International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958, Volume-8 Issue-4C, April 2019

Integrated Information System for Urban Public Transport

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Abstract*: *This paper presents an integrated information system for the monitoring and control of urban public transportation stations. In this way, users are notified through web services, smartphone application. Including information at the bus stop about routes, location of stops and times of public transport. In addition, there is a portal for the administrators of the units that allow the management of the records of the bus route. This is performed using radio frequency devices for wireless communication between the automotive and the transport station. This receives information from the mobile unit and sends it to a database present on a WEB server, where it is processed and sent to the station for its socialization with the user. In this paper an audio system that provides information on the route through a speaker located in the station and in the mobile unit was implemented, facilitating the use of this service to users with visual disabilities and illiterate population. The system was tested in three stops and two mobile units. This has proven the communication with a range greater than 20 meters. The rapid response of the system with an approximate time of up to 1 second from the bus registration at the stop to the updating of the data on the site.

Index Terms*: *Databases, GPS, public transportation, web services.

I. INTRODUCTION

The constant evolution of communication and information systems facilitated the development of human activities [1], [2]. This allows a greater and better dissemination of knowledge in all its areas [3], [4]. Currently urban environments following regional and neoclassical traditions of growth and development seek to become "smart cities" [5], [6]. In practice, the management of public transport is an axis that is taking priority in the local administration, thus promoting its socio-economic growth [7].

Innovating the way in which the urban public transportation service is managed, required the implementation of several applications that involve ICT and IoT [8]-[10]. A clear example of this is the presence of automatic passenger counters, automatic vehicle identification and location systems. In this way we seek to form intelligent transport systems (ITS) and improve the management/service that is delivered [11]. Based on these advanced technologies, both transit agencies and users have developed a greater interest in receiving information on their smart devices [12]. This allows passengers to efficiently schedule their departure time and make the right decisions for their trip, evaluating alternate routes and reduce transfer times. With this, traffic congestion in the city is prevented [13]-[15]. In addition, this type of systems facilitates the inclusion of people with visual disabilities and illiteracy, by the implementation of auditory messages.

Several investigations related to this subject have been carried out, implementing similar proposals. In [16] an information system for public transport is presented, applying the use of GPS, the TCP/IP protocol and web services. This allows the users and system administrators to know precisely the location of the vehicle, with monitors inside the transportation vehicle and at the stops. In [17] similarly, a system combines GPS and GSM/GPRS technologies. In this way the user receives a notification of the current location of the buses that are approaching the stop, monitoring the speed of the vehicle and inside an indicator of proximity to the next stop. In [18] with the use of the GPS and GSM modules, communication is established between the unit and the stop. Thus, the arrival time of the bus to the station is calculated and this information is shown to the users through a screen at the stop and an application on their Smartphone. In [19] with the use of GPS technology, users can follow the bus route from inside. While providing recommendations on alternative routes, predicting peak levels of users waiting for the next approach. This paper is divided into 6 sections, including the introduction in section 1, section 2 presents the description of system. Section 3 shows the elements of system. Section 4 talks about the implementation; Section 5 shows the results; the conclusions are presented in section 6.

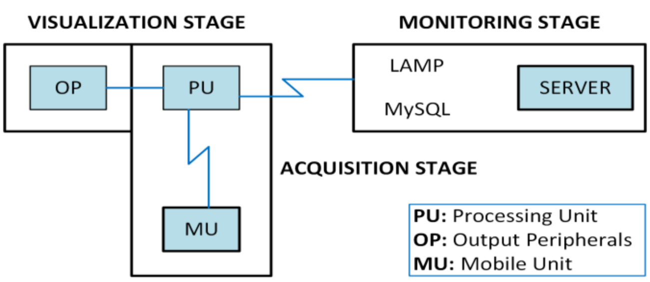

Fig. 1. General diagram of system.

Revised Manuscript Received on December 22, 2018.

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II. DESCRIPTION OF SYSTEM

Fig. 1 describes the operation of the Integrated Information System (IIS) that consists of three stages: acquisition, monitoring and visualization.

A. Acquisition Stage

Submit your manuscript electronically for review. It consists in establishing communication between the MU, PU and the server for data acquisition. It starts with the communication of the MU, next it sends the route data, cooperative to which it belongs and the unit identification number to the PU. The PU validates if the information received belongs to the routes that transit through its stop, and sends it to a database located in the web server for processing. Additionally, a confirmation notice is sent to the MU, where an audible message is played. If any of the conditions mentioned above is not met, the information is discarded.

B. Monitoring Stage

The processing of collected data is completed, for its subsequent presentation to the final user. This stage is made up of a server that, through LAMP (Acronym for Linux, Apache, MySQL and PHP), provides web services. In addition, it manages the database.

C. Visualization Stage

It constitutes the interface that is presented to the user. The information is shown through the following elements:

1) Informative located at the stop

It operates in real time and provides auditory messages in parallel.

2) Web services

Allow the user to access the IIS through a website, check the location and schedules of all stops and routes. It has a portal for the administrators of the mobile units, organizations that provide the service and control organisms that require information about the activity of public transport. The portal provides information in a detailed and up-to-date manner, according to the consultation carried out after security authentication.

3) Android application

Allows the user to consult the routes, available times and their location with respect to transport stops, by using GPS.

III. SYSTEM ELEMENTS

A. Raspberry Pi 3

Embedded board with support for several peripherals of a common computer, which works with the Linux operating system. It has GPIO (General Purpose Input/Output) pins that can be used as a digital input or a digital output. It also has different communication buses such as SPI and I^2C.

B. NRF24L01

This Nordic Semiconductor module is used for wireless communication between the MU and the PU present in the station. Said communication element is controlled by SPI communication. Table I describes its technical characteristics.

Table I. Information about module nRF24L01

Technical characteristics	Description
Frequency	2.4GHz
Channels	126 channels RF
Modulation	Gaussian Frequency Shift Keying (GFSK)
Transmission speed	2Mbps to 8Mbps
Communication	Duplex
Communication protocol	Enhanced Shock Burst and SPI
Current consumption	12.3mA RX at a transfer rate of 2Mbps
Supply voltage	1.9 to 3.6V
Distance	30 m

C. ATmega328p Microcontroller

This microcontroller is widely used and available on the market at lower cost, and appropriate technical features for the development of this paper. Such as, 2048 bytes of RAM, 20 MHz of CPU speed, 23 pins (PWM, analog and digital) and various communication buses (UART, SPI and I^2C).

D. LCD Touch Screen

It is an input/output peripheral, located in the MU and controlled by the ATmega328p. It allows visualization of the process carried out in the MU and the entry of information through its touch panel, by which the operator of the MU selects the route to be carried out.

E. Micro SD Card

It is used in the PU to store the operating system of the Raspberry card and in the MU storing the audio recordings to be played. It communicates with the microcontroller through SPI communication.

F. Web Server

In a Web environment and in a client/server architecture, the "server" part appears. It is a server-side application that makes bidirectional and/or unidirectional connections (synchronous or asynchronous) with the client. This generates a response in any language or application on the client side, i.e. the server performs the requests, and does not have to be a web browser. The only requirement that must be met is the use the HTTP protocol. The code received by the client program is usually interpreted and executed by a web browser. On the server is the MySQL database, on which the IIS is based for the provision of information to users.

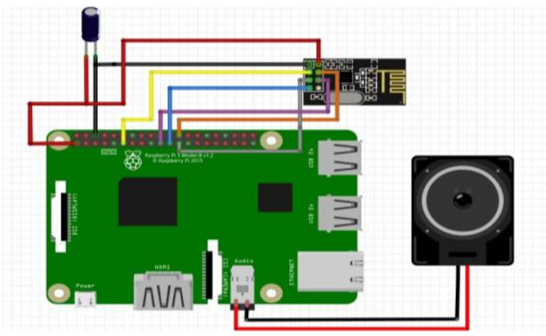

Fig. 2. Connection diagram of electronic board of PU.

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IV. IMPLEMENTATION

A. Processing Unit Device

In Fig. 2 the connection scheme implemented in the PU device is observed. Fig. 3 shows the printed circuit board that is delivered to the end user, connected to the Raspberry Pi 3 board and the communication module nRF24L01.

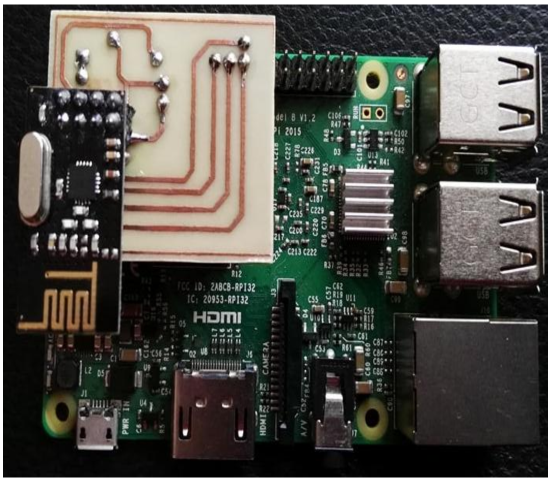

Fig. 3. Connection diagram of electronic board of PU

B. Informative Present at the Stop

The prototype present in the PU allows the visualization of information through a screen, for this the Raspberry board is configured in Kiosk mode. By default, the program that controls the communication with the MUs, starts at the moment of powering on the device, and automatically displays the information in full screen. In addition, the reproduction of an informative audio is controlled, indicating the arrival of the transport and the route it carries out. The informative is illustrated in Fig. 4.

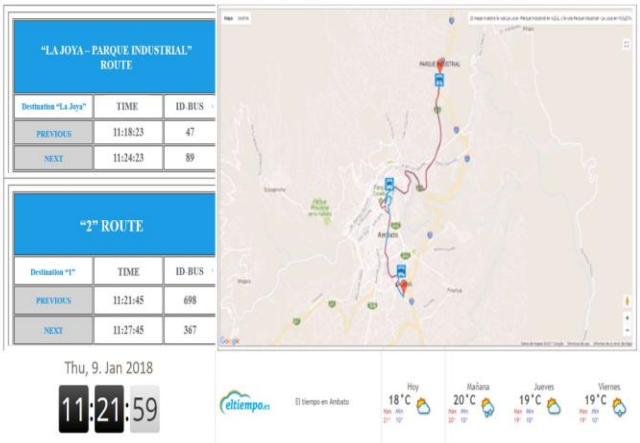

Fig. 4. Informative interface present at bus stop

C. Mobile Unit Device

In Fig. 5 the schematic diagram from the prototype present in the mobile unit is observed. Fig. 6 shows the designed printed circuit board and the working prototype. Through the prototype present in the mobile unit, the operator enters the data of the route to be made. It does this by entering a code that indicates the route and at the same time selects the address, i.e., if the bus goes from point A to point B or vice versa. Once this information is provided, the route and chosen address are displayed in the screen.

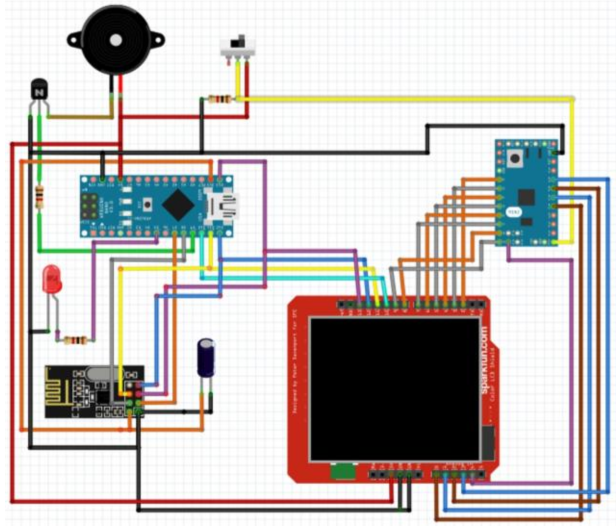

Fig. 5. Connection diagram of electronic board of MU

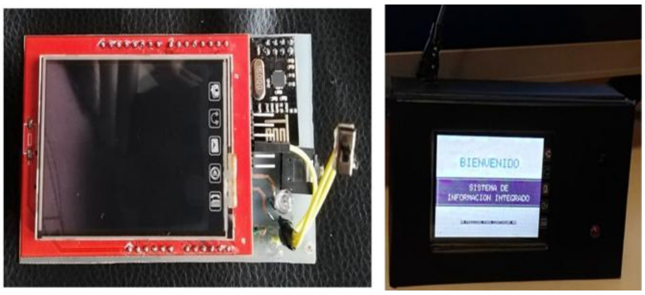

Fig. 6. Device presented to user

D. Website

It was developed thanks to the Google Maps API tool, which is based on JavaScript programming language. In Fig. 7 a part of the code written for the map of one of the routes is shown. For the creation of this map it was necessary to describe more than three hundred geographic coordinates for the route. Fig. 8 shows the website for users to search for the service. In the different options of the site the user can observe maps about the location of the available stops and routes, along with a detailed description. The users can also see schedules of each stop, and the entrance to the monitoring portal.

In Fig 9 the monitoring panel is observed, after security authentication the activity history can be consulted. There are different monitoring panels according to the selected option.

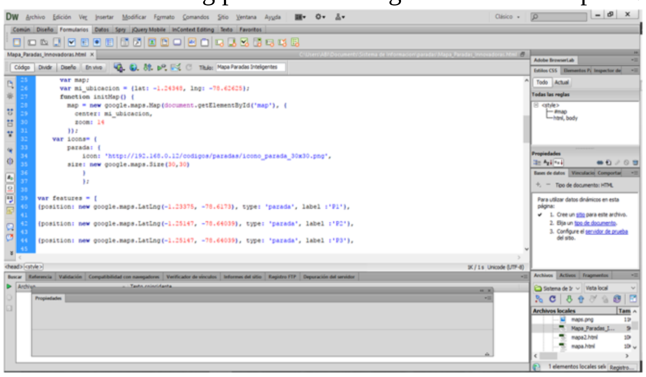

Fig. 7. Code developed in JavaScript

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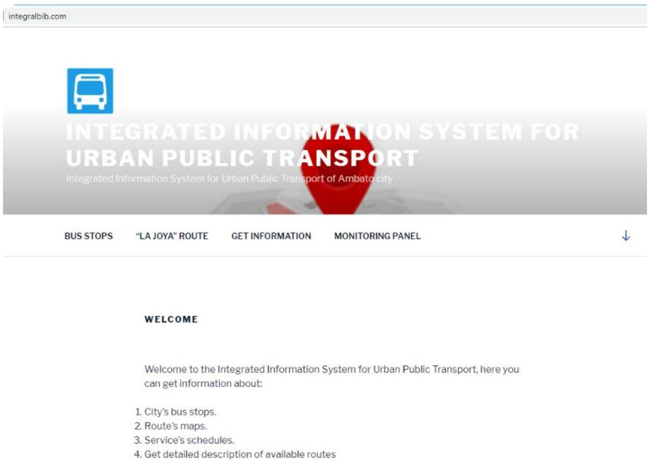

Fig. 8. Website for users to consult services offered

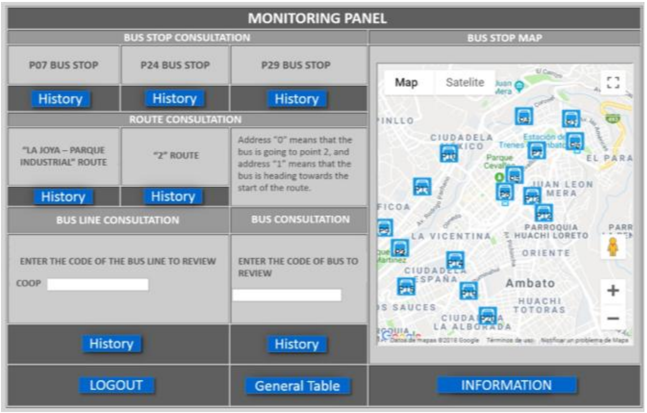

Fig. 9. Monitoring panel on website

E. Application for Smartphone

It was made on the AppInventor platform, designed for mobile devices with an Android operating system, as it is the most popular operating system among mobile devices. According to this platform, the applications developed are compatible with all versions of Android. The application was tested in the versions of Android 5.1, 4.0, 2.6, obtaining a correct and normal operation. Figure 10 shows a part of the code developed in the AppInventor programming platform.

Fig. 10. Code developed in AppInventor.

The application allows the user to make inquiries about the schedules of each of the stops. It also allows the visualization of maps on the location of innovative stops and available routes, as well as access to the system's website. Fig. 11 shows a screen of the mobile application.

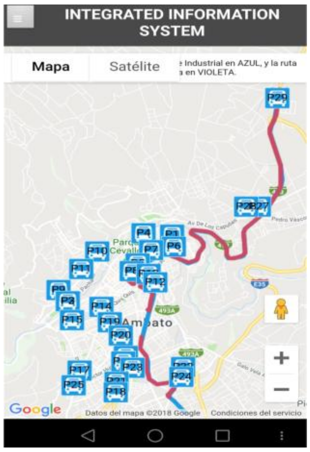

Fig. 11. Interface of application implemented on a smartphone with Android system

V. RESULTS

To carry out the tests that validate the correct functioning of proposed system, it has been implemented in three stops and two mobile units.

A. Communication between the MU and PU

Data is transmitted from the MU (controlled by ATMega328p) to the PU module (controlled by the Raspberry board) using the nRF24L01 module. These communication tests were conducted with line of sight, with a distance of up to 20 meters effectively and without loss of data packages. The transmission of data from the PU to the MU was effective, and without data packet loss up to a maximum distance of 19 meters. The delay time in the communication between said units is less than 1 second. When performing the communication tests without line of sight (with a building in between) there was no loss of the data packages sent between the units. When the distance is greater than 15 meters there was intermittent communication.

Table II. Mobile unit prototype implementation cost.

N°	Parts	Units	U. Value	Total
1	ATMega328p (Arduino Mini)	1	$ 4.50	$ 4.50
2	ATMega328p (Arduino Nano)	1	$5.50	5.50
3	LCD Touch Screen	1	$ 20	$ 20
4	nRF24L01 Module	1	$ 4	$ 4
5	Double sided Bakelite	1	$1.50	$1.50
6	Ferric Acid	1	$0.75	$0.75
7	SMD Resistor	3	$0.10	$0.30
8	SMD Capacitor	1	$0.20	$0.20
9	Speaker	1	$2.00	$2.00
10	Transistor 2N2222	1	$0.20	$0.20
11	Audio Jack	1	$0.35	$0.35
12	Sprats	6	$0.50	$0.30
13	Led	1	$0.10	$0.10
14	Switch	1	$0.15	$0.15
15	Case and Assembly	1	$3	$3
	TOTAL			$ 42.85

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B. Measurement of system speed and cost analysis

The information speed measurement tests were carried out using the "Pingdom" tool[1]. The loading and execution of all requests has an average duration of 2.08 seconds with a download speed of 3Mb/s. So, the loading time of the news will vary depending on the download speed from the internet service provider location. Table II presents a list of the respective commercial prices in US dollars of the prototype located in the mobile unit. Similarly, in Table III it is done for the prototype of the processing unit.

Table III. Processing unit prototype implementation cost

N°	Parts	Units	U. Value	Total
1	Raspberry PI 3 V. B	1	$ 55	$ 55
2	nRF24L01 Module	1	$ 4	$ 4
3	Double sided Bakelite 3x4	1	$0.30	$0.30
4	Ferric Acid	1	$0.40	$0.40
5	Capacitor	1	$0.12	$0.12
6	Cable	1	$1.50	$1.50
	TOTAL			$ 61.32

C. Energy Consumption

Table IV shows the energy consumption of the prototype present in the Processing Unit and Table V describes the energy consumption of the prototype present in the Mobile Unit.

Table IV. Processing unit prototype energy consumption

Current	Voltage	Description
5 V	0.027 ~ 0.050 A	Turning on the controller board
5 V	0.028 ~ 0.029 A	nRF24L01 in operation
5 V	0.028 ~ 0.029 A	nRF24L01 and audio output
5 V	0.026 ~ 0.029 A	Screen, nRF24L01 and audio output

Table V. Mobile unit prototype energy consumption

Current	Voltage	Description
5 V	0.021 A	Turning on the module
5 V	0.024 A	nRF24L01 in operation
5 V	0.025 A	nRF24L01 and audio playback

VI. CONCLUSIONS

The integrated information system implemented through the use of low-cost electronic components, ICT and IoT, keeps the users informed about stops and routes that the urban transport service performs. Contributing in this way to the control and monitoring of its activities, and constituting the basis for future research, due to its scalability. For the development of this paper the use of web services and applications for mobile platforms (Android) were required. Public transport is characterized by a deficient, and unregulated distribution of the defined distance between bus stops. For this reason, tests have been carried out using the Nrf24l01 module, establishing communication with a transmission speed of up to 2 Mbps, with a range of 20 meters with line of sight, and 15 meters without a line of sight between the prototypes. It must be emphasized that the transmission modules have a greater operating range than the one used (greater than 500 meters), but they have been configured for the minimum range. This is to ensure that the communication between MU and PU will be adequate, and there will be no interference or multiple connections with other nearby stops that cause confusion in the central processing unit. It also takes advantage of the low energy consumption produced by these devices. It is so the maximum consumption of the mobile unit is of 0.025 amps, and 0.029 amps of consumption for the Processing Unit. As for the response time of the system, there are factors that make it vary, especially on the client side, such as the Internet service provider bandwidth and connection speed. The establishment of communication between the MU and PU is done in less than 1 second. While the time it takes for the news to be updated, once the PU receives the MU data, varies between 1 and 3 seconds according to the tests performed.

ACKNOWLEDGMENT

To the dean Pilar Urrutia and authorities of FISEI of Universidad Técnica de Ambato (UTA), for supporting this work and future research.

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