Health and Technology (2020) 10:479–483
https://doi.org/10.1007/s12553-019-00393-6

ORIGINAL PAPER

RFID + Wi-Fi system to control the location of biomedical equipment within hospital areas and linked to an intelligent inventory

F. Salinas Gómez[1] · N. E. Suárez Escobar[1] · J. Vázquez[2]

Received: 3 September 2019 / Accepted: 27 October 2019 / Published online: 21 December 2019

Abstract

One of the most common problems in a hospital is the loss of medical equipment due to the change of areas to cover emergency needs. As a consequence, some preventive maintenance is omitted for months, causing a reduction in the useful life of the medical equipment, an additional investment of resources by the hospital and, mainly, a greater risk to the patient or medical staff. In this work we propose the development of an RFID + Wi-Fi access control system for medical equipment in the different areas of a hospital linked to an intelligent inventory. The system consists of 10 antennas mounted on each equipment with an RFID reader RC522 using a frequency of 13.56 MHz, a Wi-Fi NodeMCU card allows the transmission of equipment data to the inventory to keep it updated. The developed interface allows the interaction of the area of biomedical engineering with the records in the inventory, but also performs the deployment of important information such as: equipment documentation, an intelligent maintenance manager and an access meter based on the mobility of the equipment and the areas involved to detect needs in future purchases for the institution.

Keywords Medical equipment · Technology management · Clinical engineering · Inventory · Maintenance · RFID

1 Introduction

Clinical Engineering deals with the hospital technology management whose main objective is to achieve excellent care at reasonable costs, through the organization of medical equipment, supplies and personnel management in: equipment installation, the implementation of corrective activities, training of new personnel and the establishment of schedules for preventive maintenance. [1]. Additionally, a clinical engineer must perform small technological developments and innovations assuring an optimal cost-benefit ratio [1, 2].

An inventory is a fundamental part of a management system for hospital medical equipment and supplies. It plays an important role during audits and annual examinations, and it's considered effective, as long as the history is updated when there are changes or new information [3]. However, the reality is different because medical equipment is moved from one area to another, and frequently, there are not updates with the actual location, generating several repercussions as: the omission or delay of preventive maintenance, the accumulation of work and an increase in the corrective maintenance rate. If during the dates of preventive maintenance, this loss is greater than one week, is reduced the useful life of the equipment and a greater damage is generated, becoming a potential danger for the patient or the user. In addition, the impact for the hospital is an increase in the expenses designated for equipment maintenance. In all hospitals, the medical equipment has a unique serial number with which the biomedical engineering department can define maintenance dates and track them when they move from one area to another. However, the search of equipment in all areas is tedious, delayed, promotes the contamination of sterile areas and reduces the efficiency of the department.

The problem described above was detected by the authors of this work in two hospitals from different cities (public and private) during their professional practices. Also countless similar cases have been reported by other students in the same

✉ F. Salinas Gómez
salinasgomezfanny@gmail.com; naomi.su.es@gmail.com

✉ N. E. Suárez Escobar

[1] Biomedical Engineering Student, Polytechnic University of Chiapas, Suchiapa, Chiapas, Mexico

[2] Department of Biomedical Engineering, Polytechnic University of Chiapas, Suchiapa, Chiapas, Mexico

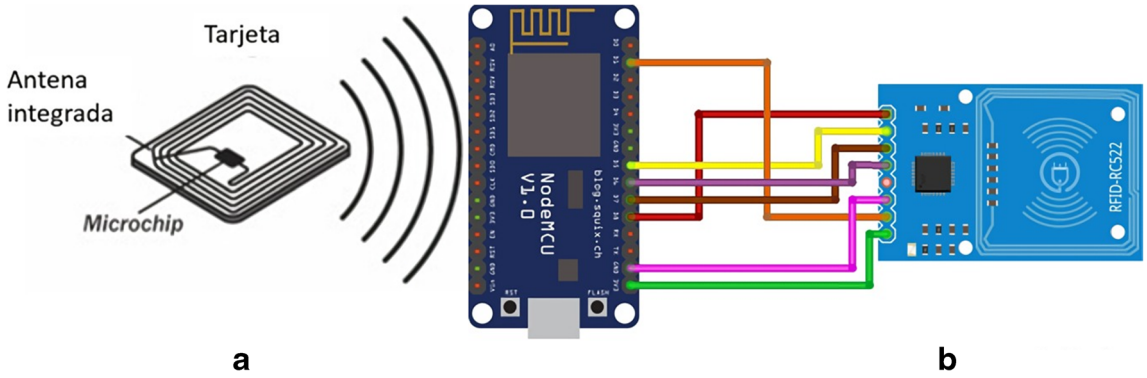


Fig. 1 **a** Elements that make up s RFID card: antenna in spiral form and microchip. **b** Connection implemented between the NodeMCU and RFI-RC522 modules

university, without having knowledge of an available commercial solution.

The development of a wireless low-cost system that allows the expeditious location of medical equipment and avoids the individual search of each of them, would be a technological innovation and a great help for the biomedical engineering department.

Currently there are companies dedicated to the control of fixed assets and inventories, Astlix S.A. de C.V. [4] uses RFID technology to track the shortages and surplus products or those that are outside the usual area of use.

In this document we present the design of an RFID system with Wi-Fi that tracks the location of medical equipment to improve information activities, monitoring and maintenance of the inventory with a computer application of a biomedical engineering department.

2 Methodology

The system consists of three important stages: the access control block that was developed with RFID technology e a Wi-Fi card, a database for the equipment inventory and the application where all the information available can be consulted.

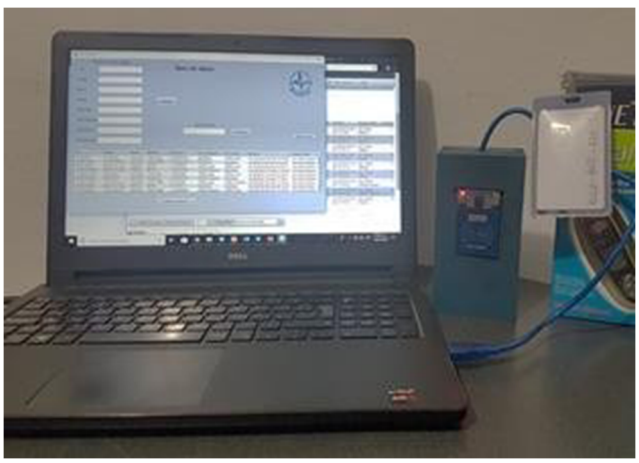


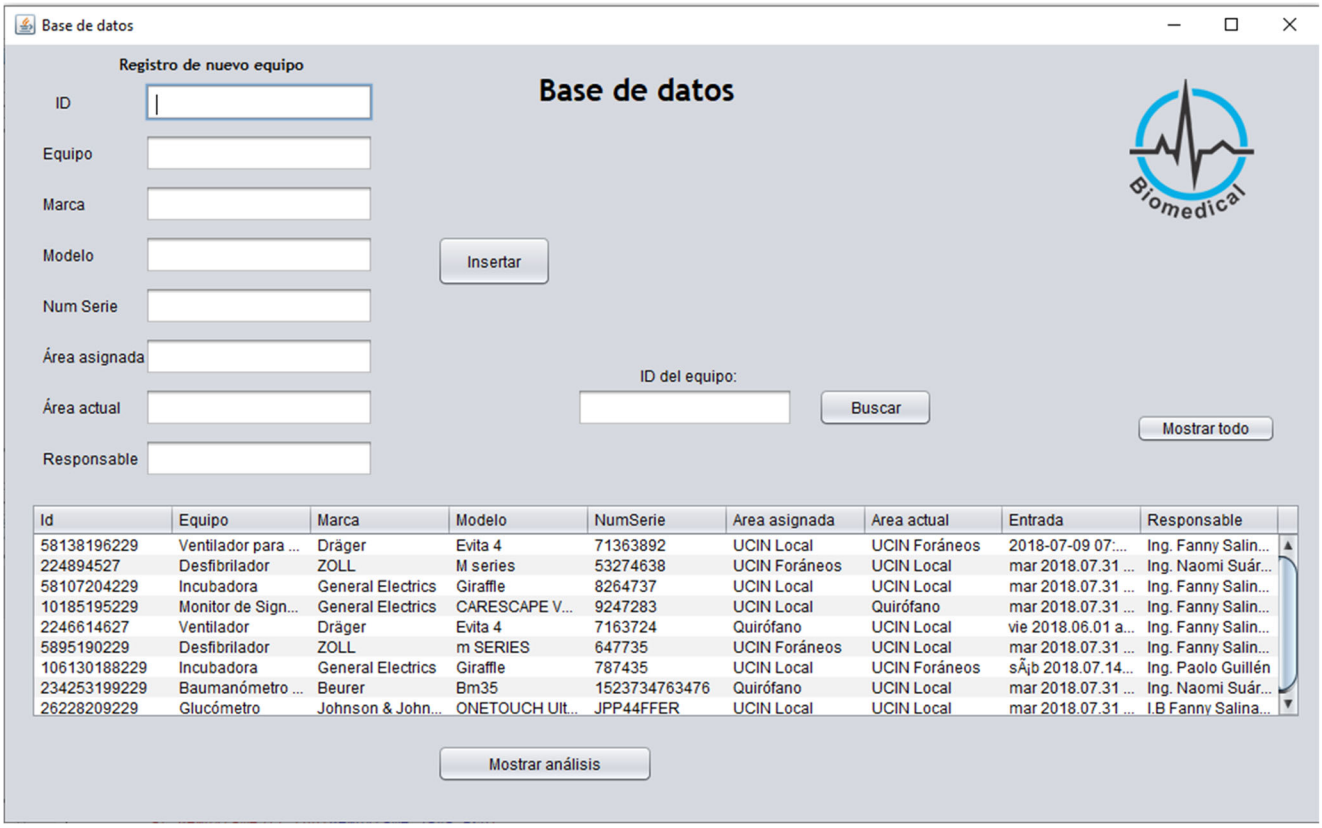
Fig. 2 System installed in the Department of Biomedical Engineering

To obtain the location of the medical equipment, a RFID & Wi-Fi hybrid system was developed. In this system, each equipment carries a card for identification, and through the use of a reader at the entrance of each hospital area, the system detects the access of the equipment and recorded it in the inventory, where it can be consulted when required. The information of each equipment can be captured in the hospital inventory using the computer application. The main steps of the development of our prototype are detailed below.

2.1 RFID and Wi-fi reading system

RFID technology is a system for the identification and detection of typical radio frequencies (125 KHz, 13.56 MHz and 868 MHz) [5]. The main feature of RFID technology is the use of a card to store information and a card reader that reads or verifies the information [6, 7]. The card (Fig. 1a) has s microchip an antenna and a read and write capacity of 1Kb, with memory is organized into 16 sectors of 4 blocks of 16 bytes each and, in addition, have a number of different series according to the ISO14443 standard. Additionally, these incorporate a high level of security in the transmissions and do not require batteries to maintain the information (known as passive radio frequency). The frequency of transmission used in our RFID system is 13.56 MHz, which has demonstrated total compatibility and without interference with standard and commonly used medical equipment [8].The card reader module used is RFID-RC522, with a 13–26 mA operating current at 3.3 V and a maximum data rate of 10 Mb/s. For the reception of the collected data from the RFID module, a Wi-Fi NodeMCU was used which has a highly integrated ESP8266 chip, a 128kBytes memory and TCP/IP protocol (both modules are shown in Fig. 1b).

The RFID card reader detects the ID number of the card when it is within the approximate 10 cm range, sending the data through the NodeMCU, via Wi-Fi the data is sent to the



Id	Equipo	Marca	Modelo	NumSerie	Area asignada	Area actual	Entrada	Responsable
58138196229	Ventilador para ...	Dräger	Evita 4	71363892	UCIN Local	UCIN Foráneos	2018-07-09 07:...	Ing. Fanny Salin...
224894527	Desfibrilador	ZOLL	M series	53274638	UCIN Foráneos	UCIN Local	mar 2018.07.31 ...	Ing. Naomi Suár...
58107204229	Incubadora	General Electrics	Giraffle	8264737	UCIN Local	UCIN Local	mar 2018.07.31 ...	Ing. Fanny Salin...
10185195229	Monitor de Sign...	General Electrics	CARESCAPE V...	9247283	UCIN Local	Quirófano	mar 2018.07.31 ...	Ing. Fanny Salin...
2246614627	Ventilador	Dräger	Evita 4	7163724	Quirófano	UCIN Local	vie 2018.06.01 a...	Ing. Fanny Salin...
5895190229	Desfibrilador	ZOLL	m SERIES	647735	UCIN Foráneos	UCIN Local	mar 2018.07.31 ...	Ing. Fanny Salin...
106130188229	Incubadora	General Electrics	Giraffle	787435	UCIN Local	UCIN Foráneos	sÃ¡b 2018.07.14...	Ing. Paolo Guillén
234253199229	Baumanómetro ...	Beurer	Bm35	1523734763476	Quirófano	UCIN Local	mar 2018.07.31 ...	Ing. Naomi Suár...
26228209229	Glucómetro	Johnson & John...	ONETOUCH Ult...	JPP44FFER	UCIN Local	UCIN Local	mar 2018.07.31 ...	I.B Fanny Salina...

Fig. 3 Interface for registering new equipment and consulting the database

inventory for record the equipment access to the assigned area and the updates of date and time.

2.2 Database

MySQL™ was used for the development of the inventory, through a database that helps us to update and insert new equipment records, create new tables, procedures and views, and set the corresponding permissions for each user.

With a .php file, the database saves the area exchanges records of each equipment inside the hospital, and keeps it related to the basic information corresponding to the serial number, manufacturer, model, technical specifications, responsible and assigned area. In such manner, is easier for the biomedical engineering department to know the real location of the equipment when they require scheduled preventive maintenance.

2.3 Computer application

The inventory interface was programmed in Java NetBeans for a computer with Windows 7, 8 and 10 operating system. The advantages of this language are: an integrated development environment (IDE), free software and open source compatible with MySQL. The interface designed allows the visualization of the information received and stored in the database. The equipment data capture needs to be done just once, when it is a new equipment, and the card reading is automated to simplify the task for biomedical engineering department.

The complete system installed for the biomedical engineering department is shown in Fig. 2.

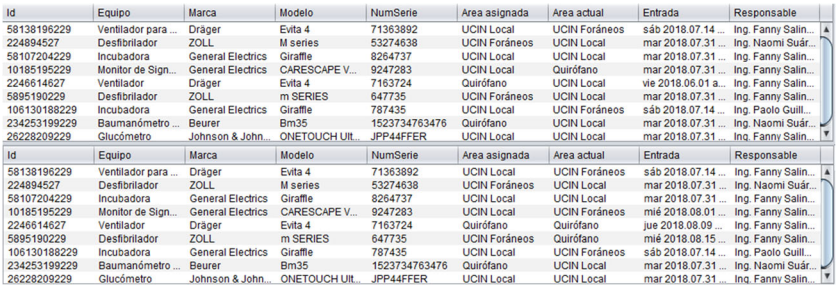
3 Results

The system was implemented in a public hospital in the state of Chiapas. In order to assure the correct use of the proposed system and also to improve the quality of care provided to the patient by the hospital, it was very important to train people in charge of the mobilization of the medical equipment by knowing the aim, impact, and all benefits of the implementation.

The registry was made with 10 equipment assigned to the system: 3 incubators, 3 radiant heat thermal cots, 3 vital sign monitors and a glucometer, which were distributed in 3 of the most active areas due to many patients transfers: the operating room, the local and external Neonatal Intensive Care Unit (NICU).

In Fig. 3 can be seen the interface with the fields for the registration of new equipment and the database with the records in the inventory that corresponds to the 10 equipment.

The detection systems were installed at the entrance of each pre-assigned area of the hospital wich allows in any area exchange, the card passes near the detector, providing the



Id	Equipo	Marca	Modelo	NumSerie	Area asignada	Area actual	Entrada	Responsable
58138196229	Ventilador para ...	Dräger	Evita 4	71363892	UCIN Local	UCIN Foráneos	sáb 2018.07.14 ...	Ing. Fanny Salin...
224894527	Desfibrilador	ZOLL	M series	53274638	UCIN Foráneos	UCIN Local	mar 2018.07.31 ...	Ing. Naomi Suár...
58107204229	Incubadora	General Electrics	Giraffle	8264737	UCIN Local	UCIN Local	mar 2018.07.31 ...	Ing. Fanny Salin...
10185195229	Monitor de Sign...	General Electrics	CARESCAPE V...	9247283	UCIN Local	Quirófano	mar 2018.07.31 ...	Ing. Fanny Salin...
2246614627	Ventilador	Dräger	Evita 4	7163724	Quirófano	UCIN Local	vie 2018.06.01 a...	Ing. Fanny Salin...
5895190229	Desfibrilador	ZOLL	m SERIES	647735	UCIN Foráneos	UCIN Local	mar 2018.07.31 ...	Ing. Fanny Salin...
106130188229	Incubadora	General Electrics	Giraffle	787435	UCIN Local	UCIN Foráneos	sáb 2018.07.14 ...	Ing. Paolo Guill...
234253199229	Baumanómetro ...	Beurer	Bm35	1523734763476	Quirófano	UCIN Local	mar 2018.07.31 ...	Ing. Naomi Suár...
26228209229	Glucómetro	Johnson & John...	ONETOUCH Ult...	JPP44FFER	UCIN Local	UCIN Local	mar 2018.07.31 ...	Ing. Fanny Salin...

Id	Equipo	Marca	Modelo	NumSerie	Area asignada	Area actual	Entrada	Responsable
58138196229	Ventilador para ...	Dräger	Evita 4	71363892	UCIN Local	UCIN Foráneos	sáb 2018.07.14 ...	Ing. Fanny Salin...
224894527	Desfibrilador	ZOLL	M series	53274638	UCIN Foráneos	UCIN Local	mar 2018.07.31 ...	Ing. Naomi Suár...
58107204229	Incubadora	General Electrics	Giraffle	8264737	UCIN Local	UCIN Local	mar 2018.07.31 ...	Ing. Fanny Salin...
10185195229	Monitor de Sign...	General Electrics	CARESCAPE V...	9247283	UCIN Local	UCIN Foráneos	mié 2018.08.01 ...	Ing. Fanny Salin...
2246614627	Ventilador	Dräger	Evita 4	7163724	Quirófano	Quirófano	jue 2018.08.09 ...	Ing. Fanny Salin...
5895190229	Desfibrilador	ZOLL	m SERIES	647735	UCIN Foráneos	Quirófano	mié 2018.08.15 ...	Ing. Fanny Salin...
106130188229	Incubadora	General Electrics	Giraffle	787435	UCIN Local	UCIN Foráneos	sáb 2018.07.14 ...	Ing. Paolo Guill...
234253199229	Baumanómetro ...	Beurer	Bm35	1523734763476	Quirófano	UCIN Local	mar 2018.07.31 ...	Ing. Naomi Suár...
26228209229	Glucómetro	Johnson & John...	ONETOUCH Ult...	JPP44FFER	UCIN Local	UCIN Local	mar 2018.07.31 ...	Ing. Fanny Salin...

Fig. 4 Area changes updated in the inventory

corresponding inventory record.In Fig. 4, shows the assigned location and the actual location of the equipment with the corresponding date and time of entrance, that was recorded automatically using the technology described in this paper.

By clicking on the "Mostrar Análisis" button (see Fig. 3), our system displays three kind of data that are relevant to any basic data analysis developed by a biomedical engineering department, but these are normally discarded in any conventional inventory. The three kind of data are explained below.

Block 1: As can be seen in Fig. 4, due to the 8 changes of area registered by the system, the database automatically generates preventive maintenance dates, according to the conventional use of the area. In this example, due to the changes of area registered by the RFID system, the inventory adjusts the date of the next maintenance (indicated as an extra maintenance).

Block 2: The inventory calculates basic statistical data like, the number of times the equipment has been used in other areas (Fig. 5)

Block 3: By clicking on the "Documentacion" button, the inventory displays a window (see Fig. 6) with information of the equipment that should be stored: invoice copy, user manual, drivers, service manual, guarantee policies, maintenance reports during the useful life of the same and a final report for its consideration as a source of spare parts at the time of its withdrawal.

4 Discussion

The system implemented allows the automatic detection and location of equipment without the need to verify each one of the labels of the equipment. The first test carried out with the system in a public hospital using 10 medical equipment, shows it is economically viable and functional to be implemented in a greater number of areas. Since, the current reading distance has little scope (10 cm approx.), we are working on the development of an antenna with greater range to avoid the need of closeness between the equipment and the card reader. An advantage of our proposal is that biomedical engineering department keeps the hospital inventory updated, in the shortest possible time. Additionally, our developed application registers each equipment exchange between the areas to detect needs by area and equipment, to be considered by biomedical engineering department for future purchases or acquisitions.

5 Conclusion

Thanks to the implementation of this system in this test, the medical equipment was easily found in the hospital during his preventive maintenance date, because the inventory keeps every updated record. After the use of our system, the biomedical department sustains a correct compliance of the

Fig. 5 Analysis interface by equipment

Fig. 6 Interface for the registration and consultation of files referring to medical equipment

preventive maintenance schedules in time and form established by the hospital. The main advantage observed until now is a better management of resources, both monetary and human, with a significant saving in the reduction of corrective maintenance or the subrogation of these. Engineers work more efficiently, because there is more time to carry out the activities planned for each day, and reduces the accumulation of work caused by poor compliance, as well as, a decreasing probability of damages that could became a risk for the patient or medical staff. In this way, the proposed system brings improvements to conventional work developed by a biomedical engineer as well as a solution to everyday problems of Clinical Engineering.

Acknowledgments Special thanks to the Biomedical Engineering Department of the Women's Hospital of San Cristobal de las Casas, Chiapas for allowing the implementation of the system in their facilities.

Funding information The authors received no financial support for the research, authorship, and/or publication of this article.

Compliance with ethical standards

Conflict of interest The authors report no conflicts of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Miniati R. Clinical engineering: from devices to systems. United States: Elsevier; 2016.
2. Denis ER. Ingeniería Clínica. Cuba: Instituto Superior Politécnico José Antonio Echeverría; 2003.
3. Organización Mundial de la Salud. Introducción a la gestión de inventarios de equipo médico. OMS; 2012. https://apps.who.int/medicinedocs/documents/s21565es/s21565es.pdf
4. I. y. D. R. Astlix - Tecnología. «Astlix,» 17 Febrero 2018. [En línea]. Available: http://www.astlix.com/
5. Puglia A, Puglia M y Hunt D. RFID-a guide to radio frequency identification. New Jersey: Wiley; 2007.
6. Herrera L y William A. «Diseño y construcción de un prototipo para el control y monitoreo de registro de tiempos de transporte urbano mediante el uso de tecnología RFID, Arduino Mega y Raspberry Pi 2,» 25 agosto 2017. [En línea]. Available: http://bibdigital.epn.edu.ec/handle/15000/18366
7. Gutiérrez Díaz MP y Villegas Téllez R. Sistema de control de acceso basado en tecnología Arduino y RFID, vol 3. Guanajuato: Universidad de Guanajuato; 2017. p. 547–550.
8. Kaniewicz D y Segal F. Implementación de la Tecnología RFID en el ámbito hospitalario. Uruguay: Facultad de Ingeniería, Universidad ORT Uruguay; 2013.