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Original Article

Implementation of a Mobile App : A Study in the Metropolitan Transportation System

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Abstract *- For many years, there have been different means of transportation, such as cars, motorcycles, streetcars, trains, etc. Thus, this denotes that public transportation has become one of the most used by the public. However, despite the implementation of public transport systems, it has not been possible to cope with the high demand, nor to solve the issue of the uncertainty of users with respect to the time of arrival of the same. However, some technologies allow obtaining information on the location of the buses and the subsequent calculation of their arrival time at the bus stops. Taking into account that users need to know the arrival time of the buses to the bus stops since this will allow them to determine their daily activities to be carried out accurately. In this sense, a mobile application has been developed to determine the location of the bus stops, show the buses that are close to this stop, determine the time of arrival of the bus, and the respective notification to the users at the time of arrival of the bus. The result is a mobile application that allows users to see the location of near-by bus stops, visualization of the buses in route to the bus stops, the determination of the arrival time of the buses, and the respective notification of the arrival of the buses at the bus stops of interest to the user; which helps users to organize their daily activities correctly.*

Keywords *- Information, Location, Metropolitan transportation system, Mobile application.*

1. Introduction

Since the establishment of the Shanghai tramway in 1908, there have been a variety of options for public transportation, such as bicycles, streetcars, buses, subways and intercity trains [1]. However, as in the country, buses have become the most viable option for daily transportation due to their affordability. These buses must provide passengers with the certainty that their trip will be safe [2]. That is why bus monitoring through the use of global positioning system (GPS) technology provides us with the necessary information to analyze the type of driving performed to provide a safer service for passengers [3].

However, many countries around the world are implementing different strategies to counteract the public transportation problem [3]–[5]. One of the countries dealing with this uncertainty is Indonesia; in recent years, they focused on developing different infrastructures to cope with the chaos of their transportation system [5]. Currently, it has a system for tracking and estimating a bus arrival time; the strategies applied by the government are giving good results because its 10 main cities already have a city bus that has a Global Positioning System module and Global System for Mobile Communications (GSM), adapting to the needs and convenience of citizens [32].

In the country, people's quality of life is being affected by the different challenges in public transportation since many companies are increasing the number of buses due to the increase in passenger demand [7]. Similarly, rapid transit systems have been implemented for users who are far from the city center to reach their destination [8]. However, in recent years in the cities of Lima and Trujillo, there has been an increase in informal buses that do not have the amenities, do not comply with the rules of vehicular traffic and do not respect the schedules in which they must cover their service [8], [9]. This causes great inconvenience to the public since they do not know the amount of time they will spend waiting for the vehicles at the bus stop and the time it will take them to reach their destination [2], [10].

The present research project has been developed taking into account the difficulties faced by citizens at the time using public transportation or rapid transit systems implemented in the city, such as the metropolitan one [7], [8], [10]. Therefore, the primary need of the users is the determination the time taken by the buses to reach the different stops of their routes [2], [9], [11]. In this sense, the use of GPS technology was proposed as a means of collecting information from the buses that are within the metropolitan route [12]– [15]. This data, in support of the Google Maps API, allows the user to be able to visualize

both the location of the bus and the waiting time with respect to a given bus stop [2], [3], [16]. In addition, use is made of Firebase services, which allows access to this data from different locations and multiple devices at the same time [17].

For these reasons, the objective of the development of the project is to implement a mobile application which shows the route and time of arrival of a metropolitan bus feeder to one of the authorized stops in consultation. This is with the purpose that the users of Lima's metropolitan buses can plan the time of their daily activities.

Next, detail the development of the following sections of the research. In section 2, literature review, an analysis of different works is made, including the technologies required in this research to solve different needs. Then, in section 3, methodology, mention how the project was developed through the use of the cascade methodology. Then, in section 4, the results show what was achieved through the implementation of this project. In section 5 discussions, analyse the similarities with other projects. Finally, in section 6, conclusions, mention the conclusions and future research possibilities.

2. Literature Review

Nowadays, emerging technology has provided us with many means to obtain information. In this sense, we can know the route of a vehicle, the time has to wait for its arrival, the state in which this vehicle is, etc. All this is to help people in their daily lives. The study of some of these technologies is developed below.

First of all, should know what GPS technology is all about. As mentioned by Pawar and Bhosale [12], GPS technology was developed more than 40 years ago under the sponsorship of the U.S. military. It has been used to solve many needs, such as agricultural needs (maximizing seed resources, better use of pesticides and saving water used for irrigation), in the location of troops during the war between the United States and Iraqi forces. However, the location data must be accurate because a millisecond glitch can generate a deviation of hundreds of meters.

The work developed by Xue et al. [13] addresses the problem of accuracy in the data obtained by GPS. Since the data can be collected from two types of transportation, vehicular or walking, this difference generates a lack of accuracy when performing calculations of both location and time of arrival if required by the user. There is a detailed study of which variables best determine the accuracy of GPS data and the different devices that can be used as support. However, in the research, the data collection is performed from the vehicles so that the waiting time can be accurately determined.

The author Sanchana et al. [3] mentions the importance of location determination through the use of GPS and GSM. Since maritime boundaries cannot be seen with the naked eye by vessels at sea. Thus, et al. [3] developed a low-cost location system using a GPS module for the real-time location of ships and GSM for network connection, which also allows notification by means of an alert when they are over the present sea boundaries. The notification system is a very helpful contribution since it serves to notify the users of the proximity of the metropolitan bus lines that are close to their stop.

Authors Pawar and Bhosale [18] conducted research on the implementation of IoT in a transportation system. In this research project, the importance of the use of networks and cloud support technology through IoT is denoted. The different sensors inside the vehicle provide the necessary information that the user requires, which is synchronized in real-time. The IoT allows us to have remote access to the information required according to the user's needs [19].

On the other hand, the authors Trapsilawati et al. [4] address the study of users' trust in location and route determination applications such as Google Maps and Waze. Through the use of a survey of users who have been using each of these applications for more than a year, a point and the routes that are determined to reach these points were determined. The result of this survey showed that users came to have more confidence in the Waze application since it provides the possibility for users to report some events within the route compared to Google Maps. However, the project makes use of the Google Maps API because the project is based on the determination of the route and not on the reports of the users, as this could generate confusion problems for the users.

Thus, the authors Gupta et al. [16] developed a system that not only allows the notification of events at a specific time but also at a specific location. This is through the use of GPS technology and Google Maps services, as they facilitate the determination of the user's location and the visualization of this through an application developed in Android Studio. The determination of the hardware and software requirements guarantees the correct functioning of the application in the fulfilment of its function. The proposal that has been put forward in this research work is of utmost importance since it provides us with the necessary technologies to notify the user by means of the location in which he/she is.

Taking into account the aforementioned work, the authors Podiyan et al. [20] emphasize the issue of privacy of location data that can be obtained through APIS. In this sense, mention is made of the Geoprivacy application, which is characterized by safeguarding the privacy of the user's location data; in addition, a comparison is made with the

Android location API for being one of the most used systems. In this way, it is determined that security policies should be improved so that users have more control over them. The privacy issue that has been addressed in this work is not taken with the importance it carries by common users; however, in this research work, this issue is taken into account since the privacy of the location of vehicles must be safeguarded.

As mentioned by the authors Arellano, Izquierdo and Andrade [21], GPS data technology can be implemented in vehicle security. The problem of vehicle theft has become a major problem that greatly affects the population, which is why a system was developed that implements GPS, GSM and RFID technology through the use of IoT. The use of Firebase allows communication through the cloud between the vehicle system and the user's mobile device. The transmitted data enables the user to check various statuses of their vehicle, such as unauthorized ignition, who is inside the vehicle, and the vehicle's location in real time. The low cost of the sensors and the use of the technologies found in the cloud make the implementation of this project viable for low-income users. Thus, we can denote that the use of GPS technology is very versatile to the extent of serving as a complement to other technologies in order to meet a latent need.

In that sense, the author Chit et al. [2] address the students' need to know the time it takes for the transportation bus to arrive at the bus stop. The uncertainty of the arrival time of a bus does not allow us to accurately schedule the programming of the activities, which is why GPS technology was used to obtain information on the bus's location with respect to the desired stop. The determination of route taken by the bus is determined in a web way so that it is visible to the owner, through mobile devices so that users can see this information and finally, the accuracy in the calculation of the time of arrival of the bus to the different stops. This data can be centralized and distributed through the implementation of cloud architecture to different platforms, either web or mobile. The tests that were performed provided the information on the bus for which the arrival time is to be determined. Indeed, the use of this system to determine the arrival time of vehicles and the technologies that converge in it are extremely useful for all those users who want to be able to organize their work times.

Finally, the works analysed above address the importance of using GPS technology in determining the location, arrival time, and trajectory vehicles can take. However, the works that these authors have developed did not develop the issue of notifications as a means of warning for these events detected by GPS technology; instead, they focused the analysis of their research on the problems of accuracy when determining the location and the privacy policies that can be established for the protection of users' location information when other applications use it.

3. Methodology

For the development of this research project, a methodology was used to guarantee the quality of the final product. In this sense, it was decided to make use of the Waterfall Methodology since its working characteristics guarantee a high-quality product.

3.1. Waterfall Methodology

Taking into account some of the characteristics of the project, it was determined to carry it out using the waterfall methodology since it is adapted to the development of the present project. Thus, denote that this methodology has a number of determined phases, as shown in Figure 1. This methodology is developed steadily downward, hence the waterfall's name, since it has to go through each of its phases, composed of requirements, design, coding, testing, and maintenance [22], [23].

The different phases of this methodology are detailed below:

3.1.1. Requirements

This phase is of utmost importance since it determines which are the requirements that the client has regarding the characteristics that the final product will have [24], [25]. At this stage, the Software Requirements Document (SRD) is obtained [25].

3.1.2. Design

In this phase, the SRD resulting from the previous stage is received, and the Software Design Document (SDD) is produced [25]. In this sense, a compilation of the technology required for developing the software and planning its infrastructure is made [24].

3.1.3. Implementation

In this stage, all the problems are solved, the solutions are optimized, and each of the components described in the SRD of the Requirements stage is implemented by means of the diagrams made in the design stage through the SDD [24], [25].

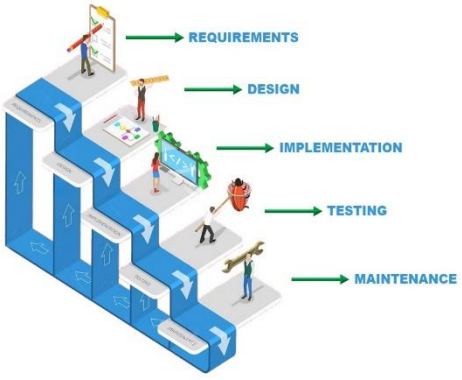

Fig. 1 Phases of the Waterfall Methodology

3.1.4. Tests

In this stage, the different features and components implemented are tested to find a solution to an existing problem [24].

3.1.5. Maintenance

Finally, the final product is obtained after going through the testing stage [25]. In that sense, in this stage, the project is implemented in a production environment [24].

3.2. Methodology Development

3.2.1. Requirements

To start with the methodology development, define the services and restrictions the project would have. In this sense, define the functional and non-functional requirements of the project, which cover the client's needs. The following are the requirements of this project.

Table 1. System Functional Requirements.

	Functional Requirements
1	The system must have a user registration module for users to be registered in the system.
2	The system must have an authentication module to identify the users registered in the system.
3	The system must have a module to visualize the map to show the bus stops near your location.
4	The system should allow the selection of a specific bus stop so that buses near the stop can be displayed.
5	The system must allow the selection of a bus within the route so that the user can visualize the arrival time at the bus stop.
6	The system must allow the display of the arrival time at the central station so that the user can determine his activities.

Table 2. Non-Functional System Requirements.

	Non-functional Requirements
1	The system must have a flow chart which determines the actions to be taken in different situations.
2	The system will use Firebase services for remote data access.
3	The system will use java language for system coding.
4	The system will use the Google Maps location API to determine the location of buses and users.
5	The system will use the Geofence API to determine the proximity between buses and users.
6	The system must accurately determine the location of the buses so that users can see them in the application.
7	The system should determine the arrival time of buses at bus stops so that users can be aware of the waiting time.
8	The system should notify of the proximity of buses to bus stops so that users are notified of their early arrival.
9	The system should notify of the arrival of buses at bus stops so that users are notified of their arrival.
10	The system should determine the route of the buses so that users are aware of the bus route.

Functional Requirements

At this point, to have detailed interactions that the system has with the user. In this sense, Table 1 detail each of the functional requirements that the system must have.

Non-functional Requirements

At this stage, mention all those requirements that do not have direct contact with the user but are of utmost importance for the correct functionality of the project. Thus, Table 2 mentions all those non-functional requirements of this project.

3.2.2. Design

In this section, the designs that the application will have been made. These are found within the system requirements, which have been correctly determined in the previous stage. In this sense, have the following.

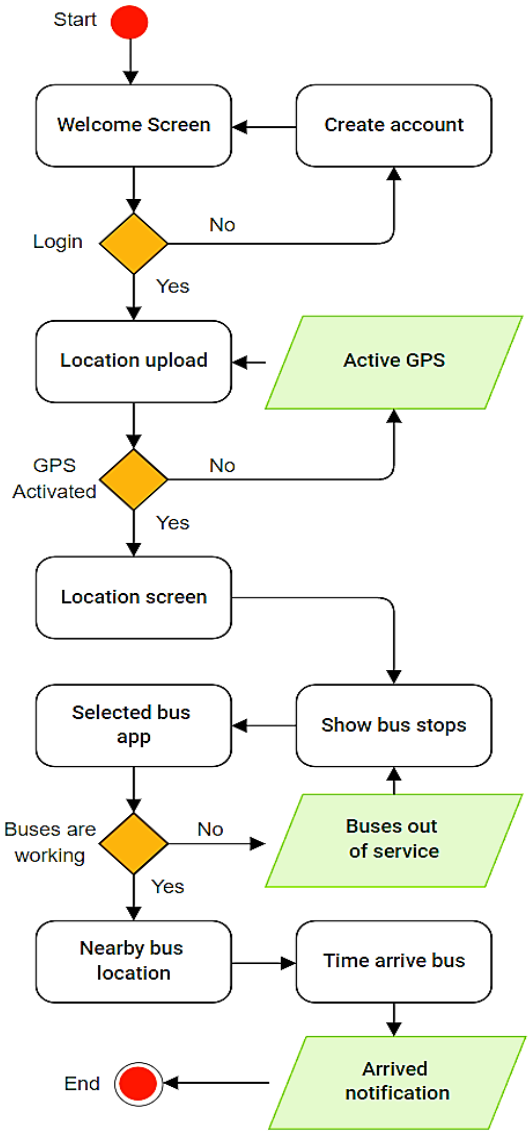

Fig. 2 System flow diagram

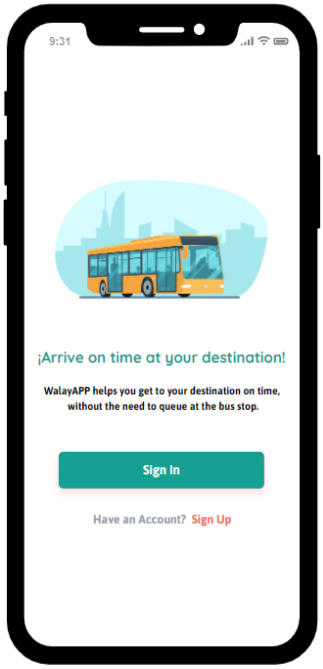

Fig. 3 Welcome module

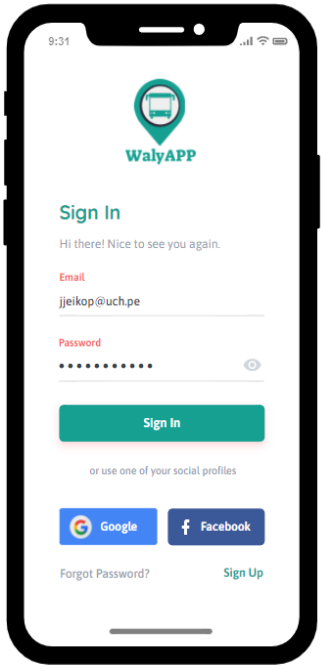

Fig. 4 Authentication module

Flow Diagram

This diagram has been developed to facilitate the follow-up of the system activities. Likewise, the actions taken in case any condition is not fulfilled are determined. This allows us to understand how the research project works.

In this sense, Figure 2 shows the flowchart of the research project with the different actions it takes in response to the actions taken by the user.

Protypes

The system has an interface developed to meet the requirements previously determined. In this sense, an interface was designed to meet these requirements. The interface design allows proper communication between the system and the users. Figure 3 shows the design of the system welcome module, and Figure 4 shows the user authentication module

Technologies to be implemented

In this part of the methodology, mention is made of all those technologies that will be implemented in the next stage. In this sense, have the following:

a) Android Studio

IDE, through which, in the implementation stage, the codification of each of the actions taken by the system will be carried out. In addition, each of the previously defined prototypes will be developed.

b) API Google Maps

This API will be implemented to detect the location of buses, bus stops, and system users. In addition, it will allow the system to determine the arrival time of the buses at the different bus stops.

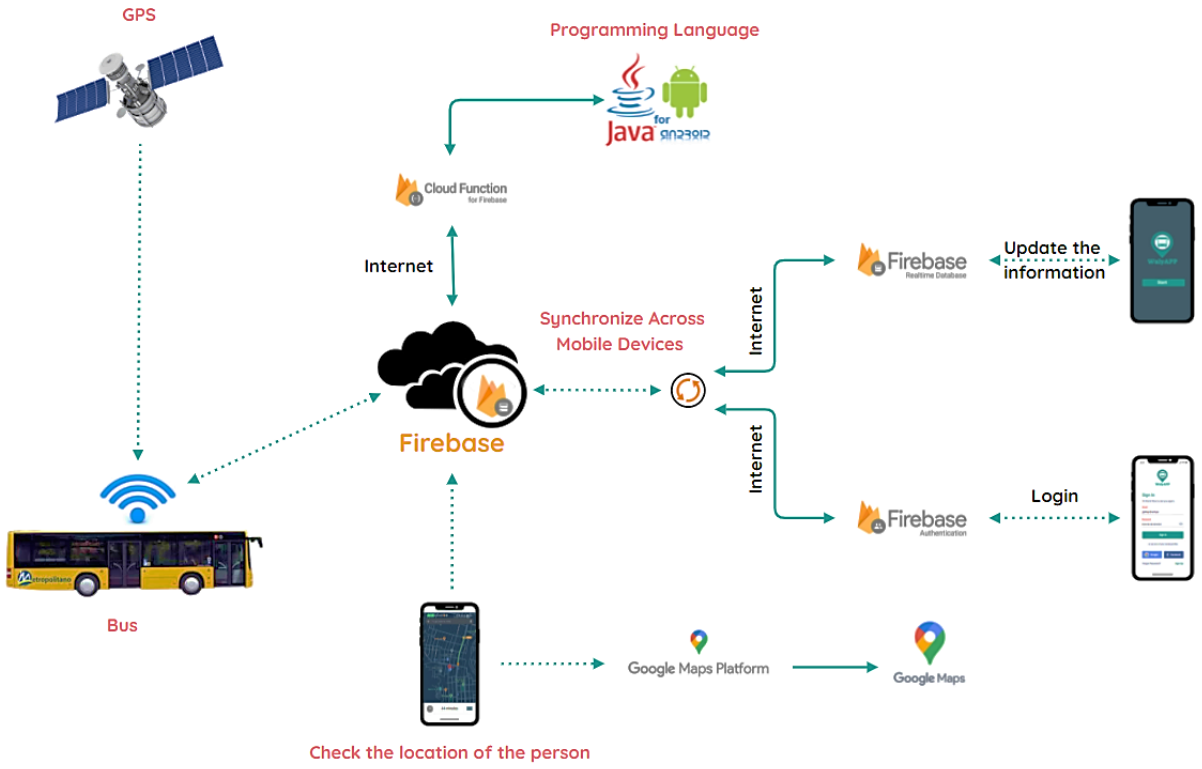

Fig. 5 Operating architecture with Firebase.

c) Firebase

This technology has been considered since it will allow the system to be able to connect remotely. In this sense, it is expected that this technology will allow storing of bus and bus stop data, which will be displayed in the system likewise, as shown in Figure 5, where the connection diagram that the system will have with Firebase services has been developed.

Implementation

In this stage, the implementation of all the application requirements was carried out by means of the diagrams and technologies previously detailed. In this way, the implementation of each of the application modules was carried out. This implementation was done through the use of the Android Studio development IDE, which allowed us to use the Java language. Likewise, the location APIS were implemented, which will enable the system to locate users, buses, and bus stop accurately [29], [30], [31].

Test

In this section, the system tests were carried out. In this way, the main functions of the system were tested. These tests allowed us to determine the correct operation of the research project.

Maintenance

At this stage, the final product is delivered to the users. However, monitoring was carried out in search of future problems in the user's interaction with the application interface, the determination of the location of the buses, the time of arrival of the buses to the bus stops, and the notifications to the users.

Fig. 6 Final product implementation

Fig. 7 Determination of user and bus stops

Fig. 8 Determination of the location of the buses

In case of any type of problem, corrections should be made, and the system should be updated in the future. Thus, Figure 6 shows the implementation of the final project on a mobile device.

4. Results

This section shows the results obtained through the development of this research project. In this sense, it shows the analysis that has been carried out in the different stages of development.

4.1. System Prototypes

4.1.1. Determination of the Location of Bus Users and Bus Stops

After the user successfully opens the application, the user's data is authenticated. If the user does not have an account, he/she can register by using his/her email or a social network.

Next, the system detects if the GPS system of the user's mobile device is activated; if it is deactivated, its activation is requested. Next, the system checks the proper loading of the user's location data to be displayed on the map.

Likewise, the information on the bus stops registered in the system is loaded correctly. The system successfully displays the map with the user's location, and the bus stops close to the user's location. In this way, Figure 7 shows how the system determines the location of the user and the bus stops that are close to his location.

Fig. 9 Determination of bus arrival

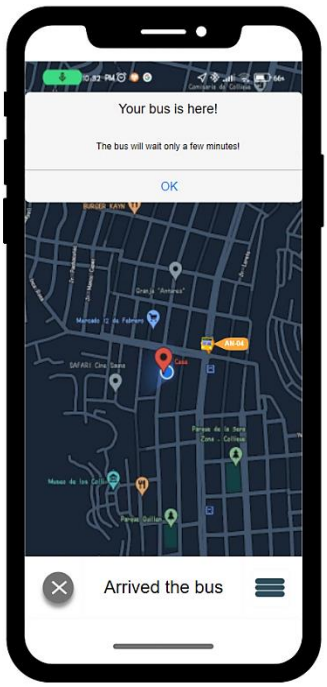

Fig. 10 Notification of bus arrival

4.1.2. Determination of Bus Locations

The user selects one of the bus stops displayed by the system. Then, the system loads the location of the buses en route to the previously selected bus stop. The correct functioning of the Firebase system in obtaining the bus data is verified. In this sense, the users in this module can determine which are the closest buses to their bus stop. With this information, a user can be certain of the early arrival of a bus. This information eliminates users' uncertainty when they do not know if a bus is about to arrive at their stop. As seen in Figure 8, the system allows us to visualize the buses on the route of the selected bus stop.

4.1.3. Determination of Bus Arrival

Additionally, the user can select one of the buses that are on route to the selected bus stop. The system estimates the time it will take to reach the bus stop. The time displayed is correctly reduced as the bus approaches the bus stop location. The user has the option to deselect the bus in question and estimate the arrival time of another bus according to his needs. The accuracy with which the bus arrival is estimated depends mostly on the Google Maps API's handling of its location information. As a result, Figure 9 shows the estimated arrival time of the bus at the desired bus stop.

4.1.4. Bus Arrival Notification

The system continues to detect the location of the bus with respect to the selected bus stop. In this sense, the system notifies the user when the bus has arrived at the bus stop. After this action, the system stops tracking the bus location. In this sense, in Figure 10, the system shows a notification that the bus has arrived at the bus stop.

4.2. Methodology Used

As previously mentioned, the development of the research project was through the use of the Waterfall methodology. In this sense, after having developed this methodology, I have found that it has advantages and disadvantages. In such a way, I found the following:

Thus, one of the advantages that have been able to find is that this methodology has simple planning, it was not necessary to perform complex training to be able to understand it, and it provided us with a high-quality final product. On the other hand, as part of the disadvantages, find that it is of utmost importance to detail the requirements specifically from the beginning since it is difficult to make changes once the development has begun. Likewise, note that the final product will not achieve the expected quality if a phase is not fully developed.

4.3. Implemented Technologies

4.3.1. Android Studio

This IDE allowed the correct implementation of the different actions that the system takes during its execution. In the same way, it allowed us to develop the system's different prototypes for proper interaction with the users.

4.3.2. API Google Maps

Implementing this API allowed the system to determine the registered bus stops' locations. It also allowed users to visualize their location with respect to these bus stops. Then, it was possible to visualize the location of the buses with respect to the bus stops in real-time.

In addition, it allowed the system to determine the arrival time of the bus to the previously selected bus stop. Finally, it allowed us to notify users about the proximity and subsequent arrival of the buses at the selected bus stop.

4.3.3. Firebase

The implementation of this technology allowed us to store the data of the buses and their respective authorized stops. Likewise, this data has been accessed by users through their mobile devices remotely and in real-time. In this sense, this technology proved to be very useful for storing data remotely, and in the same way, it made possible the remote connection with the mobile devices of the system users.

5. Discussions

Next, a comparison is made of the work with others. This is in order to find similarities and differences. In this sense, compare the opinions of the authors of other works that include technologies implemented in the project.

Begin by addressing the subject of GPS technology, which has been created more than 40 years ago [26]. In this sense, the applications that have come to have with it vary from applications in the agricultural field [26], location of

land transportation vehicles [13], location of maritime transportation vehicles [3], etc. Thus, the implementation of this technology was commonly done through the use of specialized devices [3], [13], [18], [21].

However, today this technology is found in various mobile devices in such a way that to be included in any project only needs to make use of the respective API [4], [16], [20]. These APIS have the feature of being able to access the information of the devices in which they are implemented; however, it must be taken into account the issue of privacy of this data and the establishment of policies that ensure such information [20]. However, this technology allows the development of applications that solve the different needs that may arise [3], [8], [16], [21]. Thus, this implementation was carried out considering that it gave good results in projects with similar needs to those detailed in this project [2].

As mentioned above, APIS are the ones that allow us to access this type of information to meet the existing needs [16], [20]. Consequently, these APISs handle this information differently, which may lead to different results despite performing the same action in both [4]. However, as in the implementation that was developed in the project, these APIS can work simultaneously, providing an optimal result in the solution of the different existing needs [2], [16]. On the other hand, the implementation of Firebase technology is of utmost importance. This can be seen in the possibility of users having remote access to information [21]. In addition, the synchronization of the data allows the visualization of the information changes in real-time [10]. In this way, it denotes that this technology makes use of the data according to the project's needs to be developed [17].

Now, for the determination of the location and arrival time of the buses at the bus stops. It is of utmost importance to obtain this information as accurately as possible [3], [13]. This is because it will allow the determination of the route that the vehicle will take with accuracy [4]. In the same way, the arrival time to the desired point will be correctly determined [2]. However, this data must be evaluated since there are differences in the way the APIS are implemented [4] since a slight variation in this information is reflected in hundreds of meters of difference [18].

Next, denote the utility in the implementation of notifications. These can be implemented when a device is entered into a given area [3], [16] or when another device arrives at a previously requested location [2]. However, many research projects overlook such user notification implementations [13], [21], which would add an extremely useful feature. Thus, these notifications can provide not only information on the location of the vehicle but of its different components and know if it has suffered a breakdown [2], [21].

Finally, it is corroborated that one of the advantages of this methodology is the ease of use without the need for difficult training of the personnel involved in the development of the project [25]. Likewise, a disadvantage has the development of the phases must be completed in its entirety before continuing with the next one.

Otherwise, the quality of the final product is undermined [22], [23]. Similarly, emphasis is placed on the correct analysis and determination of the application's requirements [26]. This is due to the fact that if they are not carried out correctly, it will be reflected in the final phases or even in the final product [27]. It implies returning to the project's initial phase, giving for lost work and resources used [28].

6. Conclusion

To conclude, the implementation of this application contributes greatly to facilitating the correct planning of the users' activities. This is by means of the correct implementation of the different technologies used. In this sense, the use of GPS technology by means of the APIS helped precisely determine the location and arrival time of the buses at the different bus stops.

Likewise, the use of Firebase technology has been decisive in the simultaneous management of information and remote access to it by users. All this together allowed users to be able to schedule their daily activities since the uncertainty of the location of the bus stops, the proximity of the buses, and the time of arrival to them was eliminated.

On the other hand, regarding the cascade methodology used in this project. It is well adapted to the project's requirements, needs and characteristics. In fact, it should be noted that it is not necessary to carry out extensive training to be able to use this methodology. Likewise, a correct analysis of the application requirements guarantees the quality of the final product. In addition, it is worth mentioning that once each phase of this methodology has been completed, the necessary resources are provided to develop the next phase until the project is completed.

In the future, it is expected to increase the information provided by the application through the use of IoT. In this sense, it is possible to implement new sensors inside the buses. These sensors will allow the detection of new information, such as the current status of the vehicle and the number of passengers on the bus. This will be very useful for the users of the Metropolitano's feeder system since they will have the possibility of accessing the bus information before arriving on them.

Thus, invite you to carry out the necessary research to implement these features and contribute to the improvement of the quality of life of the users.

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