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# Development and implementation of a public transportations tracking system: study case

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## ABSTRACT

Public transportation is one of the main means of transport utilized by the population, however, it is still inefficient. One of the problems seen by the population is the delay of the bus. This can happen for several reasons such as traffic or accidents on the road. Tracking a bus through GPS and GSM/GPRS can help solve some of the problems related to lack of predictability of arrival, through the planning and management of the bus system. This project proposes the development of a public transportation tracking system, which will estimate the arrival of a bus at a desired bus stop by the passenger as well as allowing the passenger to see the bus in real time. Thus, the passengers will have better control over their time. For this to become a reality, the tracking system will be integrated and programmed into a hardware module to determine the location of the vehicle and a mobile application to visualize the bus on a map. It is expected to make public transport an efficient means of transport, where the user can better plan, due to the more accurate itinerary, and the bus company can make more concise decisions in regards to route timing.

**KEYWORDS:** Map. Mobility. Public Transportation. App. Web Service. Arduino. GPS. GSM/GPRS.

## INTRODUCTION

Over the last few years, the number of vehicles on the streets of Brazilian cities have increased considerably. This increase was a consequence of tax incentives granted to the population (Lerner, 2009, p.42). According to Lerner (2009: 42), annual car sales increased between 1995 and 2000 and doubled sales of motorcycles (to 500 thousand a year). The increase also occurred until 2005, thus reaching 1.6 million motorcycles in 2007 (Lerner, 2009, p.42) and around 3.8 million in 2015 according to DENATRAN (2015). This increase resulted in losses in urban mobility and in the increase of the emission of gases harmful to the environment.

According to Lerner (2009, page 43), the level of pollution per passenger when using a car is 17 times higher than when using buses. A motorcycle pollutes 32.3 times more than the bus.

Although public transportation is one of the main means of locomotion used in Brazil, with about 29% of total motorized journeys in the Brazilian metropolitan regions (ANTP, 2013), it is inefficient and imposes on users due to long waiting and overcrowding. One of the main problems witnessed by the population is the delay of the buses, which can happen for a multitude of reasons.

New technologies have been applied in different sectors of society for the improvement of several segments, and the same must happen for public transport, in which decision-making management systems are being developed and used worldwide.

The use of technological tools such as tracking can ease the problems related to the lack of predictability in the public urban transport. New tools have been used to improve services related to public transport in several countries, such as the United States, Australia, and England (MAGALHÃES, 2008, p.23). As examples of tools, we can mention are Radio Frequency Identification (RFID), bus tracking via Global Positioning System (GPS) and Global System for Mobile Communications (GSM).

Assisted by the low cost of smartphones and the availability of 3G and 4G networks, the number of smartphone users is growing at an average rate of 4.7% per year (BYANSHUL SRIVASTAVA, EMARKETER, 2014). Although the growth rate of mobile phone users has reached a ceiling in developing countries, with the growing number of users in Asia, the Middle East and Africa, 4.5 billion users are soon expected. A report by market research firm, eMarketer, expects the growing market in emerging countries to boost the smartphone market (BYANSHUL SRIVASTAVA; EMARKETER, 2014). Aiming at the growing number of smartphone users allied to tracking technology, there is a great prospect for the development of a project that can contribute to the improvement of public transportation.

Through the planning and management of the fleet, it becomes possible to create new means of organization for public transport companies. From the use of a tracking system, it is possible to have greater control over a particular line or fleet, both by the company and by the passenger. It is also possible to determine the time of arrival of a bus to the next stop, the time of the route, in which stops the bus did not stop, average speed, etc.

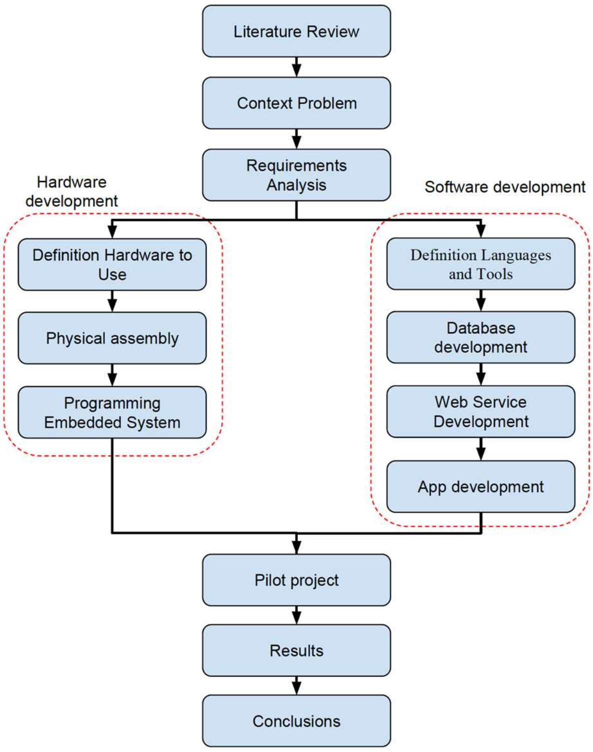
The objective of this project is to develop a system that allows the users of public transportation to track the bus via smartphone, as well to be able to have an estimate of the time of arrival at each stop.

The tracking system proposed in this project has already been utilized by other research groups for different purposes such as vehicle tracking, anti-theft, and intelligent tracking management. Maurya (2012) proposed a vehicle tracking system using GPS and GSM technology for the anti-theft system. The anti-theft system is connected to a vehicle to monitor its movement and report the status of the vehicle, while its positional data is sent to a server and a mobile device. Dinkar (2011) developed a Web-based GPS-GPRS vehicle-tracking system. The Web tracking system developed in this reference project utilized different technologies such as PHP, JavaScript, XML and MySQL with Google Map API to retrieve and display the vehicle's position on the maps. According to (Chadil et al., 2008) his work proposed a real-time tracking system using a client-server model, with the client having an embedded device with a GPS/GPRS module to identify device location. The server is a personal computer with a Web server program that receives the location information to display on the Google Map and Google Earth software.

## PROPOSED METHOD

The methodological sequence used to model the public transport tracking system through an embedded system, web system and a smartphone application is presented in the Unified Modeling Language (UML) activity diagram in Figure 1.

Figure 1 - Methodological sequence for the modeling of the public transport tracking system.

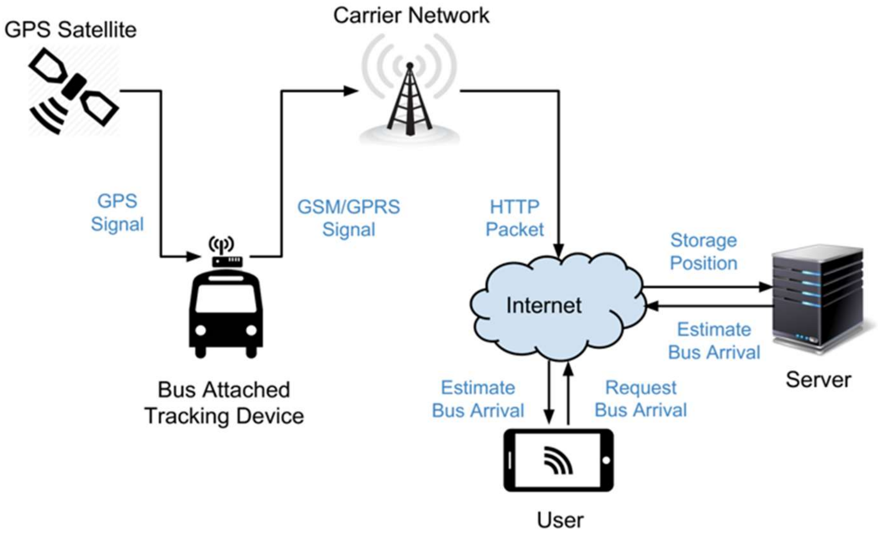



Source: Authors.

As shown in Figure 2, the data stream begins with the GPS satellite that requires at least three satellites to triangulate the exact position of the device. Once the satellites are triangulated, it is possible to obtain the position using a GPS receiver (HEGARTY, 2012). When the GPS receiver picks up its own position, a microcontroller communicates with the receiver. Therefore, the microcontroller reads this position and creates an HTTP request to send the position obtained to the server (WESTERMO, 2005). The sending of the position uses the GSM/GPRS cellular network. To process this request, a page on the server is invoked with the object's position and other parameters such as time and number of satellites, and then a collection of scripts will process and store the position of the object. After the object's position is stored in the database, the passenger can request the time of arrival of the vehicle using a smartphone. When the passenger requests the time of arrival of a bus, a Web page is invoked on the server to restore and estimate the arrival time of the bus in the requested stop.

With the requirements well defined, the project was modeled and the pilot project was tested. Then, with the results of the pilot project, the previously modeled model was adjusted until the final objective was obtained.

Figure 2 - Overview of bus tracking system.




Source: Authors.

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## PROJECT IMPLEMENTATION

This topic presents the steps for the implementation of this system. First, the technologies used and the project's schema are described, then the development of the system, and finally, the pilot project in detail.

### Definition of tools and technologies

In the development of the hardware, a device was used which integrates a GPS module that allows the location of a vehicle, person, or other objects to be determined at regular intervals. The obtained localization data for bus routes was transmitted to a database server via GSM/GPRS technologies. Subsequently, the position information was then plotted on a map to view the movement of the bus.

In this project, the Arduino Uno R3 was used. The Arduino was responsible for setting up the GPS/GSM/GPRS device, reading the GPS location and sending the location to the server using GSM/GPRS technology. The Arduino used had an integrated ATmega328P microcontroller, enabling communication with the GPS/GSM/GPRS device.

The SIM808 device used was a complete Quad-Band GSM/GPRS system that combines GPS technology for satellite navigation. This hardware device depends on a voltage source to supply at least 2 amps to power the Arduino Uno R3 and SIM808. The software used to program the Arduino was an open source program called Arduino Software Integrated Development Environment (IDE).

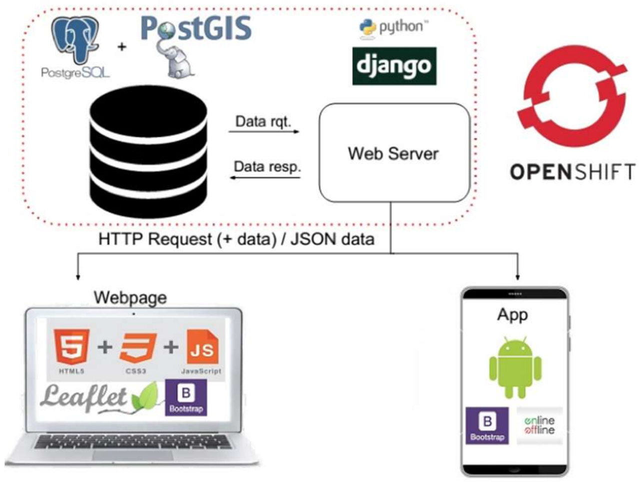
For the development of the Web platform, the following programming languages and technologies were used: Python/Django, JavaScript, HTML, CSS, Bootstrap, and Leaflet. These technologies are widely used because they offer fast implementation and easy maintenance. As an example, the Django framework that is used for agile development, which is based on the Python language, uses standards for object-oriented programming and other design patterns (RICHARDSON; RUBY, 2008).

## Patterned architecture

Figure 3 shows the web architecture for the public transport tracking system. In web architecture, technologies and protocols are used for the development of the web system and the mobile application. The data is requested through the user interface using OpenShift web server and HTTP protocol, then the data is returned in JSON format. The web interface was programmed using the following technologies: HTML5, CSS, Javascript, Leaflet, and bootstrap. The Android application has been programmed in the native language of the Java system.

PostgreSQL was used as the Database Management System (DBMS) and its spatial extension (PostGIS) for PostgreSQL positions storage.

Figure 3 - Web architecture of public transit tracking system.



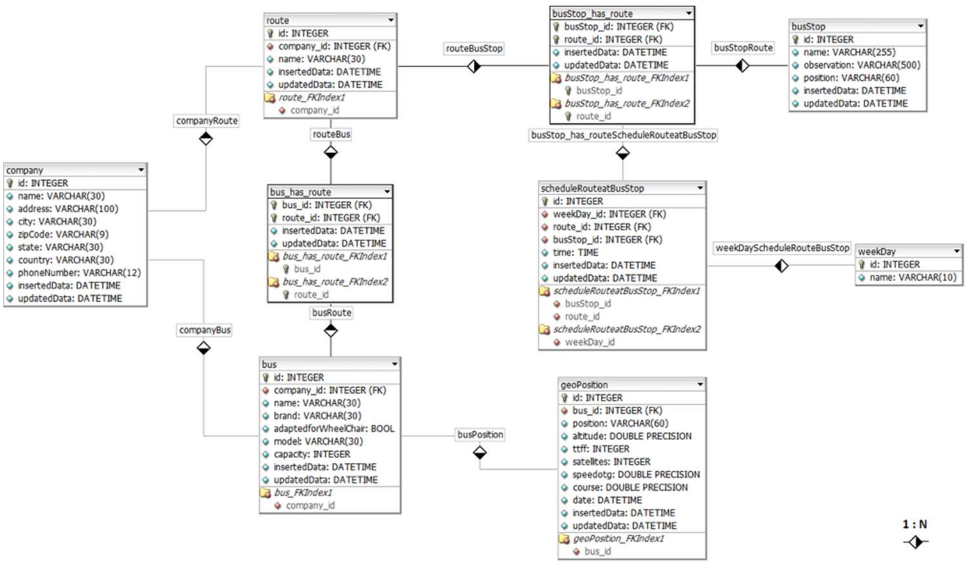

Source: Authors.

## Database development - entity-relationship model

The entity-relationship model (ER model) of the database is represented in Figure 4, in this model, nine tables were created in Entity-Extended Relationship (EER) notation. The tables are related so that they guarantee the integrity of the data.

The tables "geoPosition" and "busStop" contain position columns of geographic data. Geographic data can use its existing functions, such as calculating the distance between two geographic points and select data in specific regions.

Figure 4 - Model ER.




Source: Authors.

## System development

A map was developed using LeafLet framework in the city of Bagé-RS in Brazil with a route line. The map is composed of layers in which the bus stops and the direction of the line were plotted. Figure 5 shows the developed map.

Figure 5 - Web architecture of public transit tracking system.


Source: Authors.

The passenger is able to click on the bus stop to obtain the information on the bus arrival. Figure 6 shows the information on a bus stop. This information is: vehicle id, stop name, existence of metal shelter, existence of concrete shelter, existence of curb, painting of the shelter, existence of signs, photos and the bus arrival.

Figure 6 - Information on bus stops to be shown to passengers.


Source: Authors.

To speed up the process of creating the application, the Bootstrap framework was used. The Bootstrap framework is responsible for resizing the application screen according to each device (SPURLOCK, 2014).

Figure 7 shows the online mode of the application, this mode is responsible for loading the online map page.  Fig. 6 shows the options: a) map with the bus stop clusters; B) map with bus stops and bus location; C) information of the bus stop.

Figure 7 - Android app online mode.


Source: Authors.

## Development and installation of hardware

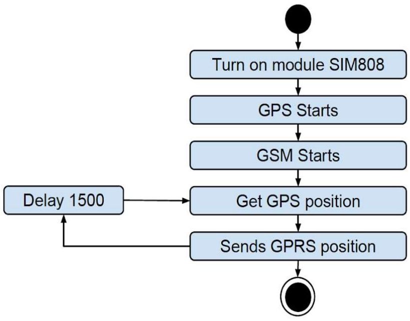
Figure 8 shows a picture of the hardware used. The SIM 808 module was attached to Arduino UNO via a shield. An acrylic box was involved to protect the circuit from dirt and water, avoiding damaging the board. The total price of the hardware was approximate U$ 100.00.

Figure 8 - Android app online mode.

Source: Authors.

The flowchart of Figure 9 illustrates the operation of the developed embedded system. The implementation of the embedded system was divided into five stages. The stages were: connect SIM808 module, start GPS, start GPRS, get GPS position, send position through GPRS. One stage could only proceed to the next if the current one was executed without error. In the programming of the embedded system, several problems occurred due to incorrect configurations of GPS and GPRS. To identify the errors in the settings, the serial output of the SIM808 module was used, so it was possible to identify the error returned by the SIM808.

Figure 9 - Flowchart of the operation of the embedded system.




```
void setup(){

    Serial.begin(9600);
    Serial.println("Starting...");

    start_sim808();

    start_GPS();

    start_GSM();
}

void loop(){

    // Get position through GPS
    gets_GPS_position();

     // Process GPS data
    process_GPS_data();

    // Send position by GSM
    send_position_GSM();

    // Wait for 1.5 seconds to send again
    delay(1500);
}
```

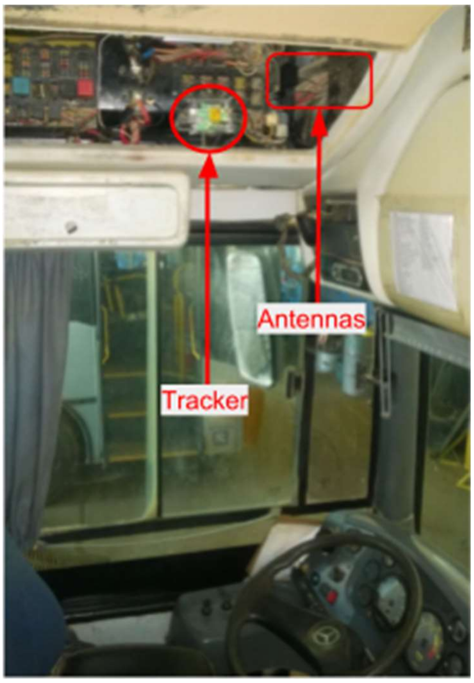
Source: Authors.

To start the hardware it is necessary to initialize the module elements. Three elements are initialized: the SIM808 board, GPS module, and GSM module. To start the SIM808 it is necessary to press the I/O button on the SIM808 board for 3 seconds, then a simple AT command from the microcontroller to the SIM808 is sent, if the return is "OK", then the board is connected correctly. After the GPS module is connected, the satellites are triangulated. In the configuration of the GSM module is necessary to set the Access Point Name (APN) of the internet provider, user, and password. After the correct initialization and configuration of these modules, it is possible to obtain the GPS position and send it to the server through the GSM network.

## Pilot project

In order to verify if the system would work satisfactorily, a test of the developed system was carried out with a bus in the urban line of the city of Bagé-RS, Brazil. A mobile network carrier that provides GPRS service in the city was used, the choice of this carrier was based on the quality of the GPRS signal. The tracker was then connected to the electrical system in the vehicle that Supplied 12 volts according to Figure 10.

Figure 10 - Indicates the location where the tracker was installed. It was attached next to the driver's cab and the electronic control unit of the vehicle.



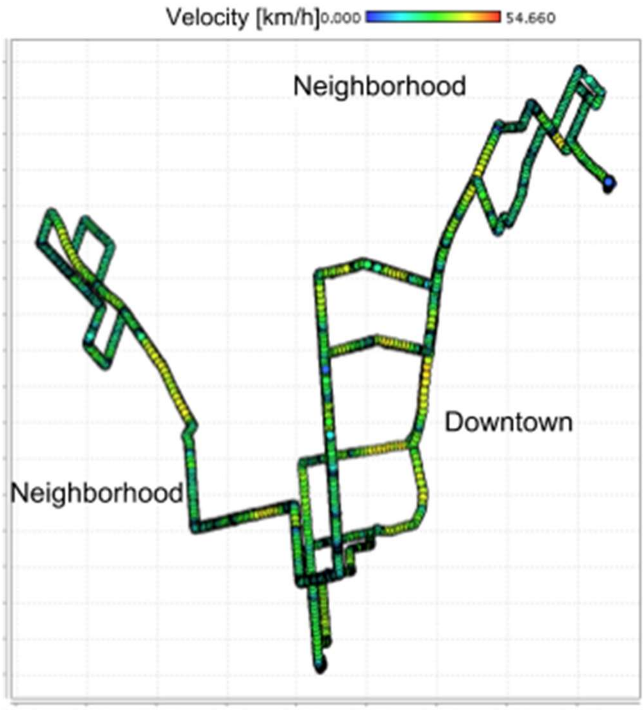

Source: Authors.

For four days, the tracker sent the bus position to the server. During this period more than fifty thousand records were stored in the database. Every 3.95 seconds the position of the bus to the server was sent, this sampling was adequate for the visualization of the moving vehicle on the map. In the experiments, 1MB/hour of data was spent, so if the bus operates for 16 hours/day, in 1 month 480MB of data would be used.

The data generated by the tracker was collected and stored in the database. The data stored were: latitude; longitude; altitude; date/time, number of satellites located and speed.

For the calculation of the vehicle arrival time at the requested bus stop, the average speed of 18 km/h was utilized, as proposed in Meirelles (2000). The calculation of the vehicle arrival time is carried out by dividing the distance between the bus' current position and the bus stop by the speed proposed by Meirelles (2000). The experimental average speed of the line studied was 14.90 km/h, so the predictability of the bus arrival will be advanced. This anticipation favors the passenger arriving at the stop in advance.

Figure 11 - Indicates the location where the tracker was installed. It was attached next to the driver's cab and the electronic control unit of the vehicle.

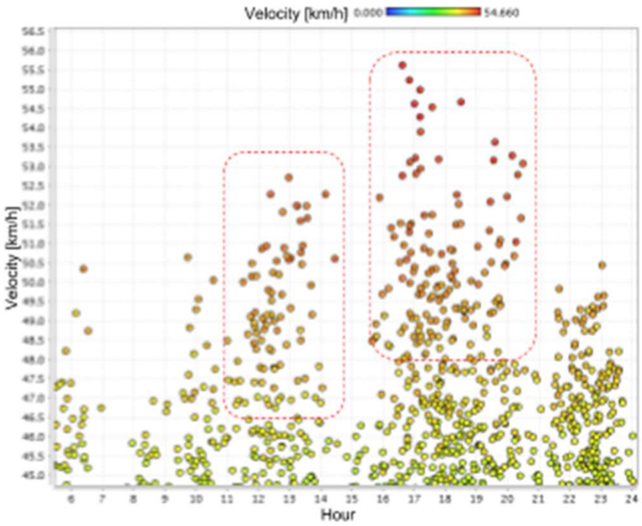



Source: Authors.

It can be seen in Figure 11 that on straight roads, the bus had higher speeds (in yellow). This kind of information can be useful for managers to control the speed in order to avoid accidents and tickets for speeding. In addition, the information can be incorporated into an algorithm and used to improve the predictability of the bus arriving at the bus stop.

In Figure 12, the maximum velocities were plotted during the daytime hours. In the graph of this figure, it is possible to check two peaks. The first peak shown is the speed between 11 am and 2 pm. The other peak velocity was verified between 4 pm and 8 pm. These peaks can occur due to the congestion of lunch as well as the closing of stores and the beginning of classes at the universities. In this way, the drivers compensate the hours spent in the congestion, increasing the speeds on the roads. Through this type of chart, managers can determine the times to make more buses available.

Figure 12 - Maximum speeds distributed during hours.




Source: Authors.

## DISCUSSION AND CONCLUSION

The main objective of this work was the development of a tracking system to assist in alleviating the problem of unpredictability of bus arrival time. For this, a Web system and an App, capable of obtaining current bus positions, were developed. After the development of the Web system and App, the embedded system was attached to a bus to obtain the vehicle position and to send that information to a server.

Different technologies were used for the development of the Web system and the application. Some of these technologies were Django, Bootstrap, and Leaflet. They streamlined the development of the system and ensured good structuring of the project. With the good organization of the codes, it was possible to reuse a large part of the functions. For example, database queries were developed on the web server, so both the webpage and the application accessed the same queries.

The hardware behaved as expected, which made it possible to track the bus by the application and estimate the bus arrival using an average speed of 18 km/h based on the Meirelles (2000) work.

In addition to providing the location of the bus in real time for passengers through the data collected, it was possible to generate knowledge for the company manager. Thus, the company manager can make concise decisions to improve the efficiency of the fleet. Besides the graphs plotted in this work, other information can be correlated with the position of the vehicle such as drivers and buses, thus making it possible to extract more information.

Through the planning and management of the fleet, it becomes possible to create new means of organization for public transport companies. From the use of a tracking system, it is possible to have greater control over a particular line or fleet, both by the company and by the passenger. It is also possible to determine the time of arrival of a bus to the next stop, the time of the route, in which stops the bus did not stop, average speed, etc.

All requirements previously formulated were met and the entire system worked in an acceptable manner. However, due to the high cost of implementing the GPS/GSM modules, for future work, the acquisition of commercially available trackers should be considered. In the market, trackers that meet the requirements system were found with values ranging from U$15.00 to U$ 30.00.

Besides the technical knowledge acquired during the research and development of the system, it was possible to verify the need for improvements in this sector, and one of the ways to improve public transportation would be through technological tools. Therefore, it is expected that passengers can benefit from these technologies in improving the quality of public transport services. The code is available on https://github.com/rodrigowindows.

# Sistema de rastreamento de transporte público através de hardware e software: estudo de caso


## RESUMO

O transporte público é um dos principais meios de transporte utilizado pela população brasileira, no entanto este tipo de transporte ainda é ineficiente no país. Um dos problemas presenciados pela população é o atraso dos ônibus, que pode acontecer por diversos motivos. O rastreamento de ônibus através de GPS e GSM/GPRS pode contribuir para solucionar problemas relacionados com a falta de previsibilidade da chegada e acompanhamento do itinerário do ônibus. Este projeto tem como objetivo o desenvolvimento de um sistema de rastreamento de transporte público que possibilita a estimativa do horário de chegada de um determinado ônibus em uma parada. Para isso, foi integrado um módulo de hardware para determinar a localização do veículo, assim como o desenvolvimento de um aplicativo para smartphone. Com isso espera-se que esse projeto possa contribuir para a utilização do transporte público, possibilitando que os passageiros possam programar melhor o seu dia, e empresas possam melhorar a gestão/fiscalização de sua frota. Sendo assim, o passageiro poderá ter um maior controle de seu itinerário, de acordo com a chegada do veículo na parada solicitada.


**PALAVRAS-CHAVE:** Mobilidade Urbana. Transporte Coletivo. Smartphone. Serviço Web. Arduino. GPS. GSM/GPRS.

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