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Real time location system (RTLS) focused on the optimization of efficiency for hospital center assistance

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Abstract

The following paper presents the development of a real-time localization system (RTLS) to facilitate the monitoring of people or objects in places where the use of radio frequency identification devices (RFID) becomes difficult. The development of the system uses ESP8266 commercial modules and 8-bit microcontrollers. Essentially the system consists of base stations and mobile points with a wireless charging system where practicality, mobility, portability and performance are the key factors for the efficiency of this localization system. Communication between the devices is done through TCP / IP protocol using the IEEE 802.11 b / g / n standard, which transmits the information necessary to determine the identification, location and if it is necessary an alert signal in case of the site's management requires some kind of assistance, offering this way different scopes in which real-time location is a key factor.

Keywords: RTLS, microcontroller, Wi-Fi, Trilateration.

INTRODUCTION

Currently the use of localization systems has been intensified [1] according to the needs of different sectors of the industry to know the real-time location of their products[2], a clear example of this overcrowding is related to monitoring patients or visitors in a hospital center, where, in addition to the location and identification, the availability of events information that alerts immediate patient assistance, when not being monitored or in need of help, may be important. This is why the need arises for a versatile location system regarding the work area being easy to handle for the user.[3]

One of the most used technologies within the location-based services is the one that uses RFID technology, this technology is defined as the wireless use of electromagnetic fields for data transfer; this transmission occurs between two or more communication devices (readers and labels) to locate objects or people [4]. In the case of real-time location, a possible solution would be the use of active RFID, in this case the labels send the signal to a reader every few seconds (just as a cell phone and a tower do) and the triangulation software calculates the position for the marked object; The biggest drawback of using this technology would be the high cost of the readers regarding their coverage. This paper proposes a low-cost RTLS technology solution, based on the implementation of an 8-bit microcontroller and an ESP8266 WIFI module implemented as either a base station as a mobile point [5], providing a practical, functional and economical solution to the location needs present at the hospital centers.

METHODOLOGY

The process begins with a mathematical analysis of the basic concept of trilateration, emphasizing each one of the operational modules in the electronic design, allowing to validate the correct operation of the proposed localization system. In general, an algorithm is proposed for the location determination based on the signal intensity (RSSI) delivered by the different network nodes[6,7], where the beacons or fixed points exchange the RSSI values measured between themselves and the mobile point. After this, an analysis of the data obtained to determine the location of the mobile point is performed, see Figure 1.[8]

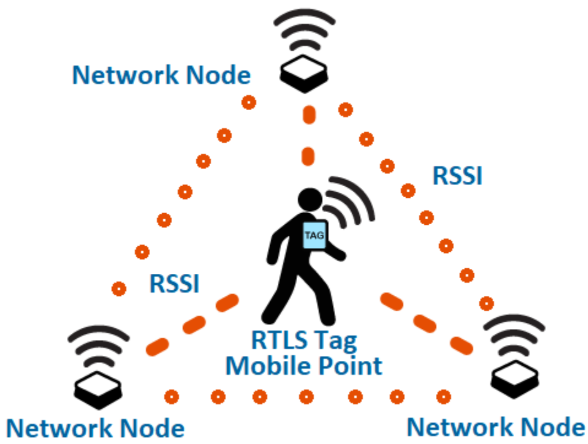

Figure 1: RSSI Location System.

Trilateration:

This method allows to know the location or coordinates of a point, depending on the measurement of distances to reference points or well-known coordinates [9]. This technique is the basis for the Global Navigation Satellite System (GNSS) placement, which provides a space-time reference frame over a specific coverage or action area. [10-12]

Gende and Molina [13] give a very complete description of the mathematical analysis associated with this technique, where it can be referenced the basic observation equation in the plane:

$$\rho = \sqrt{(x - x_0)^2 + (y - y_0)^2}$$

Where ρ is the observed quantity, $(x_0,\ y_0)$ are the known coordinates and $(x,\ y)$ the coordinates that are ignored. By presenting two unknowns in the problem, at least two equations will be required to find a solution, but a third equation will be used to find a unique solution.

$$\rho_1 = \sqrt{(x - x_1)^2 + (y - y_1)^2}$$

$$\rho_2 = \sqrt{(x - x_2)^2 + (y - y_2)^2}$$

$$\rho_3 = \sqrt{(x - x_3)^2 + (y - y_3)^2}$$

Starting from the three equations, a possible analytical resolution will be given by the solution of two quadratic equations, each of which will have two roots, with a single common root between both of the equations.

Raising to the square and subtracting the first equation to the second one:

$$d_1^2 = (x - x_1)2 + (y - y_1)2 = x^2 - 2xx_1 + x_1^2 + y^2 - 2yy_1 + y_1^2$$

$$d_2^2 = (x - x_2)2 + (y - y_2)2 = x^2 - 2xx_2 + x_2^2 + y^2 - 2yy_2 + y_2^2$$

$$d_1^2 - d_2^2 = -2x(x_1 - x_2) - 2y(y_1 - y_2) + x_1^2 - x_2^2 + y_1^2 - y_2^2$$

$$\frac{(d_1^2 - d_2^2) - (x_1^2 - x_2^2) + (y_1^2 - y_2^2)}{-2} = x(x_1 - x_2) + y(y_1 - y_2)$$

Calling:

$$\frac{(d_1^2 - d_2^2) - (x_1^2 - x_2^2) + (y_1^2 - y_2^2)}{-2} = A$$

Where:

$$\frac{A - x(x_1 - x_2)}{(y_1 - y_2)} = y$$

Replacing y in equations:

$$(x_1 - x_2) = \Delta x_{12}$$

$$(y_1 - y_2) = \Delta y_{12}$$

Then the solution is:

$$x^2\left[1 + \left(\frac{\Delta x_{12}}{\Delta y_{12}}\right)^2\right] + x\left[-2x_1 - 2A\frac{\Delta x_{12}}{\Delta y_{12}{}^2} - 2A\frac{\Delta x_{12}}{\Delta y_{12}}y_1\right] + \left[\frac{A^2}{\Delta y_{12}{}^2} + y_1^2 - d_1^2\right] = 0$$

Where two possible values of x (*x1, x2*) are generated as a solution to the system of equations, by performing the same procedure for equations 1 and 3 a total of 4 roots are obtained, of which 2 must finally coincide solving the problem.

Development also makes use of solutions through iterations by numerical methods, this is done by using the Newton's method, which describes the solution for the system of equations generated by the points with the following equation:

$$\begin{pmatrix} x_{k+1} \\ y_{k+1} \end{pmatrix} = \begin{pmatrix} x_k \\ y_k \end{pmatrix} - Jf(x_k, y_k)^{-1} * \begin{pmatrix} f_1(x_k, y_k) \\ f_2(x_k, y_k) \end{pmatrix}$$

Where $Jf(x_k, y_k)^{-1}$ is the Jacobian inverse matrix formed by the functions of the nonlinear equations system.[13]

SYSTEM ARCHITECTURE

The proposed system basically consists of 4 functional blocks (see Figure 2) which are:

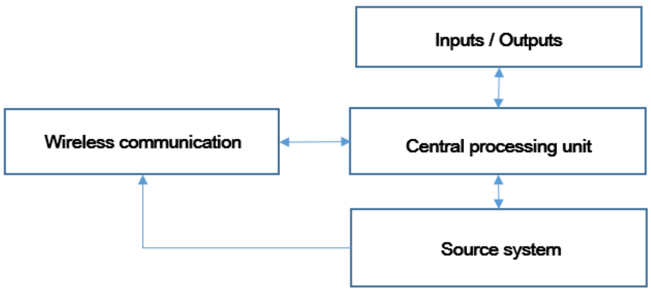

Figure 2: Proposed Block Diagram

Information processing:

The proposed system basically consists of an electronic control unit implemented in an 8-bit microcontroller (PIC18F1330), which is responsible for receiving signal levels (RSSI) and processing the received information. In the case of mobile points, this operational block is responsible for managing the inputs and outputs with which the user interacts, whether LED

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type elements (to know the current state of the device) or push buttons for alert generation. See Figure 3.

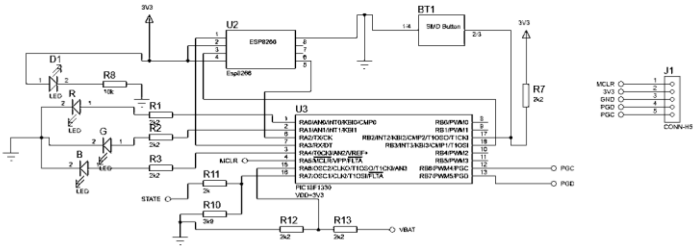

Figure 3: Microcontroller and ESP8266 Diagram

The beacons and the movable points are basically the same hardware, the only thing different between them is the type of power, since the fixed bases receive their power from an external AC source and the mobile nodes use a 3.7V Lithium-Ion battery.

Wireless Communication Modules:

Wireless communication is carried out using an ESP8266 module from Espressif Systems. This device works with 3.3V DC power; also, it works with IEEE 802.11b / g / n protocol, WPA / WPA2 security, with an operating frequency of 2.4GHZ. The device facilitates the implementing process of TCP/IP protocol stack that is managed through a simple UART communication to 15200 Baud.

Power source:

The power supply starts with a 5V DC linear regulator (LM1117DT-5.0) which allows a maximum input voltage of 20V DC. See Figure 4.

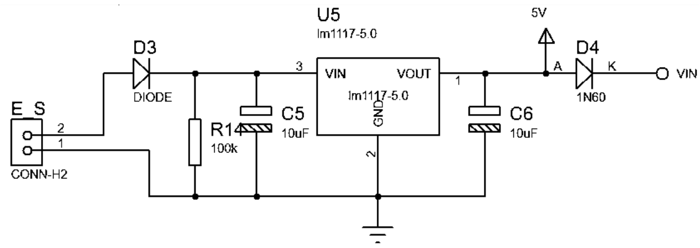

Figure 4: 5.0 Volt Regulation

The next stage is divided into two parts: the first part consists of powering the charging circuit which uses a 3.7 volts Lithium-Ion battery ideal to ease the portability of the device, see Figure 5, this is performed by the Microchip MCP7383-1 integrated circuit.

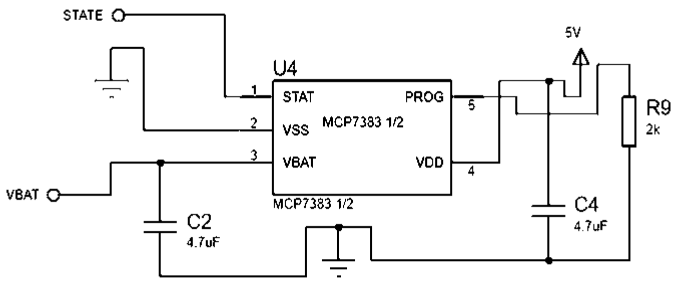

Figure 5: Charge Circuit Schematic Diagram

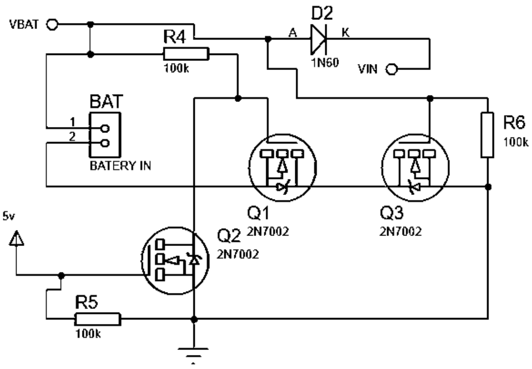

Figure 6: Switching of the external and internal power supply of the charge circuit

The second part is the voltage input to a 3.3 Volt linear regulator (MIC5205), having a very low "Dropout Voltage" (150mV), facilitating this way the use of 3.7V lithium battery. See Figure 7.

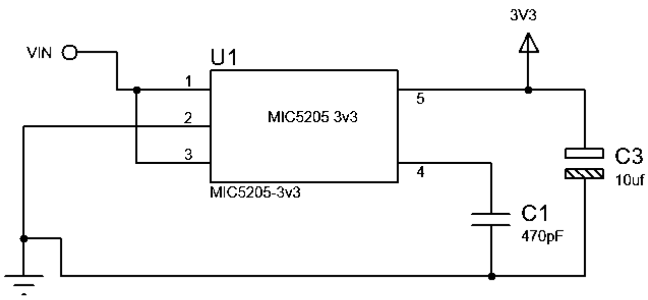

Figure 7: 3.3v Regulator Circuit

IMPLEMENTATION

The proposed RTLS system is responsible for determining the location of a mobile point in the following way: The mobile node reads the RSSI intensity of the nearby beacons and sends the information through the best quality signal beacon; the information travels through the beacon network using the TCP / IP protocol to the central processing unit, this happens because the beacons operate in 2 different modes, access point mode and station mode.

Now it is necessary to know the flowchart of the algorithm responsible for performing the coordinate calculation in the microcontroller, see Figure 8, this process allows to determine the position of the mobile point in a practical and a simple way for the coverage area of the installed network.

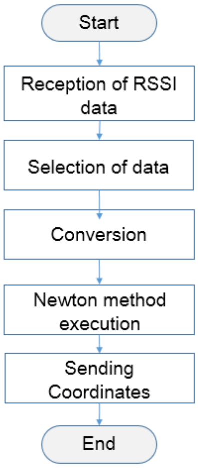

Figure 8. Process Flow Diagram

Receiving RSSI data: In this part, the RSSI census data from the mobile point is received regarding its nearby beacons.

Data selection: The 3 most relevant values of intensity are taken (with the biggest amount in dBm).

Conversion: a conversion of intensity to meters is performed using the following equation:

$$\text{RSSI (dBm)} = -10N\log_{10}(d) + A$$

Where A is the received signal value in dBm at a distance of 1 meter, "d" is the distance in meters and "N" is the propagation constant or path-loss exponent; its value is between 1.8 and 4.3 (at free space N = 2 as reference).

Newton's method execution: two of the three data in meters are taken with the coordinates of their respective beacons, the system of nonlinear equations is generated and solved through the method mentioned above, 2 possible solutions are obtained, so it re-evaluates the algorithm between one of the previously used data and the missing one, then, there is only one possible coordinate result to satisfy the generated equations.

Coordinates sending: once the coordinates of the mobile point are determined, they are sent for later graphing and interpretation.

RESULTS

In order to determine the stable behavior of the proposed system, a series of RSSI measurements were performed between a beacon and a mobile point, see Table 1, the latter located in a fixed position; this measurement sought to validate the continuous operation of the information processing algorithm that was designed for the implemented cards microcontroller. This measurement was performed during 24 continuous hours taking as a result the graphic shown in Figure 9 .

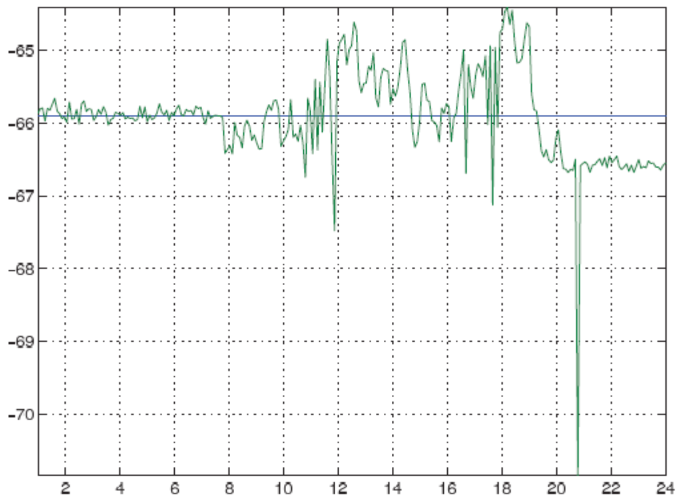

Figure 9: RSSI Intensity in dBm versus Time in hours.

Table 1: Test obtained data

Distance regarding the original point			
Sample	Point coordinates	Graphic units coordinates	Error (meters)
Mid position with iteraction 1st experiment	(218, 375)	(170, 392)	0.3
Mid position w/o iteraction 1st experiment	(218, 375)	(160, 423)	0.6
Mid position with iteraction 2nd experiment	(40, 580)	(38, 610)	0.2
Mid position w/o iteraction 2nd experiment	(40, 580)	(98, 655)	0.7

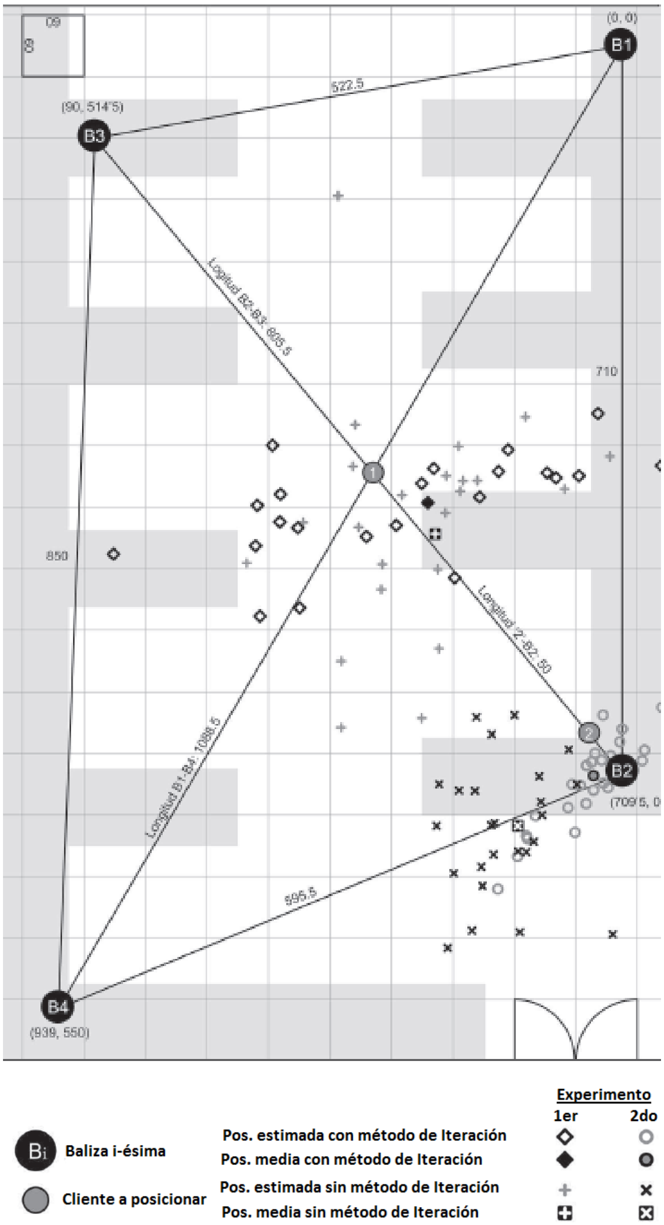

Figure 10: Dispersion of estimated positions with and without iteration method.

CONCLUSIONS

The proposed design, despite using an 8-bit architecture, had a high efficiency since it presents a minimum error of 32 cm regarding the actual position of the mobile point, guaranteeing a fast detection of the patient at delimited hospital areas, resulting in an adequate utility to determine the position and to effectively manage the attention to this system users.

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