

## **ABSTRACT**

This work consists on the design and construction of an electronic hardware and software compound prototype that allows to control the time travel of the units of the Cooperativa de Transportes "Otavalo" in the path Otavalo - Ibarra automatically using ZigBee technology as a wireless transmission medium, giving us a cheaper alternative, reliable, efficient and secure than the manual system used at present in our environment of the Cooperativa de Transportes "Otavalo".

To develop of the system it begins with a thorough analysis of ZigBee technology, then it is provided by the description of the prototype in line with the needs which calls the company and with a clear vision of what we like to achieve a comprehensive approach by block diagrams of each module which makes up the system to then choose the electronic devices that suits better the requirements of the prototype, with this, we make a brief study of these electronic components and the design schematics and software to be implemented in the microcontroller of the prototype.

Later, with the complete hardware design it is carried the Information Storage System in the Java programming language on the platform to Netbeans IDE 6.8 which is not a proprietary software and no license is required to develop applications as in MySQL which is the database used in the system.

Available software and hardware it is made the implementation and testing of the system, thus establishes the actual operating parameters of the prototype.

Finally, with all the information obtained in the development of the project we will proceed to establish the respective conclusions and suggest possible improvements to the system.

## PRESENTATION

The problem that led to the development of this project is the fact that at present there is no independent system of detailed control of travel time on the road, or if it has, there is not an efficient systems to operate manually such as the famous "credit card", the same as for demand-driven human intervention, which creates risks, traps and even corruption.

These electromechanical systems with assistance of a human to be operated upon are laborious to collect information and verify the times marked on the cards, for that it is proposed an autonomous system of control of time, to acquire these data without external manipulation and wirelessly, thus also avoiding the danger they subject the persons responsible for operating the electromechanical clock because it is not necessary that the transport unit interrupted his tour to mark the time, simply passing through the checkpoint to information is stored in said transport unit at the end of its travel information delivered automatically to the download station.

For the unloading station, this project provides a tool for managing the information collected in the pathways of transport units, allowing us to have reliable and easily accessible to better manage the administrative processes, this will be done by software developed specifically for this purpose.

This work presents the complete design of the prototype and the results obtained with the implementation of it, in addition to the conclusions and recommendations.

## TABLE OF CONTENTS

I. DATA ACQUISITION MANUAL SYSTEM.....	4
II. DATA ACQUISITION automatic SYSTEM .....	4
III. ZIGBEE [1]-[8] .....	5
IV. TCS HARDWARE DESIGN .....	6
A. MODULE-USER .....	7
B. MODULE-NODE.....	7
C. MODULE-MASTER.....	8
D. RADIO FREQUENCY TRANSCEIVER XBee [9].....	9
V. MICROCONTROLLERS FLOWCHART.....	10
VI. DATA MANAGEMENT SOFTWARE.....	12
A. MANAGEMENT WINDOW .....	13
B. LOAD ROUTES WINDOW .....	13
C. WINDOW TO CANCEL DELAYS .....	14
D. WINDOW TO DOWNLOAD THE DAILY WORK CHART .....	15
VII. DATABASE .....	16
VIII. PERFORMANCE TESTING.....	16
A. SCOPE WIRELESS TEST: .....	18
1) Scope with obstacles .....	18
2) Unobstructed range.....	19
B. INTERFERENCE TESTING: .....	20
IX. CONCLUSIONS.....	20
X. RECOMMENDATIONS.....	21
XI. ACKNOWLEDGEMENTS .....	21
XII. REFERENCES .....	22

## **I. DATA ACQUISITION MANUAL SYSTEM**

Companies interurban bus in Ecuador, most do not have an autonomous system that would allow the detailed control of travel time on the road, or if you have inefficient systems are operated manually such as the famous "credit card" (Fig. 1).

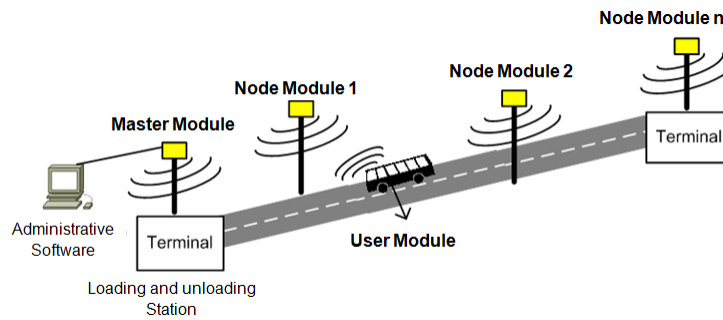


**Fig 1. Electromechanical Clock "Cardholder"**

Electro-mechanical systems with assistance of a human to be operated are laborious and represent high costs of acquisition, maintenance and control personnel, so they proposed an autonomous system of control of time, to acquire the data without external manipulation, and wirelessly based on ZigBee technology, thereby also avoiding the danger that people undergo in charge of operating the electromechanical clock.

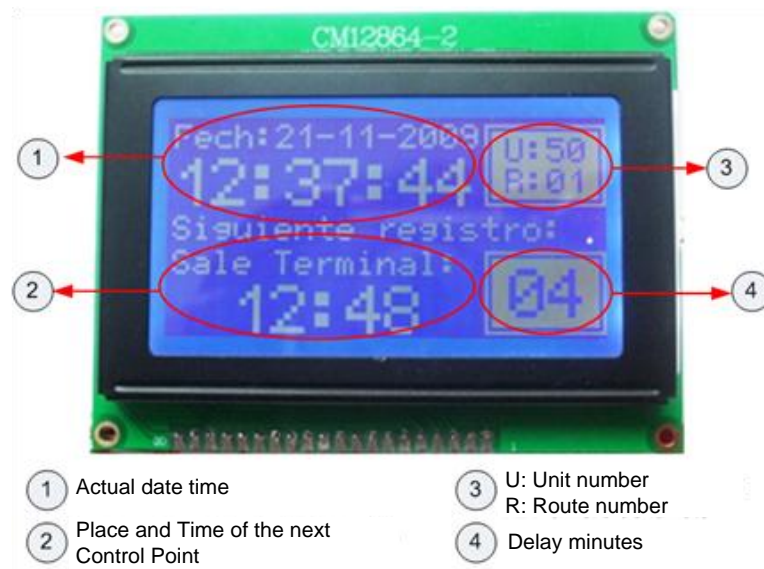
## **II. DATA ACQUISITION AUTOMATIC SYSTEM**

The general outline of Time Control System (TCS) is shown in Figure 2, in which clocks are replaced by electro-node modules and will not be necessary for the transport unit interrupt his trip to mark the time, sufficient with passing through the checkpoint for the information is stored in the unit of transport to the end of their tour automatically deliver information to the unloading station without having to wait for the end of the workday.



**Fig 2. General Outline of the TCS**

User Module also includes an LCD graphic display shown in Figure 3, in which the driver can display, among other things, the current time and date and approximate time it should be at the next checkpoint.



**Fig 3. User Module GLCD screen**

For the unloading station, this project provides a tool for managing the information collected in the pathways of transport units, allowing complete and reliable data readily available to better manage the administrative processes, this will be done by software developed specifically for this purpose.

### III. ZIGBEE [1]-[8]

ZigBee is a wireless communications protocol based on IEEE 802.15.4. This standard defines the physical layer and medium access control for wireless personal area networks with low rates of data transmission.

The ZigBee / IEEE 802.15.4 offers the following features making it ideal for this system:

- Free transmission in the ISM bands 868 MHz in Europe, U.S. 915 MHz and 2.4 GHz worldwide.
- Has a transmission speed of 250 kbps and coverage range 10 to 750 meters depending on the transmission power.
- Its architecture is based on the Master / Slave.
- Supports up to  $2^{16} = 65,536$  and 255 network nodes for each network subnet as ZigBee has a unique network identifier, which allows multiple networks to coexist on the same channel of communication without any problems.
- The access to the network using CSMA-CA is multiple access (carrier sense with collision avoidance), which is a three-stage process in which the issuer first "listen" to see if the network is free , then it transmits the data and then waits for a confirmation message from the receiver, ensuring that the message is received correctly. However, due to the two transmissions (original message and confirmation) it is lost a little efficiency.
- It has a low power consumption and low cost of devices, installation and maintenance of the network.

#### **IV. TCS HARDWARE DESIGN**

In the development of TCS was taken into account the following requirements that must be answered:

- To record the time of each unit automatically.
- Upload and download information wirelessly.
- Ensure service availability in adverse conditions.
- Endorse the information is not tampered with by unauthorized personnel.

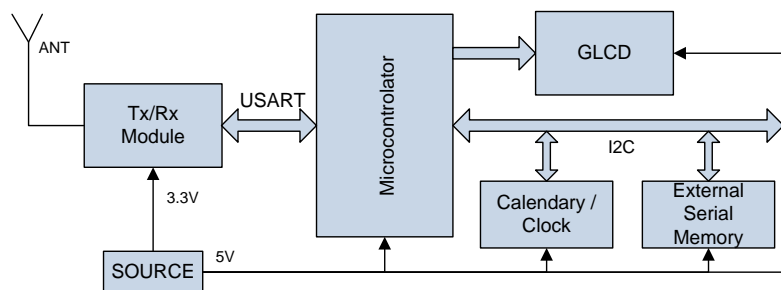
As mentioned above, the TCS consists of three modules:

### A. MODULE-USER

This is mobile and that is in each transport unit. It has an external serial memory (EEPROM<sup>1</sup>) which stores the time the unit went through the checkpoint allowing the driver to display a graphical display the current time and date and approximate time it should be at the next point control.

Module-User also downloads the stored data that has been passed by each module, node or control point wirelessly and at the end of each journey.

In Figure 4 shows the block diagram of this module.



**Fig 4. Block Diagram Module-User**

User Module consists of an RF<sup>2</sup> module (ZigBee) that deals with the Tx/Rx<sup>3</sup> data, a time clock with battery backup, an external serial memory where data are permanently stored to be downloaded, a graphic display LCD which is the interface between the module and the user, furthermore the microcontroller with all the additional circuitry for its operation and the power supply.

### B. MODULE-NODE

Replace electromechanical clocks, ie, are located in a fixed at strategic locations along the route, in the transport cooperatives have seen fit to make a time control.

<sup>1</sup> It is a type of memory that can be programmed, erased and reprogrammed electrically.

<sup>2</sup> RF = radiofrequency

<sup>3</sup> Tx / Rx = transmission / reception.

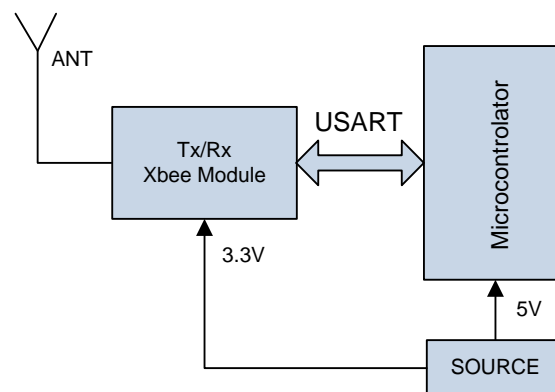
These modules do not communicate with the Module-Master, only do so with the Module-User and periodically send codes that allow you to:

- Know the location of, and
- Store in EEPROM the time the unit went through the checkpoint.

In Figure 5 shows the block diagram of this module, which is easy since it consists of an RF circuit (ZigBee), microcontroller and a power supply with a battery backup system in case you cut a regular supply of electricity.

### C. MODULE-MASTER

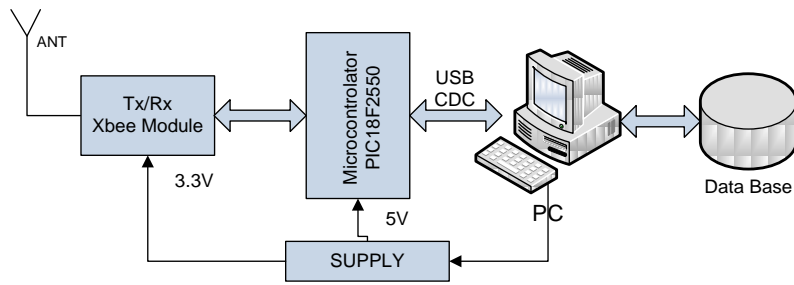
There is one, it is fixed and is responsible for collecting the information supplied by the user modules "to send to a database in which will then be processed. Routes also need to upload the units according to the table that manages the company.



**Fig 5. Block Diagram Module-Node**

This module consists of the RF circuit (ZigBee) and microcontroller with a USB interface for communication to the PC, it does not provide a backup power source and the user module will keep a backup of the information in the serial memory If external dump station is not active.





**Figure 6. Block Diagram-Master Module**

#### *D. RADIO FREQUENCY TRANSCEIVER XBEE [9]*

The transceiver module or radio frequency transceiver used in the TCS is manufactured by MaxStream XBee shown in Figure 7, which works in the 2.4 GHz band communication protocol 802.15.4 or Zigbee.



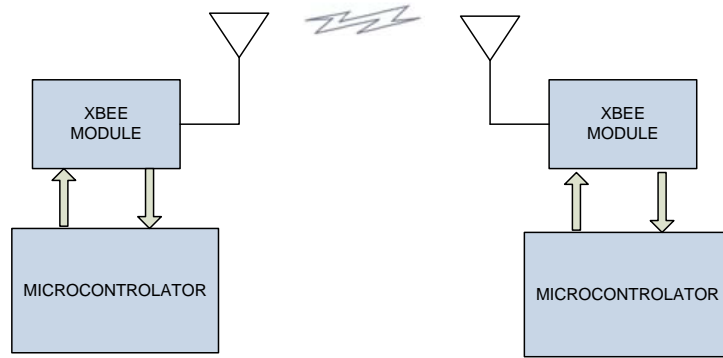
**Figure 7. MaxStream XBee module**

The XBee module connected directly to the Rx and Tx pins of the microcontroller, and immediately looks for more devices that are in the same network to associate with them, the time it takes to make the process of association is between 8 to 10 seconds.

This is the XBee module through wireless communication between fixed and master modules to the user.

The XBee modules can be programmed via hyperterminal and a serial interface with a MAX232<sup>4</sup> and a series of commands called AT.

<sup>4</sup> Converter Integrated Circuit TTL voltage levels to RS232 and vice versa.



**Figure 8. Block diagram, XBee Connection**

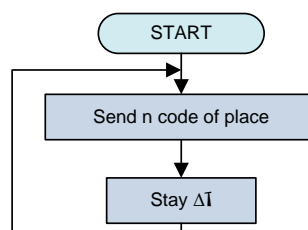
There are two types of interfaces, serial and USB, which can be used to program the XBee modules with proprietary software called X-CTU. With this software you can quickly define all the parameters you want to modify the modules.

The XBee modules will be configured to operate in the mode API (Application Programming Interface) as the frame-based API extends the level to which a host application can interact with all the networking capabilities of the module.

When is XBee API mode, all data entering and exiting the module are in frames that define the operations or events within the module.

## V. MICROCONTROLLERS FLOWCHART

Here are flowcharts of the programs of node, user and master module in the figures: Figure 9, Figure 10 and Figure 11, respectively to be implemented in microcontrollers that command the TCS.



**Figure 9. Flow Chart Node Module**

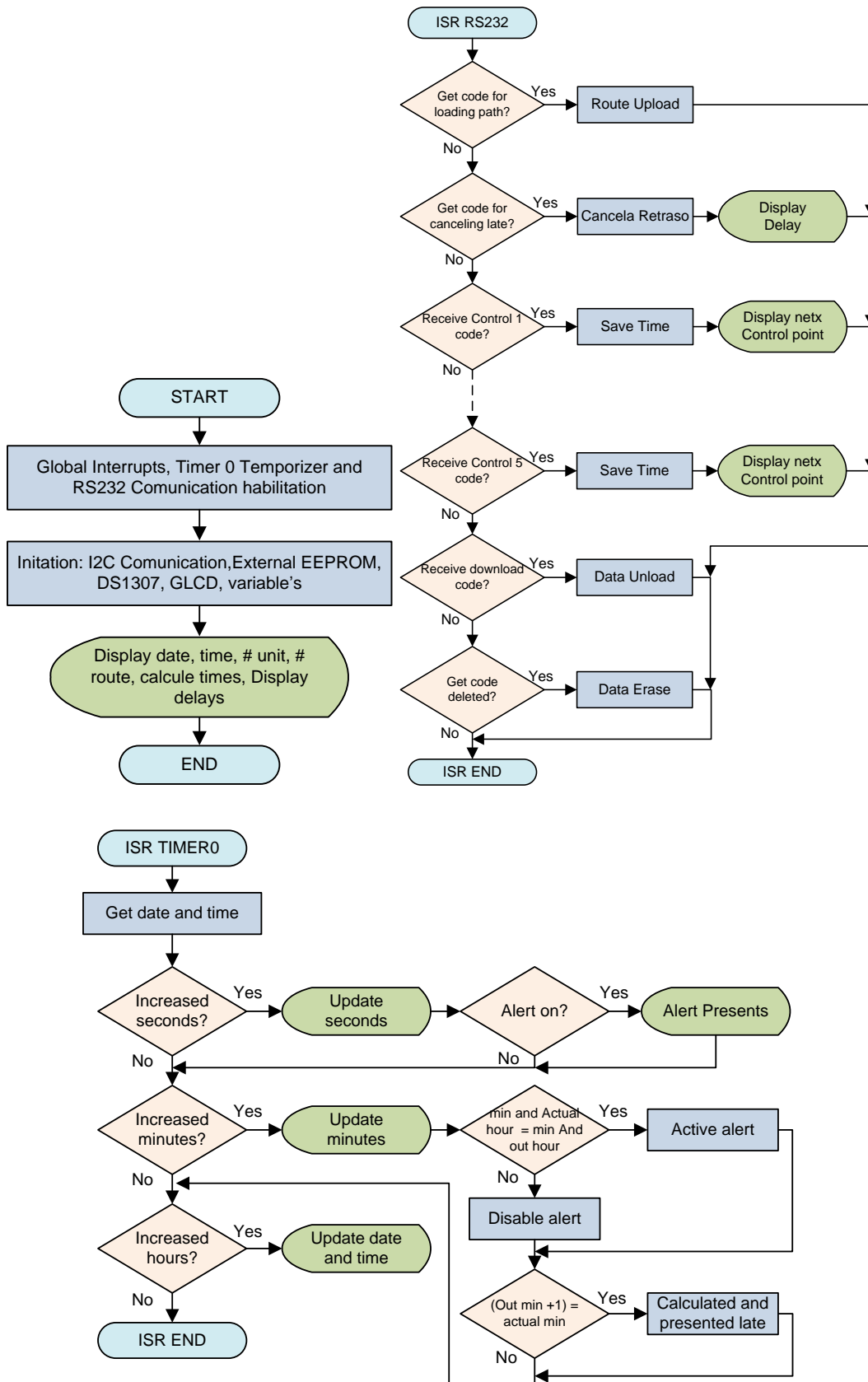
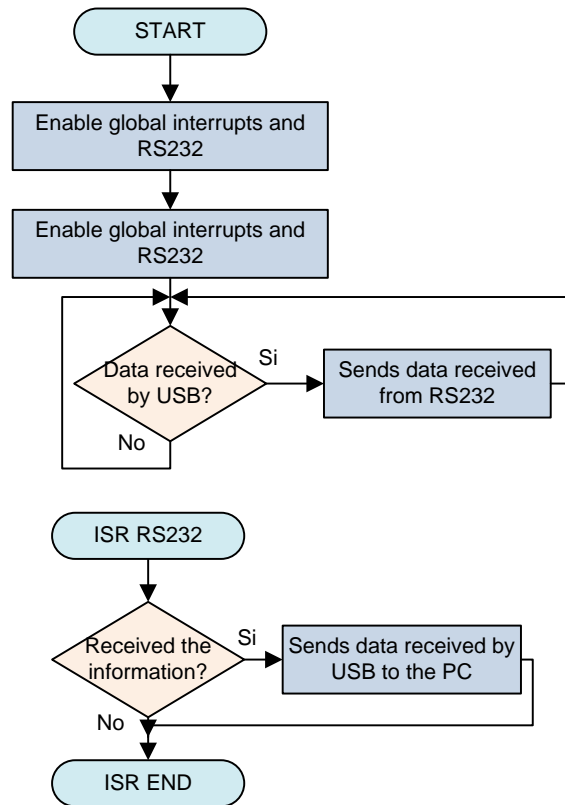


Figure 10. Flowchart User Module



**Figure 11. Flowchart Master Module**

## VI. DATA MANAGEMENT SOFTWARE

The application is developed in the Java programming language on NetBeans IDE 6.8 platform.

In Figure 12 we can see the main window of software, it has a table that is automatically updated every time I get a drive and download the data from its tracking table rows in the text being in red indicate delays that have occurred and these will be stored in a table in the database created for this purpose.

The data loaded in the table are: number of the unit identifier of the route, place of control, time allowed, time marked by unity and finally the minutes of delay that had the unit in the control site.

If you want to load on the table the data recorded in previous days, you select the desired date in the top of the window. The date selected is the current default.

In the bottom has buttons to access the Administration window, Load Path, Cancel, Delay and Working Table.



Figure 12. Software Main Window

#### A. MANAGEMENT WINDOW

This window is used to manage all enterprise data transport, data such as roads, control locations, times, destinations and information on the units.

#### B. LOAD ROUTES WINDOW

This window provides the option to select a date and the number of the unit to which you want to load a route, once selected these two data, the assigned path in the box will automatically work in the fields at the bottom Window: Route, Golf and Destination, as shown in Figure 13.

Change button gives the option to select a different route to the already allocated in the box in case work required by circumstances of transport companies, one of which is the case that a route is to be shared by two units, ie a unit working in the morning on the route and the other work on the same route but in the afternoon.



Figure 13. Window to load routes

Finally, pressing the Load button, the route will be sent to the selected unit, it will send an acknowledgment message right or wrong path.

### C. WINDOW TO CANCEL DELAYS

From this window you can select the number of the unit that is to cancel its delays and is automatically loaded into the window table existing delays as shown in Figure 14, in the lower left is presented in green the total minutes of delay on the right, in blue, the amount payable.

Pressing the PAY button offers the option to print a receipt for payment of duties delays as seen in Figure 15, here are details exactly when and where it was committed, in addition, the user module in the drive issues a confirmation of payment and minutes late marker is placed at zero.

In order to justify a delay, is selected from the table the delay you want and press the R justify button this change being recorded in the database and can be supported with relevant documentation, avoiding corruption within the company.



Figure 14. Cancel window Delays



Figure 15. Delay Payment Voucher

#### D. WINDOW TO DOWNLOAD THE DAILY WORK CHART

From this window it is assigned routes for each unit, it has two tabs, the tab Update Table to select the route that each unit will work for the selected date, while the Working Table tab you can view the table admitted previous tab and print.

## VII. DATABASE

The storage system was created in MySQL to be a management system relational database and free to use. A relational database is a set of data that is stored in tables among which relations are established to manage data more efficiently and safely.

The database is made up of 7 PTC related tables from which you have total control over the information because it is organized and provided the required consultations in the above tables presented windows.

## VIII. PERFORMANCE TESTING

After verifying the correct operation of the modules built, it was observed that there is adequate communication between the wireless range and towards the management software.

I began to assemble the different modules of the prototype with all its elements, making it necessary to perform a 35 meter extension cable connecting the transceiver and other circuitry on the master module to install on the outside of the Terminal Ground Transportation Cooperative "Otavalo" thus giving a greater coverage of the same, in Figure 16 indicates the physical location of the transceiver, it is at an approximate height of four meters.



**Figure 16. Location transceiver Master Module**



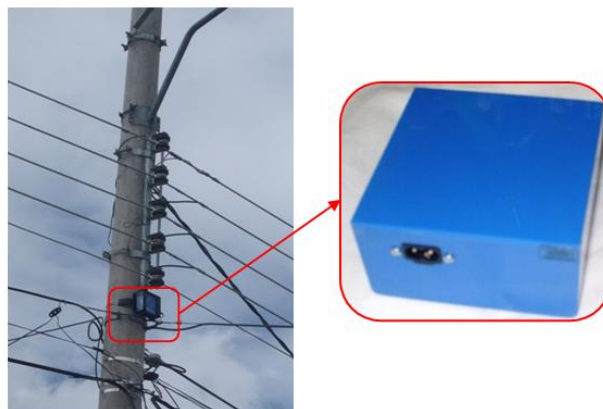
Master Module connects to Software Management via computer USB port for the operation of the TCS, which is located in the accounting office of the same cooperative in the town of Otavalo.

In Figure 17 shows the user module that was installed in the Transport Unit assigned to perform the system tests will be described later, this module should be located so as to be visible to the driver and not obstruct the wireless range of the transceiver.



**Figure 17. User Module**

Figure 18 shows one of five modules constructed nodes that comprise the system, which were installed at a height of five to six meters on poles of Northern Regional Electricity Company (EMELNORTE), located in strategic locations where the Cooperative Transport "Otavalo" sees fit to perform a time control as shown on the map in Figure 19.



**Figure 18. Node Module**

The total travel time from terminal to terminal is 40 minutes.

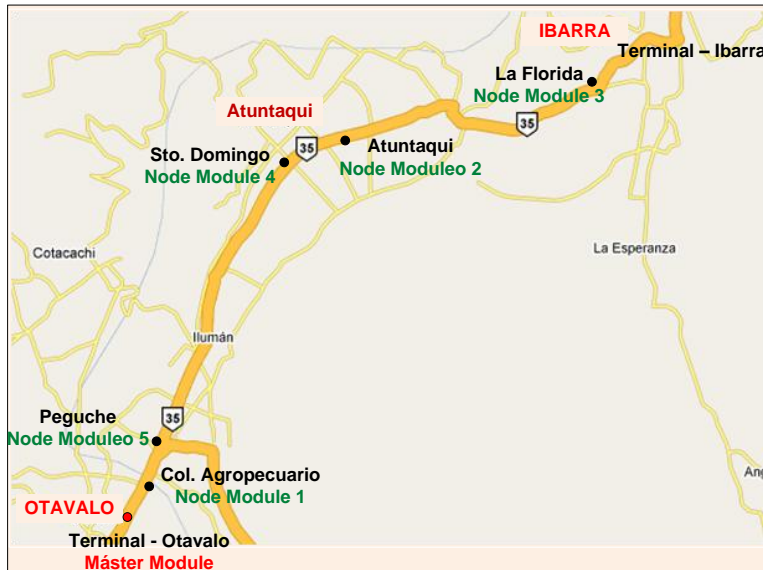


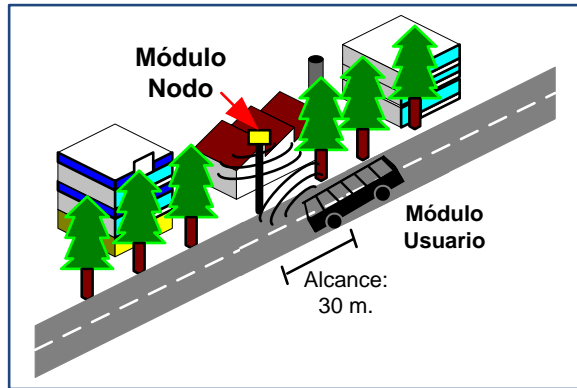
Figure 19. Real Location of Control Points

The tests focus on verifying the extent of the XBee modules with and without obstacles in order to determine the maximum speed at which you must pass the transport units for each control point and get the module information reliably and without errors.

#### A. SCOPE WIRELESS TEST:

##### 1) Scope with obstacles

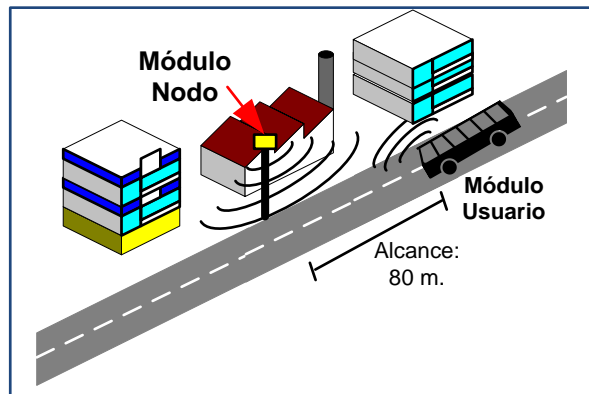
As shown in the diagram in Figure 20 Node module was placed at a height of 5 meters in a place surrounded by greenery, which resulted in a blast radius of 40 meters so that the transport unit must pass at approximately 30 to 40 km / h to record the time of travel, this is because the XBee modules used in the PTC use the access method CSMA-CA network which is a three phases in which the issuer first "listen" to see if the network is free, then transmits the data and then waits for a confirmation message from the receiver, which takes a period of 8 to 10 seconds to communicate between them.



**Figure 20. Testing scheme obstacles**

2) Unobstructed range

In Figure 21 we can see that by placing the Node Module at the same height of 5 meters and horizontal unimpeded, the operating range considerably increases by 100% over the highway that is approximately 80 meters, having move the transport unit at a speed of 72 km / h so that their movement will not be interrupted to record the time.



**Figure 21. Testing scheme unobstructed**

In conclusion, to ensure optimum performance of the TCS modules are installed on poles node whose power lines are 110 volts and are not surrounded by vegetation or buildings that may hinder the range of your wireless communication between devices that up.

## ***B. INTERFERENCE TESTING:***

When we used in wireless communication TCS the Product shall be exposed to a number of possible interference that is performed several tests of reach with equipment operating at the same frequency such as Bluetooth devices, cordless phones and microwave, the results were satisfactory the scope and fidelity of communication were not affected. While it is important to note that the closer the antennas of the devices to the XBee, displayed some minor variations in the link.

Completion of the test range and interference may indicate the validity of the system and wireless communication, as it works properly in a stable condition (keeping the modules with line of sight, ie horizontal smooth on the road) and common (temperature environment, climate within the limits of tolerance, etc..) thus I concluded that the system is valid.

## **IX. CONCLUSIONS**

- It was possible to automate the generation and delivery of information accumulated in the paths through the software and hardware designed and implemented.
- Increased reliability of the information provided because it ensures no human intervention in the process of generating and delivering it.
- The TCS can operate in case of absence of energy because it provides backup systems, both information on the modules and energy users in the node module.
- Decreases the possibility of error in the calculations of time delays on the routes because it is done by software.
- It justifies the project as it was possible to design a more efficient, reliable and economical than the system currently used in the timing of public transport units, which is currently operating in the Transportation Cooperative "Otavalo" of the province of Imbabura.

## **X. RECOMMENDATIONS**

- In the unloading station of information is recommended to avoid the use of microwave ovens and causing delays in the process of downloading time records from transport units.
- For better wireless coverage node modules, is recommended to install in places where there are no objects that could reduce the line of sight along the road within a radius of 100 meters so it is suggested to take the infrastructure Utility and install them in their public lighting poles at a height of between 5 and 7 meters.
- It is recommended that the battery backup Real Time Clock Module User once a year.
- To reduce costs of electricity consumption in the node module, you could use rechargeable gel because they have a long shelf life and require a load to the year due to low consumption of this module.
- To improve the time a link between the node and user modules are recommended to use the XBee transceiver series 2.

## **XI. ACKNOWLEDGEMENTS**

I appreciate the cooperation extended by the Transportation Cooperative "Otavalo" for its help in testing and access to data from the cooperative to the Northern Regional Electricity Company Otavalo and Ibarra agencies for their assistance in the installation of the modules nodes on street lighting poles of the company and my family to be present at all times giving me unconditional support.

## XII. REFERENCES

### INTERNET DOCUMENTS

- [1] Wikipedia. (2009). *ZigBee, IEEE 802.15.4*. Recuperados de:  
<http://es.wikipedia.org/wiki/ZigBee>  
[http://es.wikipedia.org/wiki/IEEE\\_802.15.4](http://es.wikipedia.org/wiki/IEEE_802.15.4)
  
- [2] Oyarce, A. (2009). *Guía de Usuario del módulo XBee en español*. Recuperado de: [http://www.olimex.cl/pdf/Wireless/ZigBee/XBee-Guia\\_Usuario.pdf](http://www.olimex.cl/pdf/Wireless/ZigBee/XBee-Guia_Usuario.pdf)
  
- [3] DomoDesk. (2009). *A fonfo: ZigBee*. Recuperado de:  
<http://www.domodesk.com/content.aspx?co=97&t=21&c=47>
  
- [4] National Instruments. (2009). *Zigbee*. Recuperado de:  
<http://zone.ni.com/devzone/cda/tut/p/id/7118>
  
- [5] Zigbee.es. (2009). *ZigBee-Información*. Disponible en:  
<http://www.zigbee.es/wp/>
  
- [6] Freescale Semiconductor, Electrocomponentes S.A. (2009). *Tecnología ZigBee. Un mundo de soluciones inalámbricas*. Recuperado de:  
<http://www.electrocomponentes.com/articulos/diciembre06/ZigBee.html>
  
- [7] Mayné, J. (2009). *IEEE 802.15.4 y ZigBee*. Recuperado de:  
[http://www.bairesrobotics.com.ar/data/ieee\\_zigbee\\_silica.pdf](http://www.bairesrobotics.com.ar/data/ieee_zigbee_silica.pdf)
  
- [8] García, C. (2009). *Zigbee, Comunicación para Dispositivos*. Recuperado de: <http://www.sg.com.mx/content/view/392>

- [9] Narváez, C. (2009). *Reloj de Tiempo Real*. Recuperado de:  
<http://www.bolivar.udo.edu.ve/microinternet/articulos/Reloj%20de%20Tiempo%20Real%20DS1307.pdf>
- [10] Microchip. (2009). *PIC18F2455/2550/4455/4550 Data Sheet*. Recuperado de:  
[ww1.microchip.com/downloads/en/devicedoc/39632c.pdf](http://ww1.microchip.com/downloads/en/devicedoc/39632c.pdf)
- [11] Digi. (2008). *Manual XBee*. Recuperado de:  
[http://ftp1.digi.com/support/documentation/90000982\\_B.pdf](http://ftp1.digi.com/support/documentation/90000982_B.pdf)
- [12] Microchip. (2009). *EEPROM 24LC256 Data Sheet*. Recuperado de:  
<http://ww1.microchip.com/downloads/en/DeviceDoc/21203Q.pdf>
- [13] PicManía by RedRaven. (2009). *El USB desencadenado: CDC USB*. Recuperado de:  
[http://picmania.garcia-cuervo.net/usb\\_3\\_cdctransfers.php](http://picmania.garcia-cuervo.net/usb_3_cdctransfers.php)
- [14] Ashram-Astaroth (2009). *Módulo UART Comunicación Serial*". Recuperado de: <http://www.ashram-astaroth.tk/articulos/modulo-uart-comunicacion-serial.html>
- [15] Carletti, E. (2009). *Comunicación Bus I<sup>2</sup>C*. Recuperado de: [http://robots-argentina.com.ar/Comunicacion\\_busI2C.htm](http://robots-argentina.com.ar/Comunicacion_busI2C.htm)
- [16] Wikipedia. (2009). *USB communications device class*. Recuperado de:  
[http://en.wikipedia.org/wiki/USB\\_communications\\_device\\_class](http://en.wikipedia.org/wiki/USB_communications_device_class)
- [17] Digi. (2009). *X-CTU Configuration & Test Utility Software*. Recuperado de: [http://ftp1.digi.com/support/documentation/90001003\\_A.pdf](http://ftp1.digi.com/support/documentation/90001003_A.pdf)

- [18] Moreno, C., “Construcción de una red ZigBee prototipo para la adquisición de datos desde transmisores de corriente de dos hilos”. Proyecto de titulación, Escuela Politécnica Nacional, Quito, Ecuador. Marzo. 2009.
- [19] Reinoso, E., “Diseño e implementación de un prototipo para una red de domótica y seguridad para un hogar utilizando el estándar IEEE 802.15.4 ‘ZigBee’”. Proyecto de titulación, Escuela Politécnica Nacional, Quito, Ecuador. Noviembre. 2008.
- [20] Andrango, W., Borja, E., “Diseño e implementación de una red inalámbrica para sufragio electrónico basada en el estándar ZIGBEE (IEEE802.15.4)”. Proyecto de titulación, Escuela Politécnica Nacional, Quito, Ecuador. Marzo. 2007.