Real-Time Monitoring of a Mobile Ticketing Solution

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***Abstract*—Mobile ticketing in public transportation is starting to replace the old ticket card. As technology evolves, there is the need to reduce the complexity of existing public transportation systems. Usually, it is required that users memorize different areas of the city, know the exchanging points and the complete schedule for a specific transportation vehicle. This context, together with the fact that technology is rising as fast as ever and that the users are increasingly accepting mobile payment solutions, motivated the development of a new solution for mobile ticketing. This solution is based on existing technologies, such as Near Field Communication and Bluetooth Low Energy beacons through a Check-In/Be-Out system and one of its main objectives is to eliminate the need for users to understand the sys-tem. This solution has been extensively evaluated and tested, in the Metropolitan Area of Porto, during one year with about 190 real passengers. However, implementing an entirely new system on top of an existing one can be prone to several flaws. In order to detect and solve errors, abnormal situations or inconsistent behaviors that may occur in any new system, a real-time monitoring system was setup on top of the mobile one. The focus is to collect and gather information from different sources, so it can be displayed and observed. Therefore, this paper details the monitoring system that was developed and presents the main results regarding its deployment.**

***Index Terms*–Mobile ticketing, mobile payment, monitoring, bluetooth low energy**

I. Introduction

Public transportation implementation in any city revolutionize the way the people move around it. However, as more and more lines are created and updated, public transportation systems tend to grow more complex and so does the need for the customer to understand the fare system. Mobile ticketing comes to alleviate all these burdens.

A mobile ticketing solution, called Anda, was developed and tested in the Metro-politan Area of Porto (AMP) for over a year. This paper presents the design and implementation of a monitoring system that was used to monitor the mobile ticketing solution during the testing phase. The main goal of the proposed system is to catch and detect errors as swiftly as possible, resulting in less problems for the customers that fully utilize the mobile ticketing solution. It also provides a fast and steady approach to facilitate flaw and error handling.

The paper organized as follows: the next section presents the related work concerning monitoring systems and the main approaches to mobile ticketing solutions. Section 3 describes current fare system of the Metropolitan Area of Porto. Section 4 presents the future mobile ticketing solution, Anda, which is the system being monitored in the present paper. Section 5 expands on the monitoring system, explaining in detail the proposed approach, technologies and main goals of the monitoring. Lastly, Sections 6 presents the main conclusions and future work.

II. Literature Review

Several mobile ticketing solutions have been proposed, based on different technologies: NFC [1], [2], internet connection [3], [4], and QR Codes [5]. Research on mobile ticketing have also addressed mobile payments adoption factors [6], [7], payment schemes and architectures [8], privacy and security issues [9], and evaluation of mobile ticketing solutions [10]. Studies related to the monitoring of mobile ticketing systems are scarce.

Most monitoring systems focus on the monitoring of the business aspect of mobile ticketing. This includes the monitoring of fraud, statistics of use and number of fares purchased. Others focus on the traffic and schedule adherence of the circulating vehicles [11].

Regarding the deployment of mobile ticketing systems, a few stand out, such as Masabi and Cubic. Masabi is a company that offers a solution for public transportation based on mobile ticketing. It is the first to prove successful in the area of mobile ticketing, being also the first to take mobile ticketing to volume in 2007 and proved the concept. Masabi's solution has the name of Justride, implemented as a cloud-based mobility platform and layers its foundations in the concept of Software as a Service (SaaS) [12]. It allows for pre-ticketing, meaning that the customer needs to purchase tickets before boarding the public transportation vehicle. Besides the customer point of view, Justride is comprised of three different products: Justride Retail, the mobile application used by the end customers, Justride Hub that allows for companies to have a dashboard that aggregates different

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kind of data and analyze it, enabling the ticketing agencies to control and maintain their business, and Justride Inspect, a validation system.

Cubic is another company that has a solution in the mobile ticketing area, named NextCity [13]. It centers on three core principles, the delivery of an integrated customer experience, one account and integrated operations and analytics. It also contains a revenue management system, which runs efficiently and reliably, with 24 billion transactions processed per year. It also provides financial clearing and settlement, business analytics, device and asset management, prepaid benefits, fare table management, customer service infrastructure, fraud analysis and fare collection engines. The payment, customer-side, is also handled by Cubic, either by contactless smart cards or NFC using smartphones. It also allows for analytics of all the data collected via Cubic's service.

The next section introduces the ticketing system implemented in the AMP.

III. Andante Ticketing System

The public transport network of the AMP covers an area of 1,575 km^2 and serves 1.75 million of inhabitants. The network is composed of 12 operators: 128 bus lines (73 public and 55 private), 82 metro stations and 19 train stations. Sociedade de Transportes Coletivos do Porto (STCP) is the public bus operator of AMP, was created in 1946 and currently has 73 bus lines and 4 different types of vehicles in their fleet. Metro do Porto (MP) has 6 operating metro lines, 102 vehicles in their fleet, 82 stations and in 2017 alone sold 58 million tickets. It was created in 1994 and is now planned to open one new line and expand an existing one in 2019. Comboios de Portugal (CP) has 2179 kilometers of railroads in Portugal, 258 vehicles (trains and locomotives) and was founded in 1856. To these three public transport operators, other nine private bus operators have joined: Resende, Espírito Santo, Maia Transportes, Valpi, ETG, MGC, A. Nogueira da Costa, Auto-Viação Pacense and Auto-Viação Landim.

The electronic ticketing system implemented is an open (ungated) system that divides the AMP in 46 zones through a ring of zones system. This system means that the fare takes into account the number of ring zones the user traveled, since the rings of zones are counted around the zone where the user began his journey, until the limit of rings of zones acquired (Z2 if it is two rings, Z3 if it is three rings and son on). In Fig. 1 is an example of this ring of zones if a user enters in the C1 zone.

The Andante system works by way of a RFID smartcard with pre-purchased tickets that range from Z2 to Z12, with a time range of one hour for the minimum fare (Z2) going all the way to two hours and fifteen minutes in the maximum fare (Z12). Besides the pre-purchased tickets, there is also a monthly pass with a subscription plan and in this scenario, areas are counted differently for billing purposes, as the user pays for the zones he will be traveling during the subscription plan, not a ring of zones system.

The Andante system is based on a Check-In/Be-Out approach, as the user pre-purchases the ticket and validates it before starting his journey in the designed vehicle of choice. If there is the need to change vehicle or line, it is necessary for the user to validate his ticket again and when the journey ends, there is no need for the user to check-out.

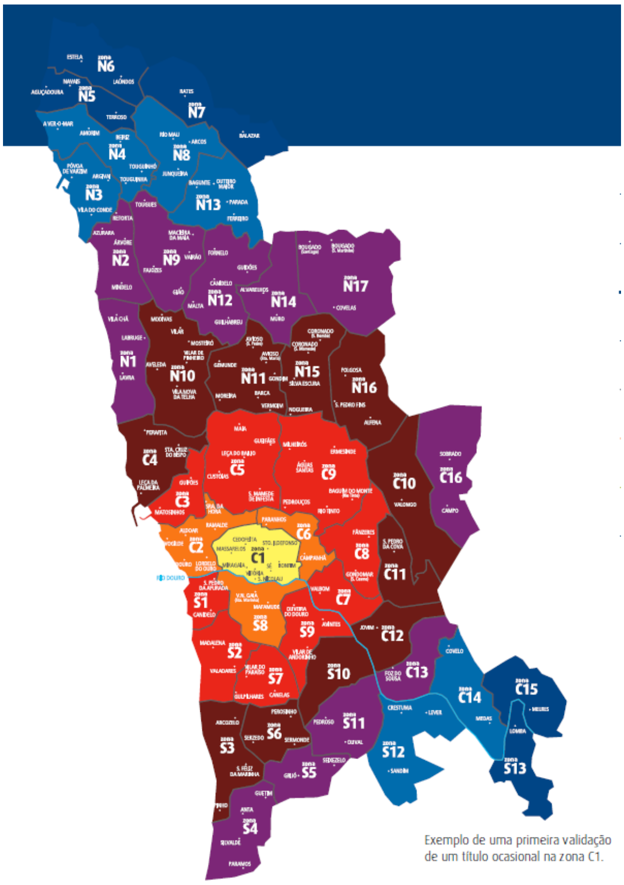

Figure 1. Validation in C1 zone [14]

IV. Anda Ticketing System

As seen in section 3, the Andante system is quite complex, has many zones, 12 operators and many types of tickets. Therefore, a mobile ticketing project started being thought out and developed around 2013 by [15]. At the time, a prototype was developed for the bus operator, STCP, which consisted in the pre-purchase of Andante tickets and the activation of those tickets. In 2015, a second prototype explored the possibility of the use of QR Codes to aid a potential mobile application in the context of mobile ticketing in Porto [5]. Only in 2017, a more robust application started gaining traction, with the name of Anda. A Check-In/Be-Out approach to mobile ticketing that has the main goal of being a platform that is seamlessly integrated with Porto's intermodal public transportation network, while simultaneously bringing the users a pleasant experience, either by its simplicity of use, or by the many advantages that a service like this can offer [16].

The Anda project consists of a mobile application that serves as an interface that interacts with the Andante system. The main technologies used are BLE and NFC. On one hand, NFC is used to validate the beginning of a journey, by tapping the users' smartphone against the validator containing the NFC antenna. On the other hand, BLE beacons are currently broadcasting the station in which they are in, allowing the users to be tracked throughout their travel so that the application can estimate the journey, scanning for beacon's signals. The end of the travel is then mainly deduced if the users starts walking or stops capturing the beacons signal during fifteen minutes. However, the system considers other parameters when calculating a valid end of journey: a user capturing the beacon signal for more than ten minutes straight or disconnecting the Bluetooth of his smartphone for more than two minutes.

For railroad vehicles, the beacons were installed inside the validators that were used for the check-in with the Andante system and as for the buses, the beacons were installed inside the vehicles. A very important competitive advantage of the Anda system is the post-billing and tariff optimization. At the end of the month, the customer pays the bill and does not need to understand the fare system or buy any kind of ticket, as the application does it for him. There is also a tariff optimization algorithm that charges the customer the minimum fare considering the journeys made during the entire month. For example, in the current system relying solely on Andante travel card, a user buying 28 Z2 tickets would spend 33.60€. However, on the future system, Anda, the application would buy a Z2 monthly pass, only charging 30.60€.

This system has been tested over a year by more than 190 real customers. Analysis of customers' feedback allowed to identify a set of problems. Users reported that sometimes the beacons signals are not detected, sudden crashes of the application, beacons signals are not well interpreted (beacons emitting signals of other beacons), and unsuccessful validations.

In order to make sure all these bugs and errors are detected and solved, a monitoring system is being setup above the Anda system, and is presented in the next section.

V. Monitoring System

The monitoring system was planned to be available in every system it needed to be ran. Considering this, the solution found rested in a responsive web application, meaning that it can be accessed via smartphone or computer.

A. Information Sources

There are currently five information sources to load all of the Anda's relevant information to an external database, which directly feeds the monitoring system. All of this data is gathered and refined previously by an external company and is then sent via e-mail to the authors of this paper.

1) Excel file containing information about the users

This excel file contains the name of the user (a volunteer participant), his email, and a UUID. This UUID serves as an identifier for every log that is saved whenever the users share a report of a situation that happened throughout a travel.

2) File containing the current state of internal database of journeys

Each of these files is updated daily and contains information about the users and their journeys. Regarding the users, it is used to identify any new user that is not present in the previous excel file. Regarding the journeys, the file contains journeys performed by the users registered in a given month, how the journey ended, the time and station the journey started and finished and the operator in which the journey took place.

3) File containing information about the users' phones

This excel file feeds another subset of the monitoring system that is not directly related to the users, but rather to their phones. It contains each mobile phone specifications, such as operating system, brand, model, manufacturer and Bluetooth version.

4) File containing beacons communication since 2017

This file is updated daily with information about the BLE beacons being used and active. It contains the serial number to identify each beacon, their last communication date, the operator it belongs to, the station or vehicle it is located in, the intermodal zone and line it operates on, and the number of hits since the beacon went online.

5) Logs of the users phones

These logs are saved whenever a user travels using the Anda system. It contains an internal log of the users' phone developed by an external company, and contains information about BLE signal that is caught, if any, when the travel starts and finishes.

In an ideal system, most of this recollection of the information pertinent to Anda would be collected within Anda itself. The information related to the users, such as e-mail, name or phone would be fetched directly from the internal database where it is stored. The beacons communication could be retrieved by setting up a receiver at every station that were capturing the beacons signals at all times. This way, the monitoring system would detect in a matter of minutes if a beacon were malfunctioning or poorly configured.

Finally, regarding the journeys, the logs should be maintained but, once again, the rest of the information should be fetched directly from Anda's internal database. However, during the pilot and test phases, part of the information that is needed to monitor the system is spread through different files and databases, mainly due to the existence of different technology providers involved in this project.

B. Data Model

1) Project structure

The project rests on a NodeJS web application, using Handlebars as a template engine, Express as a middleware and MySQL for the database. The server has two main responsibilities: 1) daily retrieving all of the e-mails and files to populate the database, and 2) feeding the web application. This web application is an interactive dashboard that allows any user to fiddle with different types of information, organize it, compare it and aggregate it.

When it comes to the parsing of the e-mails, the server fetches, through the Gmail API, two e-mails per day (one containing information about the beacons' communication and another containing information about the daily travels). Then, it runs the e-mail data through a parsing system and inserts all of the information in the database. The parsing of the excel files is done in a similar fashion, except it is through "xlsx", a NPM module.

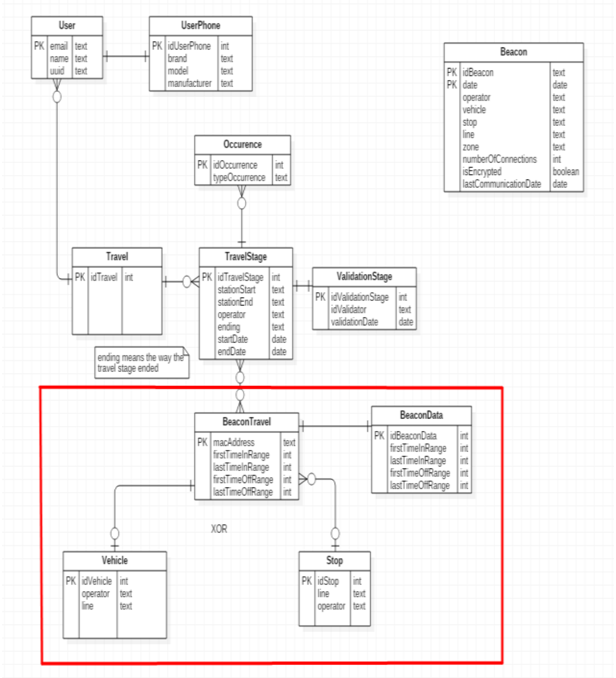

Figure 2. UML view of the database

2) *Database*

The database is represented in Fig. 2 through an UML. The UML can be divided in three main areas: users, travels and logs. All tables inside the red rectangle are not yet implemented, but are thought out, to store the logs of all of the travels made by the users.

3) *Views of the web application*

The web application possesses three main views (although more can be added):

- Landing Page: This view contains an overview of the entire system, such as the percentage of successful travels and the number of beacons not communicating for over a day. It also possesses a timeline of the Anda system, as well as some global statistics.
- Beacons' communication: This view shows the variation of the communication of the beacons between two specific dates. It compares the number of hits between those dates and shows that information in three ways. A table with filters and searches, a chart comparing all of the beacons in a specific station and another chart showing the progression of the number of hits of a beacon daily.
- Occurrences: The monitoring system already flags some travels where may have occurred problems. This flagging of the travels is done if the user entered and exited the same station, if the user did not manage to validate and start a new journey or if the travel ended by a timeout, a disconnect of the Bluetooth connection of the user's smartphone or if the application crashed. The view itself possesses all of the occurrences detected since the deployment of the dashboard and the crosscheck of different data and errors, to discover the root of those errors.

C. *Limitations of the Monitoring System*

Currently, external files and e-mails solely update the database. There are two major problems with this approach. On one hand, the structure of the files and e-mails may change and the parsing module of the monitoring system will need to be updated, to keep up with structure changes. On the other hand, if the files stop being updated or the e-mails stop being sent, now, there is no other method of populating the database.

There is also a known problem using the Gmail API, to collect specific e-mails. The query given to the API may not return the desired e-mail, even though it should. Then, when inserting this information in the database, the information will not be correct.

As of now, there is no monitoring of the validation process because the information of the validators, where they are located and if the validation was successful is not available.

D. *Results*

After analyzing and fiddling with the dashboard, some interesting results are already evident. Fig. 3 and Fig. 4 showcase a portion of the global information the landing page contains, such as the percentage of successful journeys, the number of beacons not communicating for over a day, and the variance of the number of occurrences according to each month.

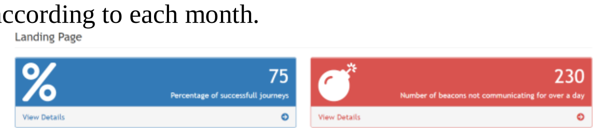

Figure 3. Landing page information

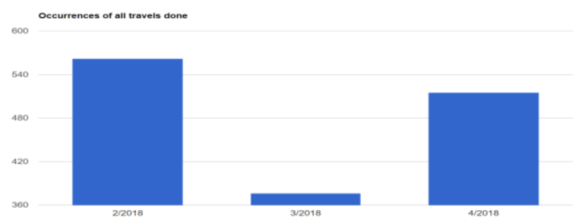

Figure 4. Number of occurrences per month

Besides that, some beacons at the same station may be improperly located, since when comparing their number of hits during, for example, a week, the results show that some beacons receive a greater number of hits, as evidenced by Fig. 5. This beacon malfunction can be already detected just by sorting by their last communication date in the same station.

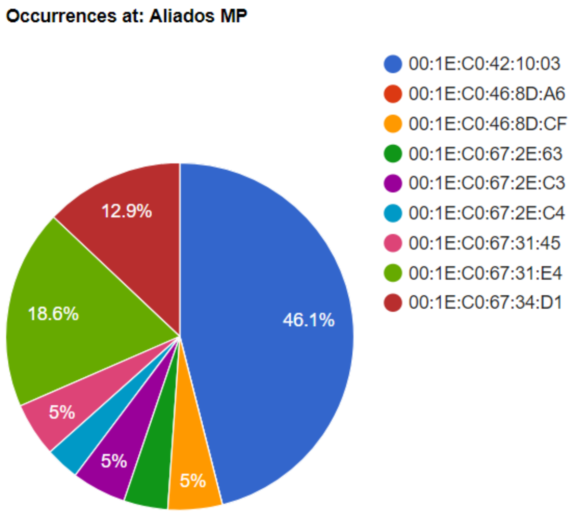

Figure 5. Percentage of hits per beacon, placed in the same station

Finally, Fig. 6 and Fig. 7 show that errors may be correlated to other data, such as the smartphone used or the station in which the user entered. It also allows seeing what smartphones have the most success in using the application and what stations are less prone to errors. This correlation is useful in order to know which smartphones and stations are more error prone or more successful. Consequently, it allows focusing on these examples and applying them, for example, to other stations.

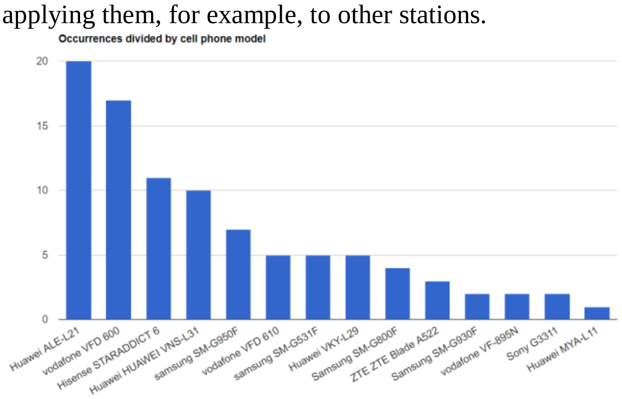

Figure 6. Number of occurrences by type of smartphone used

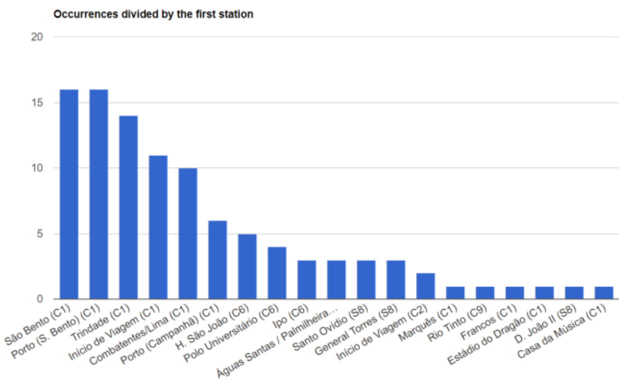

Figure 7. Number of occurrences by station of the start of the travel

VI. Conclusions and Future Work

This paper presents the design and implementation of a monitoring solution based on an existing mobile ticketing solution, called Anda. This dashboard is capable of providing anyone who uses it a complete view of the state of the ticketing system and track all events and occurrences in real time. It allows to visualize which public transport operators are more prone to either success or error, in addition to their respective stations and vehicles. It is also capable of facilitating the maintenance of the ticketing system. For instance, it is possible to identify beacons that are inadequately located in certain areas or even poorly configured. It also allows to draw conclusions from the users' equipment, by detecting errors occurred due to inefficient and low performance smartphones.

This work consists in a proof of concept that there is the need to monitor any mobile ticketing system, not only to fix and correct errors, but also to discover its strengths. Other results can be deduced by the monitoring system such as the busiest hours, the least travelled routes, the smartphones with the most success or even plan preventive maintenances for known error prone validators and beacons.

Regarding the evolution of the monitoring solution, further information, features and datasets could be added in the future. For instance, the logs of the mobile ticketing application could be used to discover which beacons' signal are not being captured throughout the journeys; data from the validators could be collected and analyzed to identify different types of errors occurring during the validation stage; and data from the transport network topology could be added to detect missing beacons' signal or public transportation delays.

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