	1.95%	2.87%	2.37%	2.92%	2.18%	1.95%
Login to first byte	99.82%	99.94%	99.91%	99.90%	99.92%	99.95%	99.93%	99.34%
OBUs w/ login attempts	397	396	397	402	294	244	394	395
Failed Connection Attempts	1,785	868	1,644	1,545	259	270	847	635
N. OBUs affected	230	156	149	225	66	49	134	229
Median Activity per OBU	14.3 h	14.5 h	14.5 h	14.5 h	8.0 h	4.9 h	14.1 h	14.5 h
Perc(95) Activity per OBU	18.1 h	18.4 h	18.6 h	18.4 h	17.4 h	17.0 h	18.4 h	18.5 h

Figure 31 - Daily service metrics for STCP

NUS

	March 14, 2017 Tuesday	March 15, 2017 Wednesday	March 16, 2017 Thursday	March 17, 2017 Friday	March 18, 2017 Saturday	March 19, 2017 Sunday	March 20, 2017 Monday	March 21, 2017 Tuesday
sessions	63,366	36,841	71,270	61,863	18,321	5,755	48,700	1,332
Devices	18,115	14,034	19,056	17,257	6,231	2,659	15,971	651
OBUs w/ sessions	27	28	29	29	21	11	24	21
Traffic (Gb)	71.12	51.05	83.70	66.34	24.51	10.56	51.40	1.85
Median Devices	1,758	1,034	1,725	1,591	526	17	1,483	47
Median Traffic	32.36	46.78	33.45	34.59	38.15	59.28	31.36	21.21
Median Duration (min)	5.4	5.4	5.4	5.3	5.4	5.4	5.4	5.3
Perc(95) Duration (min)	11.9	12.2	11.8	11.8	11.6	13.5	11.6	11.3
Sessions (< 10 sec)	15.77%	13.96%	15.40%	15.61%	17.28%	18.40%	16.76%	22.07%
Sessions (> 1 hour)	0.01%	0.01%	0.00%	0.01%	0.02%	0.00%	0.00%	0.00%
Login to first byte	98.94%	98.75%	99.06%	99.00%	99.03%	99.48%	99.10%	99.25%
Median Activity per OBU	15.1 h	15.2 h	15.0 h	14.3 h	12.7 h	3.4 h	9.5 h	14.1 h
Perc(95) Activity per OBU	18.1 h	18.0 h	17.8 h	17.3 h	16.3 h	13.6 h	16.4 h	17.0 h

Figure 32 - Daily service metrics for NUS

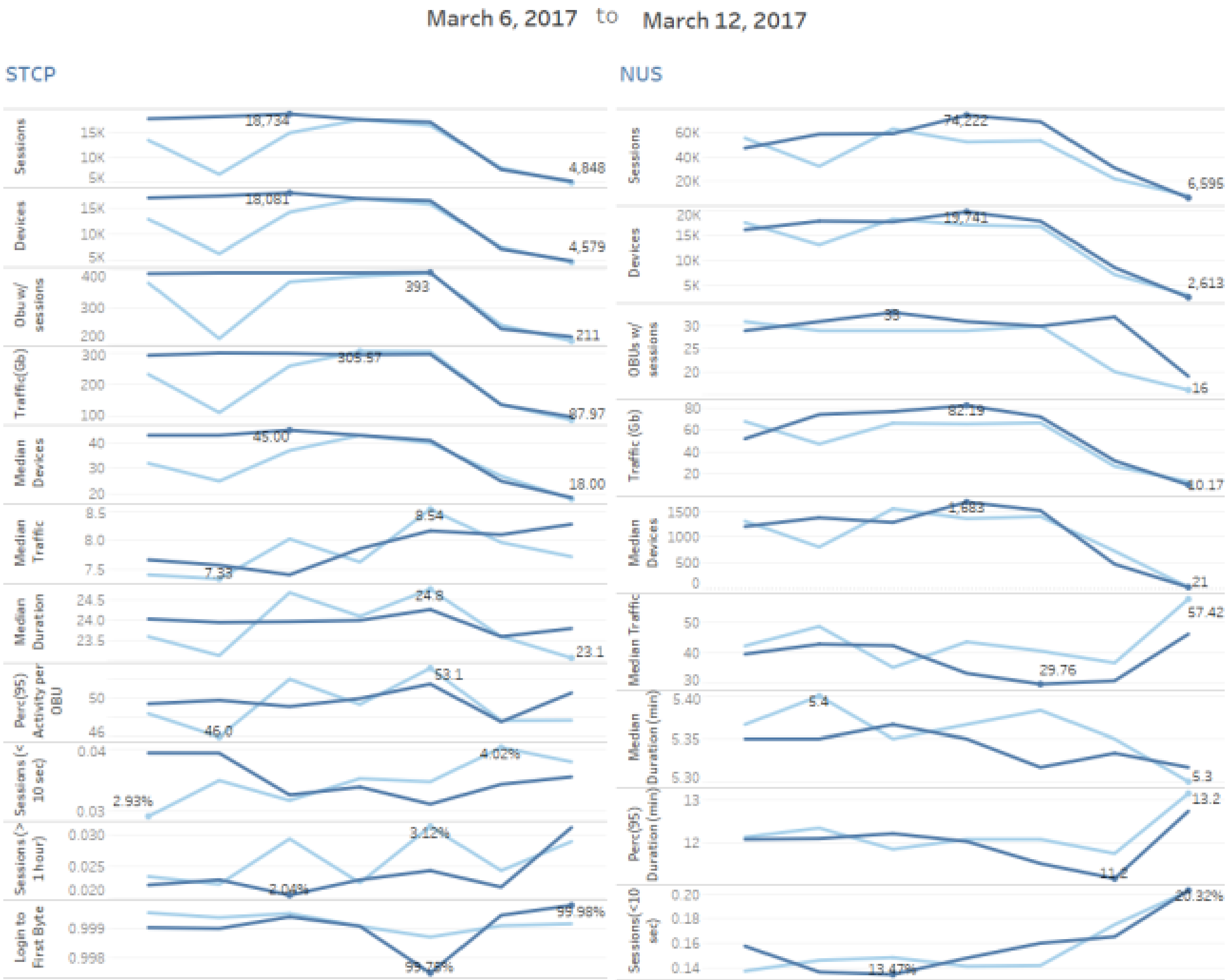

Figure 33 - Weekly time series metrics for STCP and NUS (1/3)

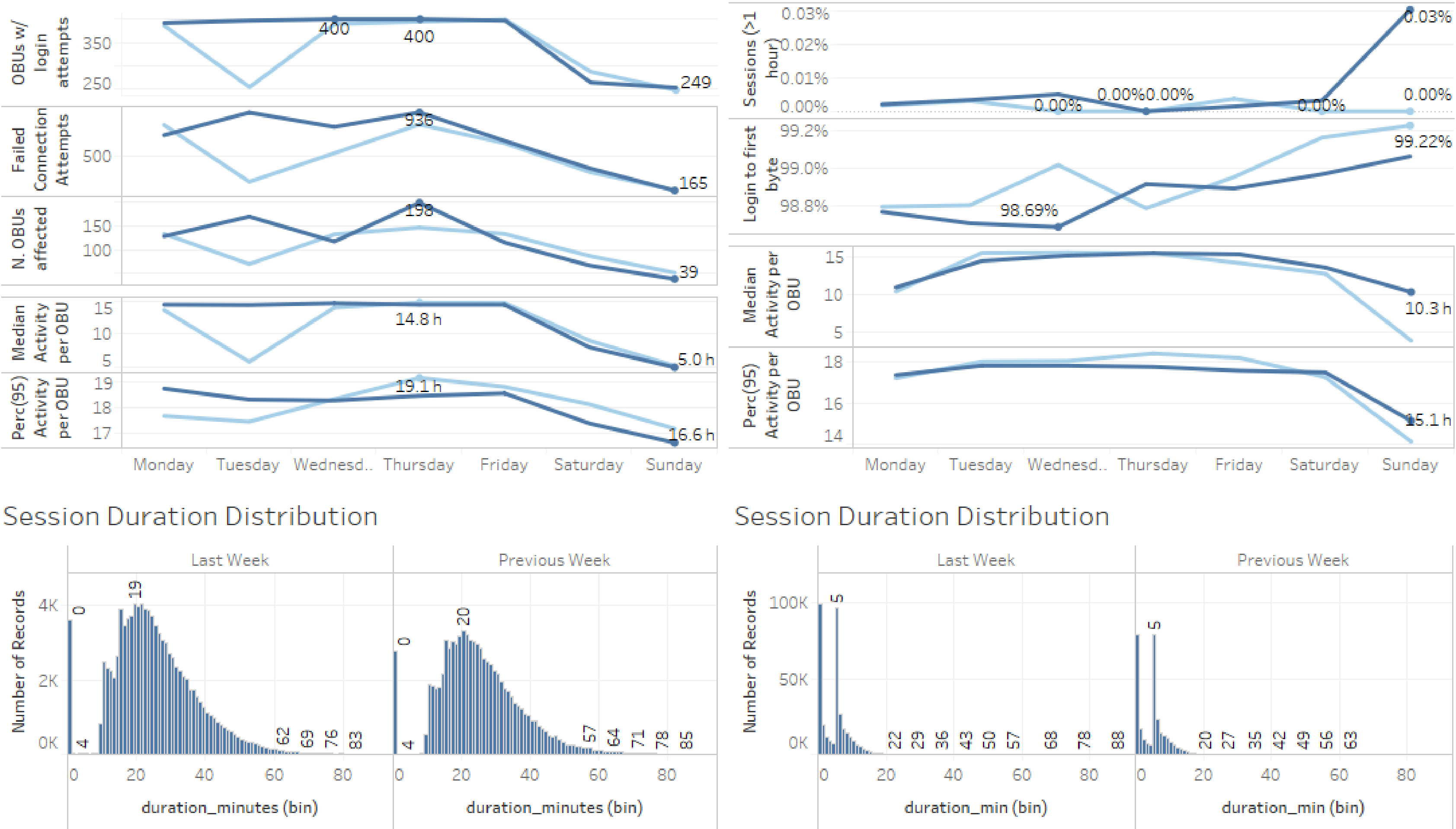

Figure 34 - Figure 33 - Weekly time series metrics for STCP and NUS (2/3)

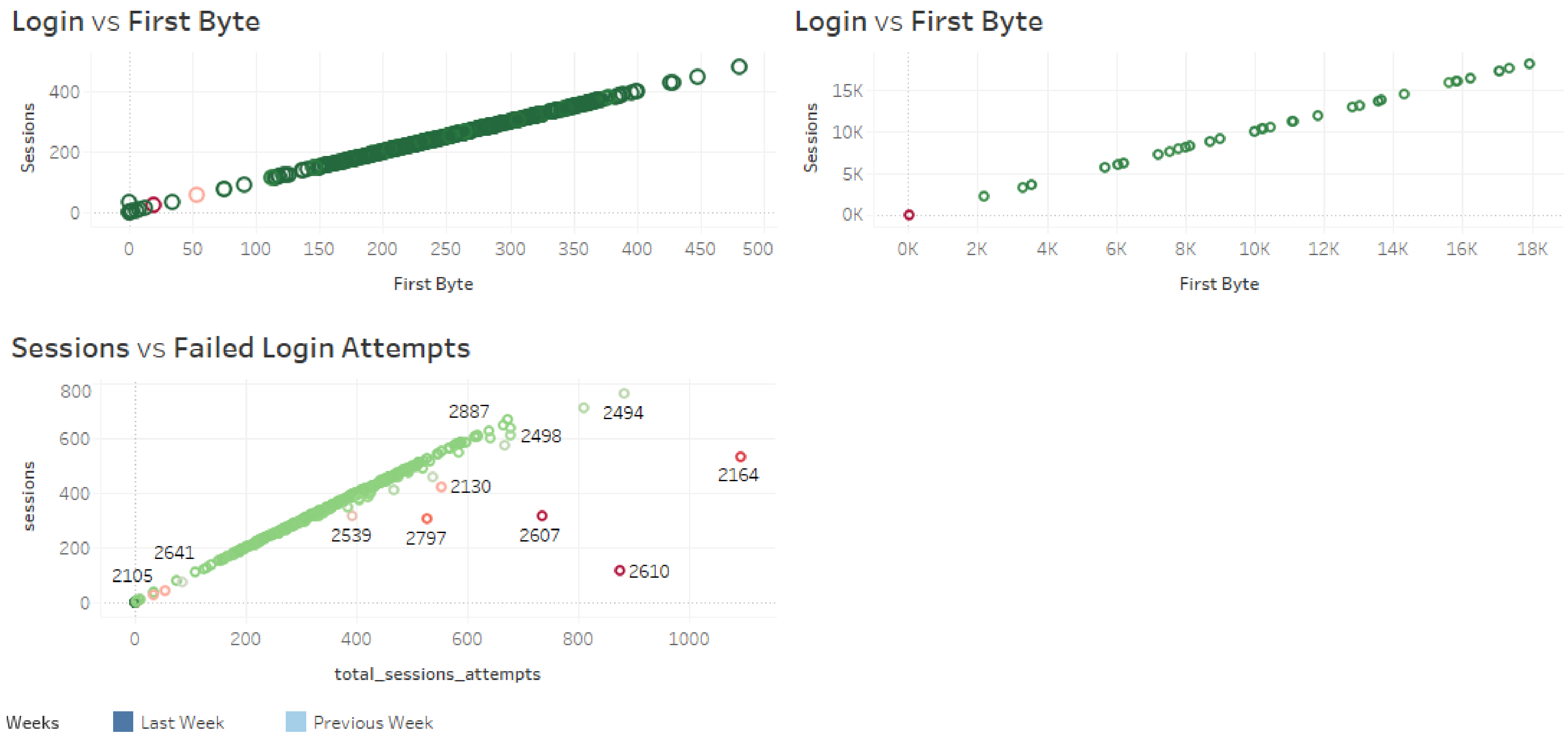

Figure 35 - Figure 33 - Weekly time series metrics for STCP and NUS (3/3)

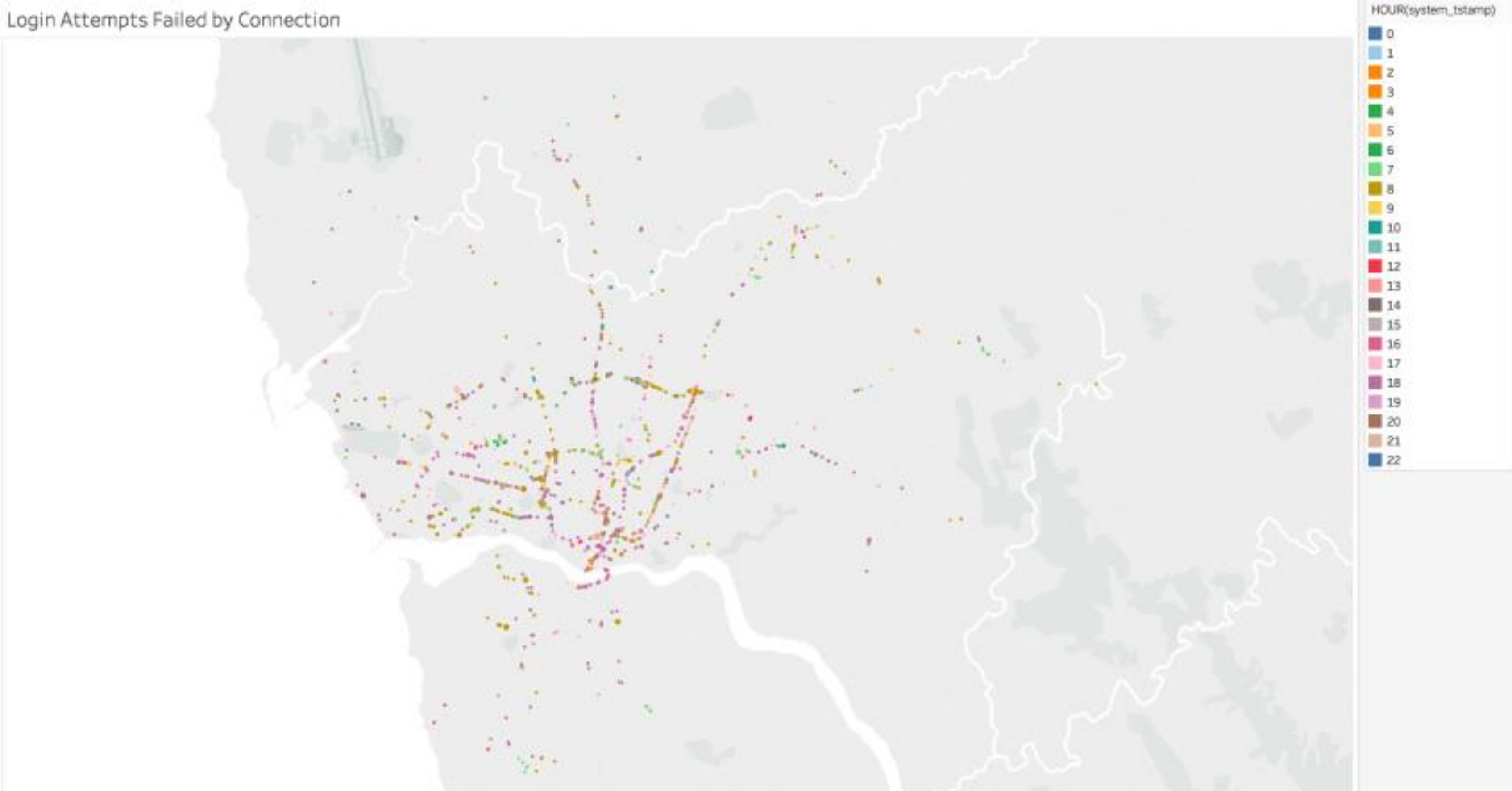

Figure 36 - GPS location of *Failed connection attempts* (FCA) on March 14th in STCP

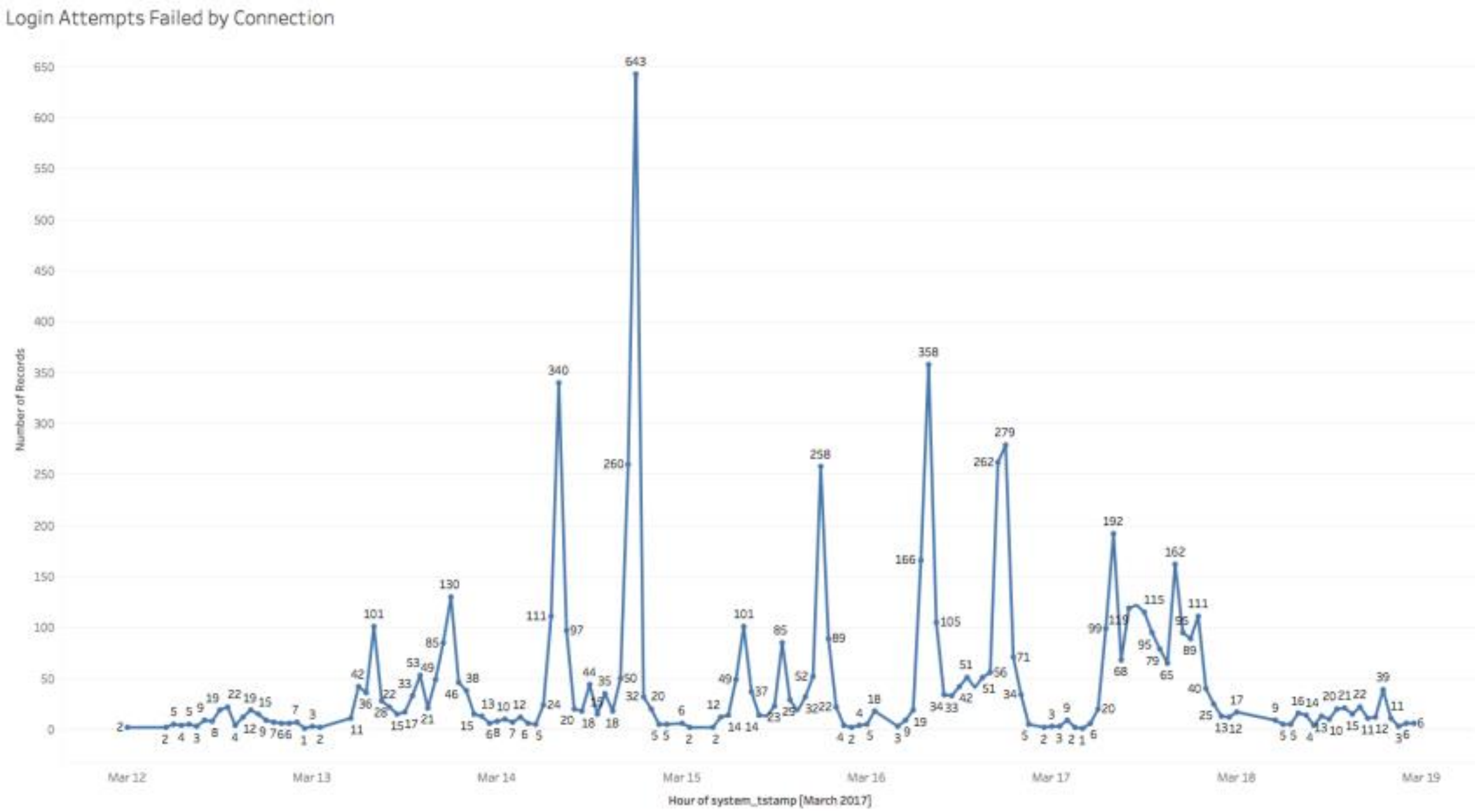

Figure 37 - Hourly Failed connection attempts from March 12th to March 19th in STCP

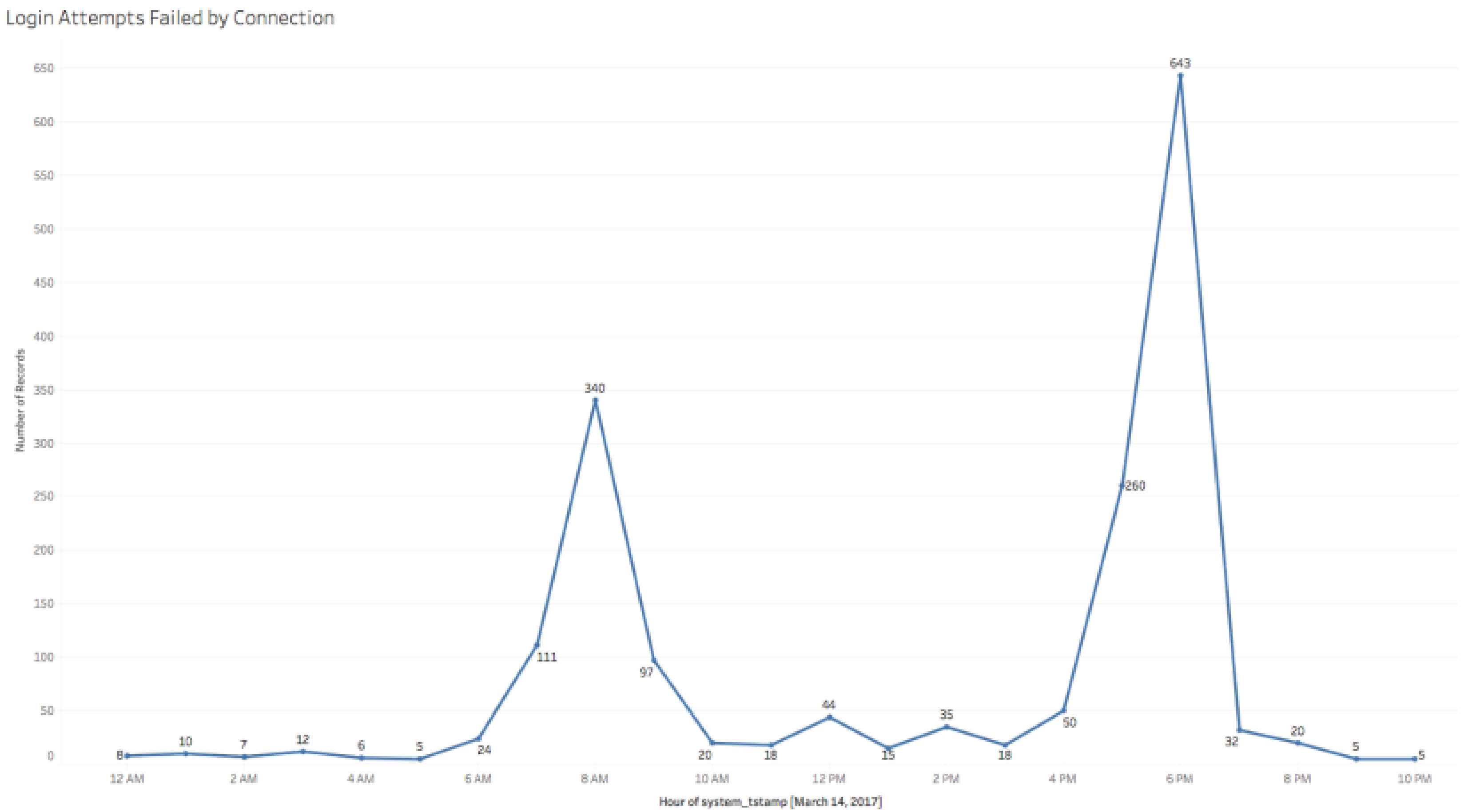

Figure 38 - Hourly *Failed connection attempts* on March 14th from 12am to 10pm in STCP

Appendix D: Interview script

To collect feedback in a structured way, a standard list of questions and "lessons to be learned" for the calls was done. These were compiled based on articles by Fishbein (2014) and Tunguz (2015). At the end of the call, the answers were reported and the mobile Wi-Fi product-market fit was assessed by measuring feedback in a quantitative fashion. The following script was executed in the interviews:

General fleet overview

- Can you tell me about "the company"?
- How big is the company?
- What type of routes do you operate?
- Are they scheduled or *ad hoc*?
- What is the passenger profile (tourist, commuter, etc.)?

Wi-Fi for passengers

- Do you currently offer free Wi-Fi on your vehicles? If yes: what was the driver to install Wi-Fi?
- How did you go about choosing the provider?
- What made you choose that solution over the competition? How is that going? What is the experience of your users like?
- What issues/feedback have you had with the service?
- How did you measure the success of that project?
- How did you manage the service (Wi-Fi metrics, user analytics, etc.)?
- Did you monetize the service (advertisements, paid Wi-Fi, etc.)? If no: why not?
- How critical do you see high-quality Wi-Fi as a differentiator of your service?

Passenger intelligence

- What information do you have about your passengers and traffic patterns (demographics, where people enter and leave the vehicle, busiest locations)?
- Why do you need this information?
- What could you do if you had it? How would it help your business?
- How easy is it for you to decide how to optimize your routes? Which data do you have available to make those decisions?

Passenger engagement

- How do you get feedback from your customers?
- Do you run recurrent field surveys? What is the hardest part of doing it?
- If you had instant access to your passengers whenever you wanted, what would you like to find out? How would it help your business?

Connectivity hub

- How do you see the role of connectivity in the public transport sector, as an enabler for a great rider experience?
- What sort of devices do you have on your vehicles (driver console, CCTV cameras, ticketing, etc.)?
- How do you manage the data transfer between all those devices? What is the hardest

part of doing it?

- If you had unlimited bandwidth on your vehicles, what could you do with it?
- How much would you be willing to pay for a solution that gave you Wi-Fi, passenger intelligence, rider engagement and could be the data hub for your vehicles?

Public tendering (directed to private fleets operating on public routes)

- What's the concession medium duration?
- Is Wi-Fi on buses a requirement of the public tender? If so, are vendors recommended/specified?
- If not, does Wi-Fi represent an advantage?
- What platforms do you use to apply to public tenders?
- Who pays for Wi-Fi?