Automatic Attendance Confirmation with IoT

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ABSTRACT

The Sistema de Gestão de Transporte de Doentes (SGTD) needs new methods to record the hours of entry and exit of users of health units. The system that currently exists does not guarantee accuracy in the records, thus affecting the incorrect accounting of the transport service provided.

The solution proposed in this report aims to modernize this process, through an automatic detection system that seeks to offer greater reliability in the data obtained, while reducing the human resources necessary to carry out this same activity.

This work addresses topics related to the technologies to be used to develop the solution, how they are being applied today and how they can be applied in order to guarantee a viable operation in the future.

A system was implemented that, using Bluetooth beacons together with a mobile application installed on users' smartphones, is able to detect their presence in healthcare facilities. This solution proved to be capable of monitoring the presence of users on the site, but due to some initial implementation problems, it was not possible to extend the system's functionalities to the limit.

Author Keywords

SGTD; Bluetooth Low Energy; Beacons; Control of physical accesses ACM Classification Keywords

1 INTRODUCTION

The registration of the time when a patient enters or exists a medical center is made manually by the administration staff present on the site through the Sistema de Gestão de Transporte de Doente (SGTD). Since this registration is made manually by the staff, there is a chance that some human errors occur, leading to a miscalculation of the accounting for the transportation service provided. This activity can be automated, using new methods and technologies, creating a new way for registering patient's entry and exit times.

Since, at present, the vast majority of the population owns and uses smartphones in their daily lives, it is evident that one can take advantage of their capabilities, in order to improve the dynamics of the process execution - both at the user and health care provider level.

In this project, an alternative to the current method is proposed, which involves the use of Bluetooth Low Energy (BLE) [3], a short-range data transfer technology with low energy consumption. An implementation of this specification of the Bluetooth standard is found in most smartphones available on the market, guaranteeing possible use on a large scale, thus allowing a greater evolution of similar services in the future.

The idea is to create a mobile application that patients can download on their smartphones and, in healthcare facilities, install a series of BLE Beacons in strategic locations. These devices are chosen because of the possibility of advertising their identity at a reduced cost, and the signal emitted by them can be captured by smartphones, so that they perform a certain desired action.

With these two components working together, it is possible to notify the SGTD automatically through the mobile application, about the entry and exit of users, without the need for other stakeholders, making the process more efficient and accurate as to the times of the events.

In this report, the system currently used through the SGTD will be presented, the activities that define the various processes and the disadvantage of the approach that is followed. Later, other projects will be presented that, in a certain way, have similarities with the desired solution, in order to better understand what are the steps that must be taken to fulfill the objectives. The operation of several technologies will also be explained to understand the advantages and disadvantages of each one and choose the one that makes the most sense, within the scope of the project. Finally, an initial solution to the described problem will be presented, which will also contain a desired architecture for the system.

1.1 Goals

The development of this project has objectives that it proposes to fulfill, which are explained below.

Accuracy in launching events: one of the most important factors to consider when addressing this problem is the need for the times of entry and exit recorded in the system to describe the actual situation of the user's journey within the health unit. That is why it is necessary to implement a solution that is able to measure, with great certainty, this data. This objective can be compromised due to the existence of situations where the detection of a Beacon should have occurred but did not happen, as the opposite, with the existence of a wrong detection that should not have occurred but was registered in the system. The data that are stored in the system must describe the user's stay in the health unit and must be analyzed to see if there is coherence between them.

Transparency: it is desired that the registration of the user in the system does not require any type of action on the part of the possible players in the check-in and check-out process (site administrators and user). The process must be performed automatically by the system, even in situations where the user has his smartphone locked (stored in his pocket, for example). The only interaction that must exist is the appearance of a notification, which notifies the user that the event really happened and at what time it was registered in the system. In this way we can obtain a system where the services are simple and intuitive to use. Since many of the possible users can be people of considerable age, often with difficulties working with certain technologies, there is a need to create a system accessible to these users as well.

Costs: beacons are originally low-cost equipment. However, they need to be installed in strategic locations so that it is possible to guarantee the use of the minimum possible resources, without compromising the desired service quality. In addition, these must be the only type of hardware to be put in place, reducing the complexity of the system. It is also necessary to take into account that, for users, data transfer costs have to be minimal, so it is necessary to implement an architecture that reduces the amount of information that has to be exchanged.

Security: the system must ensure that the detection record is actually carried out by the user in question and not by another person. As the proposed solution is supported by wireless communications, it is necessary to take this into account and ensure that there are no eavesdrop attacks (especially if the messages exchanged contain sensitive information, which must be confidential). In the same way that the current model guarantees the authenticity of the user's entry and exit when it is marked in the system, the new methods must also guarantee these requirements.

Multiplatform: The service must be available to all users. For that it is necessary to certify that it is supported by all types of smartphones and operating systems, be they iOS or Android. Since support for Windows Phone is ending, this operating system is not considered for the solution [20].

2 STATE OF THE ART

Throughout the evolution of society and technology, various services have appeared, which, to calculate the tariffs applied to their use, are based on the beginning and / or end of certain activities. The SGTD needs the same type of information so that the transport can be correctly valued and subsequently paid to the transport entities. The price of the transport is calculated based on the distance traveled by the transport, fixed rates that can be applied if necessary, for example, the application of oxygen or a delivery kit and the duration time at the destination. If the grouping consists of more than one user, the duration time at the site is the same for all users, being calculated by the difference between the last hour of departure and the first hour of entry.

2.1 SGTD

Currently, SGTD [1], an information system developed by Link Consulting, is used to control and manage activities related to the patient transport process.

The entire process, which ensures the user a transportation by ambulance, goes through several phases. Initially, a doctor in the role of prescriber prepares a transport request in the clinical system. In this register, the patient's personal and clinical information is stored in the system, as well as the necessary information for transport: the date and time at which it will be carried out, the destination and the reason for the journey. The transport request registered in the clinical system is then imported into the SGTD to be handled - first at the administrative level, to verify the information, time and place of destination and, in a second phase, to be approved by the clinical director of the prescription site in cause. From the moment it is approved, the transport requisition is designated as a transport credential, and there is legitimacy to carry out the transport. A transport credential may contain one or more provisions, depending on the type of treatment / examination / consultation that the user will perform. A provision identifies a transport that is will perform. This means that, a credential can contain several transports for the user, all with the same medical reason. These transports are carried out on different days.

Periodically, the SGDT runs an aggregation algorithm that creates groups from all the provisions already approved in the system. A group is a set of users that can be transported together, created based on certain criteria such as time interval between provisions, origin of the transport, destination of the transport, etc. The goal is to group as many users as possible, making transportation more efficient while maintaining the specific needs of each individual. These groups are presented as suggestions to the transport entities, who make the decision to carry them out or not. Carrier entities may reject group proposals submitted by the SGTD. If this rejection action is not carried out, at a predetermined time on the eve of the transport, the proposals are tacitly accepted by the carrier. After the acceptance of the group, the transport entities confirm the transport. The fire brigades that will carry out the transport are assigned to the accepted groups, as well as the driver and vehicle. From that moment on, the groupings are visible to the transport destination entities.

Upon arrival at the destination, the entity providing the transport service addresses an administrator of the health unit, who will have to enter the time of arrival at the location and the subsequent time of departure, when these take place. This information can be replaced, if the user does not attend the scheduled appointment, with a note of no-show. With the information provided in the previous topic, the SGTD accounting algorithm, responsible for valuing transport groups, has all the information necessary to determine the costs of the group, thus ending the process.

Although it is not possible to confirm the existence of errors in the registered entry and exit hours, health units believe that these errors actually occur. In the current system, there is no way to evaluate the transport and the entry and exit times, only with the use of a new system can numbers be obtained to support these measurements.

2.2 Attendance Systems

The use of new technologies in schools and universities to control student attendance is beginning to emerge. Using different approaches, they have significant results that help in this paradigm shift, making it possible to adapt the same knowledge to the case under study. The RFID and NFC systems are two examples of technologies used for this purpose.

2.2.1 RFID

In several universities, methods have been implemented that use Radio Frequency Identification (RFID) [6,7] to control the attendance of students in classes, in order to replace traditional methods, by calling or by passing the attendance sheet. These projects had as main elements RFID tags, which contained the identifiers of each student, and a reader that allowed to read the frequencies of each tag. These components were complemented with an information system that kept the logs of the readings carried out and later to be processed properly.

The use of this method demonstrated, in both cases, improvements in the efficiency of the attendance verification process, due to the time this activity took. In addition, as all data is directly stored in a database, there is no longer a need to manually enter presences in the system, resulting in a reduced resource allocation.

Although RFID is a simple technology, with a trivial and low-cost identification process, it is not possible to use it in this project due to the need to distribute tags to all SGTD users. This process could become expensive due to the high adhesion to the service, since it would also be necessary to configure each of the labels individually, in order to identify each user.

2.2.2 NFC

Another approach to this problem is the use of Near Field Communication (NFC). One example of this use is the University of Cartagena [8], which, with the aim of creating a technological environment, has allowed it to become an intelligent university. After obtaining positive results in the study, carried out to understand the impact of NFC on university life, implementations for checking attendance and the first tests in classes began.

The NFC component in this system consists only of an NFC reader and a mobile application installed on smartphones, both for students and teachers. At the beginning of each class, the teacher logs in on his mobile phone to be able to inform the system, through the NFC reader, that the class will begin, whose location is also recorded. At that time, students can also log in and make their presence known through the reader.

The system was designed so that, in each class, a cell phone can only be presented once, which ensures that a student cannot register twice with his cell phone. At the same time, it is assumed that students will not exchange cell phones to make attendance. In addition to the interest on the part of students and teachers to adopt this new technology, the results showed that there is really a decrease in the time spent, compared to the traditional method.

2.3 Location Technologies

Two technologies present in current location systems are GPS and Wi-Fi. The first is well known by the general public. It started to be available to motor vehicle drivers, in devices dedicated exclusively to navigation on public roads. With the evolution of technology, GPS began to be integrated into smartphones and diversified its scope for pedestrians and bicycles.

Although Wi-Fi is known mostly for the use of wireless local area networks, this technology can be used in two specific cases, related to location. The GPS system combined with this technology is able to increase its accuracy, which in most situations is already quite high. On the other hand, the use of a wireless local network allows the creation of an indoor location system, which allows an individual to know his location within a building.

2.3.1 GPS

There are several position detection technologies available on the market. The most widely used is the Global Positioning System (GPS [9]), a satellite-based navigation system that provides real-time positioning. The location is made from the distance between the GPS receiver (which is on the ground) and three satellites that are in Earth’s orbit.

This positioning has a 95% confidence interval, when there is no physical barrier between the GPS receiver and the satellites. For the SGTD, it would be necessary to know the location of all health care establishments so that, when the user arrived and left the place, the system was notified about each event. It would also be necessary to decide which point in the site would be chosen and take into account that each site has its own characteristic topology and size. The positioning of the user inside a health unit through GPS is also unreliable, since this system is mainly aimed at outdoor use. The reason is that the signal received, when inside, is attenuated, increasing the margin of error in positioning. Although this error is not problematic when, for example, you are driving a car, for indoor positioning, the area of operation is smaller, and the error is more problematic. These problems make GPS an unreliable technology to solve the problem in question.

2.3.2 Wi-fi

Other studies [10,11,12] also demonstrate that Wi-Fi can be considered as an indoor location technology. This method depends on the Received Signal Strength (RSS), a signal that the device (computer or smartphone) receives from an Access Point (AP). For this, it is also necessary to have knowledge about the plant of the area under analysis and where the APs are located. Through RSS triangulation, a similar method, when calculating positioning, to GPS, it is possible to determine a probable location of a device in a given area

Wi-Fi [19] works on the same signal range as BLE (2.4GHz). In contrast, energy consumption is higher: it is necessary that the equipment (APs) be connected to the current, making its positioning on the site a more elaborate task.

2.4 Bluetooth Low Energy

Bluetooth Low Energy was developed by the Bluetooth Special Interest Group for short-range wireless communications and has been incorporated into the Bluetooth version 4.0 specifications. This new communication model, similar to the Bluetooth standard, has the particularity of having lower energy consumption, as well as costs and rates of information transfer. As Bluetooth is still a growing technology (it is expected that in 2021 it will be incorporated in more than 41 billion devices) [2], it can be assumed that Bluetooth Low Energy will also be part of everyday life and that the Internet market of Things increase.

Bluetooth Low Energy [4,5] was designed to transfer small packets of information, so that the devices that support it can inform about its status. It operates in the 2.4GHz band, thus defining 40 radio frequency channels, separated by 2MHz each, 3 of which are for advertising and the rest for data transfer [14,15].

When communicating between devices via BLE, there are different roles for participants [13]: Broadcaster: periodically broadcast packets of data defined through specific advertising channels; Observer: seek to find packages that have been sent by advertisers; Peripheral: device that has the role of slave in connection with a central device; Central: device that has the role of master in connection with one or more peripheral devices.

2.5 BLE Beacons

BLE Beacons are electronic devices that periodically broadcast messages, using Bluetooth signals [16] (which follow the BLE protocol), which are detected by devices that are around them. This communication is unidirectional, as beacons do not have the role of receivers, they simply broadcast information, thus following the topology presented in section 2.4 of Broadcaster and Observers.

The messages they transmit are defined by the protocol used in the communication. Some of these protocols are iBeacon developed by Apple and Eddystone developed by Google. Both define an information packet that contains the beacons identifier, while the remaining packets are specific to each protocol.

The signals from the beacons can be detected by smartphones, tablets or computers, as long as they support BLE, thus being considered as observers in this communication. Observers aim to detect signals from beacons and execute a process after that detection. This means that beacons signal when an action must be performed by the observer. For the processes not to be executed whenever a device finds a beacon, the observers can be configured to filter the signals coming from the beacons, through its identifier. In this way, only when a beacon with a specific identifier is detected will a certain process be executed on the observer.

2.5.1 iBeacon

The iBeacon protocol [18] presents the concept of a region around the beacon, which allows smartphones to determine when they enter or leave the range of the region, while estimating the proximity to the beacon, through the strength of the received signal. The identifier of a region is defined by three fields that have a hierarchical relationship, and at the same time are the identifier of the beacon that defines it:

UUID: composed of 16 bytes, must be specific for each mobile application.

Major: composed of 2 bytes, used to increase and define a particular use of the application and thus be more accurate in identifying the beacons.

Minor: composed of 2 bytes, it allows an even greater precision for the uses in the application.

2.5.2 Eddystone

The Eddystone format [19] can be detected by Android and iOS devices. Packages can include the following paylods:

Eddystone-UID: a unique and static ID, which includes 10 bytes referring to the service identification and 6 bytes referring to the instance. This is the equivalent of the UUID parameter referred to in the previous section.

Eddystone-URL: a URL that can be used directly by the user and opened in a browser, in order to display a page.

Eddystone-TLM: contains information about the beacon, such as battery status and geographic coordinates. This information can be used for monitoring and maintenance purposes.

Eddystone-EID: a dynamic identifier that can be resolved to a static identifier.

For the protocol to work properly, beacons must contain Eddystone-UID or Eddystone-EID. The other two fields are optional.

2.5.3 Smart Places

Smart Places [21] is a project developed by Samuel Coelho with the aim of providing services, through an application, based on the user's proximity to the location. These services can be implemented in different locations, such as restaurants or museums, where each one is specific to the location. In this way, the user uses only one application that integrates the various services.

The system consists of:

• Mobile application for users: application used to access the services provided by each Smart Place.

• Mobile application for owners: application used by owners of a place where they can configure, list, delete or edit a Smart Place.

• Developer APIs: APIs used by developers to create services specific to each Smart Place

• Server: place where data about each existing Smart Place can be found.

• Beacons: devices used to check the user's proximity to the location.

Each Smart Place is created by an owner through the mobile application for owners. Then, they need to place beacons in place, each configured with a tag for a specific purpose.

When in the presence of a beacon, the mobile application for users notifies the user that he is in a Smart Place. The application first communicates with the server to identify the Smart Place to which the beacon belongs. After it is identified, the application communicates a second time with the server to present the services available to the user where it is located.

In this project, it is important to observe the interaction between a beacon and a mobile application. When in the presence of a beacon, the mobile application executes a process where it initiates a communication with the server in order to return information about the location. This shows how the beacons can be used together with a mobile application in order to detect the presence of users within the health units.

It can also be seen that the final result of this process varies depending on the beacon identifier. This means that the mobile application can behave differently or perform different processes depending on the identifier of the beacon it has detected.

3 – SOLUTION

3.1 Technologies

The main operating systems we find installed on smartphones available on the market are Android and iOS. On both platforms we can find the technologies that were discussed in the proposed solution. However, due to some security methods existing on iOS, which do not allow the execution of tasks for an indefinite time, it was decided to use Android exclusively. Since the solution is to keep the smartphone detecting signals from beacons for long periods of time, iOS is no longer an option for testing.

3.1.1 Bluetooth Low Energy

Signal by which smartphones can detect the beacons that are around them. This signal was configured so that smartphones could detect only the signals from beacons that were part of this project. The detection of a beacon happens only when a smartphone enters the range of the signal, this event happening only once.

3.1.2 Wi-Fi and GPS

To ensure that the user is close to a beacon, even if there is a signal detection, information such as the Wi-Fi networks that are being detected by the smartphone and it’s GPS coordinates are used. Knowing which networks are at the location where the beacon was placed and it’s GPS coordinates, we can make a comparison with the data that is detected by the smartphone and the data from the beacon’s location.

3.2 Implementation

This implementation consists of a mobile application, a Server, Beacons and External Information System (SGTD).

3.2.1 User / Mobile Application

Android smartphones contain the technologies mentioned above, necessary for the implementation of the solution. Initially, Ionic Framework was chosen as a development tool for Android. This Framework would allow to develop a code base executable by several operating systems, continuing to offer access to native technologies and with an easy and fast development. However, many of the plug-ins needed to access native components are developed by the community and do not reach the desired performance levels.

In this scenario, the smartphone aims at registering and authenticating its user, collecting data related to the user's movement in a closed space and sending them to the server. The processing of the data that is collected is carried out by the server, not overloading the smartphone with this task, focusing only on the detection of beacons.

User Registration and Authentication - User registration in the system involves filling out a form that requests data about him. The data consists of the user medical service number, mobile phone, and a password. With the registration made, the user can log into the application and identify himself to the system. User identification is required to create a record of the data collected by the application for each user.

Beacon and localization detection - The great challenge of this project was the continuous collection of user positioning data. This process must be performed, regardless of the status of the application and the smartphone (excluding the situation when it is turned off). The application can be found in two states; foreground, when the application is being used and the user can see its interface on the screen; background, when the user cannot see the application interface, because the user is using other smartphone features or because the process has ended. Running in foreground does not create any constraint for the operating system. Data collection can be performed indefinitely, since the operating system assumes that the user is aware of the use of resources. The same does not happen when the application is in the background, where the operating system can stop the application’s execution because it is not being used by the user. This management of the operating system makes it necessary to change the smartphone's settings and disable the energy saving option for this application.

The data collection process starts when the smartphone detects a beacon. It contains sensors that allow it to detect the beacons and read the information that is being transmitted in the Bluetooth signal, observe the Wi-Fi networks that are nearby and obtain the GPS coordinates. These data, once acquired, is sent to the server in JSON format.

To detect the beacons, a library called Android Beacon Library [22], developed by Radius Network, was used. Although this library was not implemented for the detection of beacons configured with the iBeacon protocol, the tests carried out showed that the detections continue to occur in a viable way.

Transportation History - Although the main function of the application is the detection of beacons and the transmission of data about it, a feature was implemented that informs the user about future and already carried out transports. With this feature, the user can view the date and time of his next transport, as well as the location and type of treatment. In addition, the user has access to his travel history, where he can see what time he checked in and out at the location.

3.2.2 Server

The server application was developed in Node.js due to its fast processing capabilities and the way it handles simultaneous requests. These features allow multiple users to submit concurrent requests and allow them to be processed efficiently and with reduced response times.

The developed application is installed on Microsoft Azure. This cloud service allows the server to be available to any user of the mobile application.

The server's role is to receive and process requests sent by the mobile application. In this sense, several APIs were created, which allow the user to register in the system, log in and send data related to their location.

Registration and Log In - Registration and login are two simple processes, implemented in almost every service available online and therefore already quite common. The registration process aims to store the data that was requested from the user in the system, to later be compared with the data that is received when the user wishes to authenticate. If authentication is successful, the server generates a JWT token [23] that is sent to the user. The token is generated using user data, which is encrypted by the server. Only he can decipher and verify the data that constitute it.

Detections - Upon receiving a detection registration request, the server checks for the existence of the authentication token in the message. This process consists of decrypting the token, verifying its validity and validating between the sender of the message the data found in the token. If one of these steps is not performed successfully, an error response is sent. In case of success, the server creates a record of the user's detection that contains the detected beacon, the GPS coordinates, the Wi-fi networks, as well as the date and time when the detection occurred

3.2.3 Beacons

In this project, each beacon has been configured with a different ID, which aims to identify this project, mark different spaces in a building and recognize which building the beacons are in. Depending on the space or building where the beacon is located, a specific ID is defined for each case.

The iBeacon protocol is used, since the mobile application only has to contain a beacon identifier. All beacons to be used are configured with the same uuid, in order to represent this project. The application only has to contain this identifier and is able to detect all beacons.

3.2.4 SGTD

SGTD is the system where all information needed about users and their transports is located. In this project, the SGTD has the role of confirming the identity of users and returning data about their transports.

SGTD offers a set of APIs that can be used in the development of this solution. These APIs follow a REST architecture and can be accessed through HTTP requests.

Mobile Number Validation - When registering, the user is asked to provide the mobile phone. The SGTD contains a service that confirms the existence of the mobile phone in the system itself. This way it can be guaranteed that only users known to the SGTD, can have access to the application developed in this project.

Get Transport Provision - When a user detects a beacon, it initiates a process to register this detection on the server. To ensure that only users, beneficiaries of the transportation service, will create detection records in the system, a service is used that verifies the existence of a provision for a given day. The response to this request contains the transport provision as well as the destination, if any. This service uses the user's mobile phone to confirm his identity.

Next Transport and Transport History - In SGTD there are two services, with a more informative character for the user, where data about the transports carried out and to be carried out can be obtained. Although these services do not influence the solution and the goal related to the detections, their use makes the mobile application more useful for the users.

Entry Time and Departure Time Record - These two requests are to register the time of entry and exit of a user of a health unit. After the transport has been carried out and the user has created several beacon detection records, it is necessary to transfer this data to the SGTD and thus continue the transport management process. In these requests, the provision of transport carried out by the user and hours of each event are communicated.

4 EVALUATION

In order to assess the functioning of the system, a real test was designed in the building of the company Link Consulting. The purpose of this test was to show that detections continued to occur even in an uncontrolled environment and that the data obtained could demonstrate user activity throughout the day. This test was carried out by Link Consulting workers over several months, where it was possible to carry out an assessment of the system's performance and understand which errors existed.

4.1 Test Description

This test was carried out in the Link Consulting building, which allowed beacons to be placed in different spaces, in order to observe the movement of workers throughout the space. The method used to install the beacons on site was a beacon per floor.

Due to the existence of a single access to all floors, it was ensured that, from the arrival of a worker to the building until the moment he arrives at his desk, he would approach at least two beacons; one beacons that was placed at the entrance of the building and another that was on the floor where the worker was. With this simple movement, it was possible to measure the time of arrival of the worker as well as the flow of movement within the building.

The results obtained would then be confirmed by the workers themselves. This example is capable of simulating the arrival and departure of a patient from a health facility.

4.2 Beacons Configuration

As described in the solution, the goal of the beacons is to identify the project, the physical location where it is located and a specific section of that location. For this, the beacons were configured with uuid, a major and a minor in order to fulfill these three objectives.

The Link Consulting building consists of seven floors, of which five were chosen from these seven. In the access to each of the five floors, a beacon was placed, all configured with the same uuid.

When comparing this building with some health units, being these hospitals or health centers, we can see that in terms of size, the Link Consulting building is smaller. For this reason, the value of the major for each beacon followed a simple configuration that better adapts to the building's characteristics. With a beacon on each floor, each one was configured with a major equal to the number of the floor where it was located; the beacon on floor one was configured with major 1, the one on floor two with major 2 and so on.

Finally, as we want to identify all these beacons as belonging to the Link Consulting building, the same minor value was attributed to all of them.

4.3 User Transportation

For each user participating in the test, provisions of the transport service were created in the SGTD. These provisions were used to simulate the transport of a patient, and a daily provision was generated for each user throughout the test period.

Each detection that is made by a user is sent to the server, which then checks with the SGTD itself if there is any provision for that day. If it exists, the detection is registered or, otherwise, the process is aborted.

4.4 User Location Confirmation

In order to confirm the location of users on the site, even with the existence of beacon detections configured to identify the building, information unique to Link Consulting's location was used. The characteristics used in this confirmation process were the GPS coordinates of the building and the Wi-fi network that is installed in it.

This process is carried out through the registration of these data on the server and the location of the provision of the transport service, which can be found in the SGTD. The user, when making a detection, sends the GPS coordinates that are being obtained on the smartphone to the server, as well as a list of Wi-fi networks. The server can thus compare these data with those relating to the location..

However, despite having been implemented and tested on a much smaller scale, this confirmation process was ignored, as the priority has always been to observe the existence of beacon detections. Even so, the GPS coordinates and Wi-fi networks data obtained by the smartphone were recorded, so that these methods could be evaluated in relation to their operation and accuracy.

4.5 Test 1 – Ionic based Application

As planned in the proposal for this project, a first mobile application was developed using the Ionic Framework. This test was attended by nine Link Consulting workers, who volunteered to carry out this activity.

This solution was active for a month, with users having obtained zero detections in this period. In this case, in addition to the malfunction of the beacon detection process, it was not possible to understand the behavior of the smartphone's GPS and Wi-fi sensors.

4.6 Test 2 – Android Native Application

Due to the unsatisfactory results obtained in Test 1, a new strategy was designed in order to be able to obtain beacon detections. With this approach, it was expected that the lack of middleware between the application code and the smartphone sensors would increase performance in the beacon detection process.

This test had the particularity of being carried out during the pandemic caused by Covid-19, reducing the number of Link Consulting workers to perform the test to just one. However, the daily life of this worker remained similar to that of the times before the virus, so the conditions found in the first test were maintained.

When observing the detections made by this user, we identified that there is an average of twenty-four beacon detections per day, with eight days over the month where they occurred. We also identified that in these eight days the first detection always occurs between 8:30 am and 10:00 am, and the last detection between 17:30 pm and 19:00 pm. These hours are very similar to the normal hours of a worker.

Another characteristic that was observed in these eight days is that there was only one day when the first detection did not occur on the lowest floor where the entrance to the building is located. The opposite happens at the last detection of each day, where there is only one detection record on the floor where the building's exit is.

Regarding the location confirmation mechanisms, these are registered in about 63% of the detections. Despite this small number, in all cases it was possible to confirm the user's correct location.

4.7 iOS Native Application

After the success of the native application for Android, when compared to the development in Ionic, the development of a native application for iOS started. The initial step was to start developing a process responsible for detecting beacons

The tests that started to be carried out were performed with an application whose sole function was to detect beacons. At this stage, all other features that can be found in the Android application, such as user registration and the authentication process, were ignored.

It was observed that the application was able to detect beacons quite accurately, as these occurred whenever the smartphone approached these devices. It should be noted that this process was first tested with the application in foreground.

As already mentioned in section 3.1, iOS development had to be abandoned due to the application execution when it was in the background. When another application was opened on the smartphone, the execution was interrupted, so there were no more beacon detections. The same thing happened when the smartphone was locked, making iOS development irrelevant to this project. In Android, this problem was solved once the battery saving option was disabled when running a specific application, an option that is not available in the iOS operating system.

5 CONCLUSIONS

This project goal was to implement a system capable of registering patients' entries and exists of a health unit. The solution would be fundamental to automate this process performed at SGTD, thus making it less subject to human error. The main point to be resolved is the service accounting, because if the entry and exit times are incorrect, the accounting will also be incorrect. In the absence of a mechanism nowadays to verify the registered hours and the user's stay at the health unit, it was proposed to create a system capable of recording them.

For that, it was necessary to study some existing technologies, capable of solving this problem, to understand the advantages and disadvantages of each one and to choose the one, or those, that were better adapted to the transport of the user and his passage through the health unit. At this point it was clear that BLE beacons were showing good results in the reference literature, with regard to the indoor location systems and detection systems. Even though they are promising, there are still two technologies, more popular and known to the population, which have a great impact on location systems; GPS and Wi-Fi. Together, the use of these three technologies is able to assist in the creation of a system with high precision and efficiency, which detects a user in a health unit as well as his movement within it.

The solution therefore consists of a mobile application capable of detecting beacons found in health facilities, using GPS and Wi-Fi at the same time to confirm the user's presence at the location. The development of this application proved to be a challenging due to several factors. Initially, the solution was designed to work on both Android and iOS. In order to assist the development process, there was a need to use a framework like Ionic. Despite the development of several test applications, it has never been possible to obtain good results regarding the detection of beacons. Even with the lack of success in this solution, it continued to be developed insistently, having been abandoned in a final phase, at a time considered late, in view of the project's developments.

This problem caused the development on native Android to be rushed. Even though there was a substantial improvement in the behavior of the application, there was a great waste of time in the development in Ionic, not allowing the implementation and testing of other mechanisms for the execution of the application in the background. The method used in this project is intrusive in terms of user experience and should only be used as a last resort.

However, the results obtained were promising. The application was able to detect beacons consistently, and the logs can describe the user's movement within a building. In the end, entry and exit times, user and location can be stated, using GPS and Wi-Fi confirmation mechanisms to confirm his presence.

One of the major problems that can be found in this service is in the users' adhesion to the application. Without a benefit for using the application, it is difficult for users to install and use it. This can be nitigated if the final product is an application that is installed once and works for a long time after the user has opened it the first time. And at this point, it is not possible to say that the developed application is capable of working that way.

Despite a short development, the application was able to obtain detections consistently and accurately. However, the final result can be improved, increasing the degree of reliability.

• Improved background operation: as stated, the solution for running in the background is intrusive and the application should keep running for extended periods of time. This result can be obtained using push notifications that, on the day of transportation, wake up the application. This way, resources are not wasted in the period when the user does not have transportation.

• Process of leaving the health unit: at this time, the entry and exit times are sent to the SGTD through a daily event. This event can be replaced by an event that is launched, according to the user's displacement and their distance from the health unit where they are located.

• Flow management system: with the various detection records in the system, it is possible to create a system that analyzes the movement of users within health units. The movement is reflected in the registered detections because they contain the identifier of the detected beacon. When connecting the successive detections, it is possible to recreate the user's steps inside the health unit and thus perform an analysis of the flow existing in the same.

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