International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-6, March 2020

A Wi-Fi Based Indoor Positioning System for Hospitals using Fingerprinting

EL ABKARI Safae, JILBAB Abdelilah, EL MHAMDI Jamal

Abstract: ***How to ensure an efficient medical personnel and equipment management within a hospital and help patients specially in emergency medical conditions. This paper presents a Wi-Fi based indoor positioning system for hospitals. It firstly presents the proposed indoor positioning procedure, analyses the advantages of Wi-Fi compared to the common positioning technologies; then designs the server-based indoor positioning system for hospitals. Finally, fingerprinting algorithm is used to position in real time. Shown as result of the conceived system tests, indoor positioning within hospitals can be realized.***

Keywords: Indoor positioning, Wi-Fi, RSSI, fingerprinting, server-based, hospital, healthcare

I. INTRODUCTION

In recent years, the concept of intelligent medicine emerges with wireless and computer technology development [1]. The most advanced technology -Internet of things [2] is used in intelligent medicine to make the interaction between two entities (medical personnel, medical institutions, medical equipment, patients) possible and easy to build an intelligent informatization system. Through intelligent medicine based on advanced concept and technology, we provide indoor positioning, thus a tracking and improvement of the hospital management and patients' treatment experience.

Indoor positioning technology is increasing in various domain nowadays. It is rarely used in hospitals while commonly used in museums and shopping malls [3–4]. Wi-Fi, Bluetooth or RFID (Radio frequency Identification) represents the most used technologies for indoor positioning applications. Wi-Fi technology offer the advantages of positioning, monitoring and tracking in a large-sized area using the existing network infrastructure. It also permits self-location propriety which is the basis of most of applications. Bluetooth technology uses the measured signal strength to locate objects. It can be easily popularized and integrated in mobile phone and PC. But this technology remains relatively expensive and vulnerable to interfere with noisy signals specially in complex space environments. Radio frequency identification is radio frequency based. It is a non-contact technology mainly used for recognition and positioning by two-way data communication. It has a lack of communication ability, short distance efficiency and integration difficulty into other systems. But it is low cost, has a high transmission range and provide location information in few milliseconds.

In this paper, we introduce a Wi-Fi based indoor positioning systems for hospitals. It positions in real time within hospitals exploiting Internet of things advantages. Our proposed system can bring convenience to both patients and medical personnel due to its fast response, accuracy and ease of use.

Manuscript received on February 10, 2020.
Revised Manuscript received on February 20, 2020.
Manuscript published on March 30, 2020.
* Correspondence Author
Safae El Abkari*, Department of Electrical Engineering, Ecole Normale Supérieure de l'Enseignement Technique, Rabat, Morocco.
Abdelilah Jilbab, Department of Electrical Engineering, Ecole Normale Supérieure de l'Enseignement Technique, Rabat, Morocco.
Jamal El Mhamdi, Department of Electrical Engineering, Ecole Normale Supérieure de l'Enseignement Technique, Rabat, Morocco.

II. WI-FI BASED POSITIONING

This method uses the Wi-Fi technology standards and hardware to position or track. Depending on the intended purpose and conditions of the locating environment, we make a distinction between server-based and client-based approach.

• **Server-based:** positioning process takes place via Wi-Fi locating node or Wi-Fi locating tags that receives positioning signals, measures their strength and forward them to the application platform. The server then calculates respective locations; therefore, no application is required for this positioning type.

• **Client-based:** positioning process takes place on the users' device. An application is required to evaluates signals from Wi-Fi locating nodes. It has an available back channel (push notifications…).

A. Server-based Positioning

Indoor positioning process via server refers to position calculation via a server within a locating area. It is frequently used for people and objects tracking without any required application.

• *Wi-Fi Locating Nodes/Tags indoor positioning technology*

Those nodes are hardware components. They are capable of detecting all Wi-Fi end users, flexible and suit track objects in large areas perfectly.

• Third-party providers Indoor positioning technology

It uses a system from a third-party provider (Aruba, Cisco…).

B. Client-based positioning

Indoor positioning via client refers to the calculation of the position directly via the device of the end user (smartphone usually…).

It requires an application to analyze available Wi-Fi signals strength and provide positioning. This method is often used for navigation project where communication with the user is needed.

Table I. Comparison of three of common indoor positioning techniques

Technology	Accuracy	Range	Suitable for	Power consumption
Wi-Fi	< 15 m	< 150 m	Area detection	Medium
Bluetooth	< 8m	< 75 m	Area detection	High
RFID	< 10 cm	< 1 m	Spot detection	-

Table 1 shows the difference between Wi-Fi and two other technologies of indoor positioning techniques [5]. Compared with Bluetooth and RFID, Wi-Fi has the advantage of the use of the existing WLAN installed in hospitals, large coverage and a good low cost-power ratio.

In this paper, we used ESP8266 Wi-Fi module, as shown in the following figure. It is based on IEEE 802.11 b/g/n standard, and can meet the requirement of Wi-Fi based indoor positioning systems.

Fig.1. ESP8266 NodeMCU module

III. INDOOR POSITIONING PROCEDURE

The proposed system based on Wi- Fi supports the user throughout entire tracking process as a tracking service provider. It provides a flexible indoor positioning system adaptable to various users' needs and circumstances. In our case, our developed system is conceived to be tested in hospitals using ESP8266 NodeMCU for network constitution.

In order to optimize the management of the medical personnel and the equipment in a complex domain such as healthcare, we propose a tracking system procedure illustrated in the following figure.

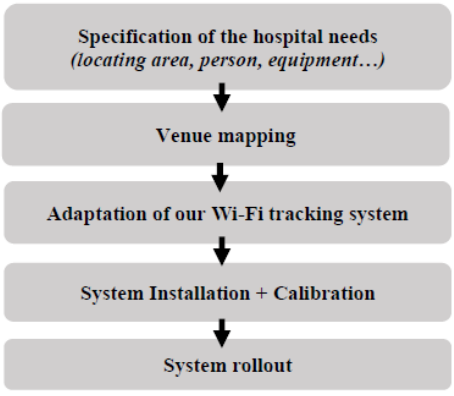

Fig.2. Procedure of our tracking system

A. Specification of the hospital needs

We identify the needs of the hospital. In this regard, we focus on the following question:

- What is the specific problem to solve?
- How/What is the indoor environment of the hospital (buildings…)?
- What are the assets (static or mobile objects) and who to track (patients, doctors, visitors…)?

B. Venue Mapping

We digitalize the hospital environment. then, define ESP8266 module-based network specifications and mark locating APs as important locations.

C. Adaptation of our Wi-Fi Tracking System

Based on the specification of hospital needs step, we identify the requirement of the application. We adapt our proposed system to enable localization of people and goods in real time within a hospital by including possible problems (technical limitation).

D. System Installation + Calibration

We install the locating nodes taking into account hardware parametrization. Then, we record the required positioning data to calibrate on site using our algorithm.

E. System Rollout

With preliminary test result long the way, we offer a full locating-service system in close coordination with the application.

IV. OUR PROPOSED WI-FI BASED POSITIONING SYSTEM

A. System Architecture

The Wi-Fi based indoor positioning systems for hospitals is a server-based system. It was designed based on multiple network cells, as shown in Fig.3.

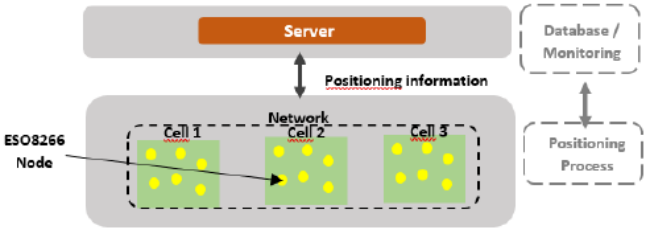

Fig.3. Composition of our system

The positioning network layer: ESP8266 NodeMCU nodes were chosen as hardware component of the system working under IEEE 802.11 b/g/n standard, due to their ease to use and small sizes.

First ESP8266 modules were configured as the locating nodes in certain places. Then, these modules' mac address and the region where they locate were put into database server. When the object or the person to locate is within a cell of the network, locating nodes receives RSSI from the node to position to calculate its position and forward it to the server.

The server maps the calculated locations according to information from the pre-configured ESP8266 locating nodes.

The platform layer: it can be optional and should be designed to meet user requirements (simplicity…). It includes server and the person responsible of the supervising and the management of the hospital. He is responsible of interacting with the system while server is responsible of information processing.

B. Functional Architecture of the positioning Network Layer

The network layer shown in figure 4 constituted of three functional parts: ranging, indoor positioning and the data (within all the network). The ranging process in each network cell consists on the measure of the distance between the node to locate and the locating node based on RSSI measures values. The indoor positioning can be subdivided into obtaining coordinates within a network cell (relative position) and the network (absolute position).

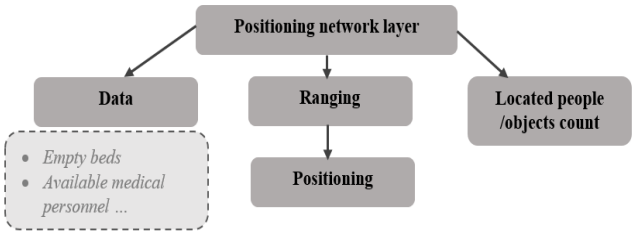

Fig.4. Architecture of the positioning network layer

a. Ranging

This step deals with the determination of the distance between the locating node and the node to locate. When a node is within the Wi-Fi positioning network covered by Wi-Fi, the locating node will receive the MAC address, SSID and the RSSI. The received MAC Address is compared to the stored MAC Address in database. If it exists, we can obtain the location of this node. This process is as follows:

- **Step 1:** The node to locate approaches the covered locating area.
- **Step 2:** Locating nodes immediately receives the node to locate information (MAC Address, SSID, RSSI).
- **Step 3:** Received MAC Address is compared to data stored in database.
- **Step 4:** The processing of the received signal starts in order to determine the location (relative position) if data is available in database.

b. Fingerprinting Algorithm

The location of the node to locate is reflected by ESP8266 locating nodes as part of the locating network. Fingerprinting technique is used then to position within each cell constituting the network. This method [6] consists of two phases:

- **Phase 1:** Collecting the positioning points form a map by dividing the locating environment into a grid and signals.
- **Phase 2:** Compare collected data to measured ones to find matches from the database that stores each reference point locations.

According to MAC address and RSSI information, this method permits the determination of the current position of the node to locate from servers. This obtained location will be displayed in a 2D map which helps to find the nearest point to the locating node. Besides, it ensures the management of material and personnel resources in different hospital department (empty beds, available equipment…) will be possible.

V. THE EXPERIMENT

The prototype of the Wi-Fi positioning network was built with ESP8266 modules to represent the positioning network layer, PC was used as the database and monitoring layer, Arduino was used as the development tool. The experiment results are shown in the following figure.

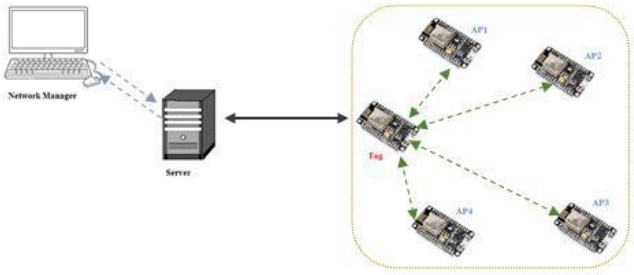

Fig.5. The design of the positioning system prototype

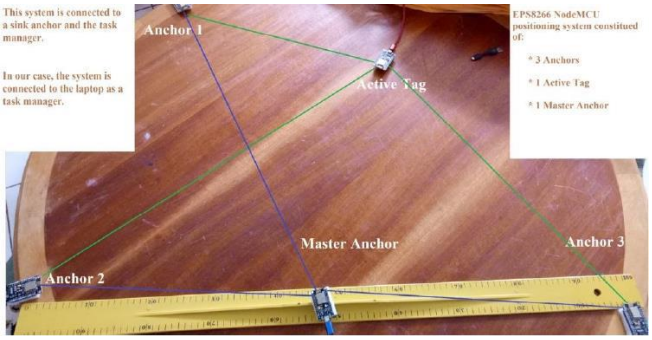

Fig.6. The prototype of the positioning system [7] (1 cell + server)

a. Ranging

The pre-stored database is constituted of locating nodes list. Each locating node has a unique MAC address and SSID (table below). Each Locating node has a known position within the network.

Table II. List of mac address, ssid and position within our network

MAC Address	SSID	Position within the network
5C:CF: 7F:0B:98: D8	ESP 1	Position 1
A0:20: A6:00: F7:3A	ESP 2	Position 2
5C:CF:7F:1B: 7A:C2	ESP 3	Position 3
A0:20: A6:00: F7:3A	ESP 4	Position 4
A8:D9:B3:0D:AA:CE	ESP 5	Position 5

When the object or the person to locate approaches within a network cell, the locating node will start ranging procedure. Hence, the relative distance of this node can be determined [8].

Table iii. Ssid, rss and ranging distance

SSID	RSS value	Ranging distance (m)
ESP1	-55.05	1.202
ESP2	-61.71	3.120
ESP3	-68.12	2.365

b. Positioning

Once ranging is applied in the network cells. We start the positioning and the mapping in our indoor environment. For this, we use fingerprinting technique. For the experiment, we used five nodes to locate (red) and five locating nodes (blue). Obtained results shown in figure below are similar to real values so this technique is applicable and efficient.

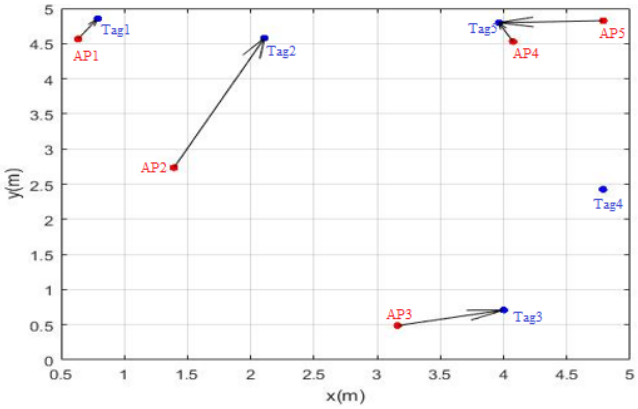

Fig.7. Fingerprinting within one cell with five locating nodes (blue) and nodes to locate (red) in a 5m x 5m area

Fig.7. is the map displayed at the server level where the people and objects positions are marked. Based on the pre-stored list of MAC address, SSID the calculated positions, we build this once network cell map. It shows the nearest locating which can be potential empty beds or available doctors or nurses.

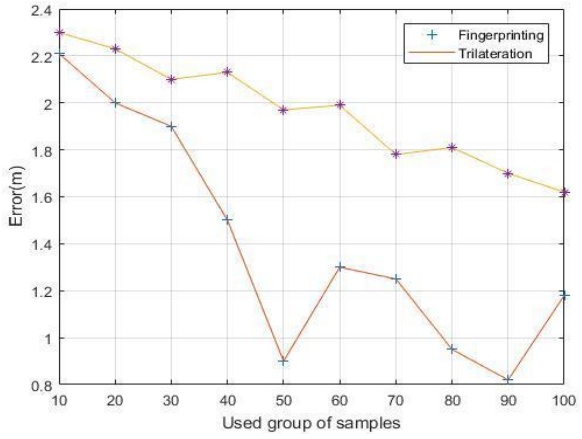

Fig.8. Positioning error based on number of groups

Table IV. Mean error using trilateration and fingerprinting

Localisation Error (m)	Technique	Processing of samples		
		Mean	Median	50% of sample groups
	Trilateration	1.963	1.980	2.146
	Fingerprinting	1.401	1.275	1.702

Table 4 gives an overview of the performances obtained with the same positioning system with different techniques. Fingerprinting allows a gain of 0.71m with the same Wi-Fi measurements used with trilateration.

VI. CONCLUSION

In this paper, Wi-Fi based indoor positioning system for hospitals is introduced. First, our system was designed based on ESP8266 modules and a two-layer architecture of the positioning network, the server monitoring and database management. Fingerprinting algorithm is used to position and help build the positioning map to efficiently manage the medical personnel and equipment. Finally, experiments were conducted to verify our proposed system feasibility. Such a Wi-Fi indoor positioning system is of great importance, not only for hospitals, as it can save manpower and time for patient and material resources for hospital specially in emergency cases.

VII. PERSPECTIVES

Besides accuracy, our future works will focus on the construction of a dynamic database that will be maintained without human interference.

REFERENCES

1. Michelberger, "iCare: Intelligent Medical Information Logistics", Proceedings of International Conference on Information Integration and Web-based Applications & Services. ACM, (2013).
2. H. Kopetz, "Internet of things", Real-time systems, Springer US, (2011), pp. 307-323.
3. M. B. Kjæ rgaard, "Indoor positioning using GPS revisited", Pervasive Computing, Springer Berlin Heidelberg, (2010), pp. 38-56
4. R. Tesoriero, "Using active and passive RFID technology to support indoor location-aware systems", Consumer Electronics, IEEE Transactions on vol. 54, no. 2, (2008), pp. 578-583.
5. Faheem Zafari, Athanasios Gkelias, Kin K. Leung, "A Survey of Indoor Localization Systems and Technologies", IEEE Communications Surveys & Tutorials. 2019.
6. Wei Ting, 2010. "Indoor localization method comparison: Fingerprinting and Trilateration algorithm", University of Saskatchewan, Canada. *http://rose.geog.mcgill.ca/ski/system/files/fm/2011/Wei.pdf* (2 June, 2011)
7. *S. el abkari, J. el mhamdi: "*Multiple Tags Positioning Algorithm using ESP8266 NODEMCU System*", in:* International Journal of Engineering Research and Advanced Technology (IJERAT), Vol.5, Issue 8, August -2019.
8. W. Debus, RF Path Loss & Transmission Distance Calculations, Axonn, Technical Memorandum, 2006, pp. 1-13.

AUTHORS PROFILE

Safae El Abkari: Ph. D student. She completed her Electrical Engineering and Computer Science Bachelor degree in Ecole Normale Supérieure de l'Enseignement Technique de Rabat, Morocco 2013. In 2015, she obtained master of Electrical Engineering. Her interest in research motivates her to work hard to conceive and create interesting research projects. Her main expertise is Computer Science, Biomedical Engineering system, and Telecommunication. Her other interest includes software engineering, design and implementation system such as locating system with multiple technologies.

Abdelilah Jilbab : is a teacher at the Ecole Normale Supérieure de l'Enseignement Technique de Rabat, Morocco; he acquired a Computer and Telecommunication PhD from Mohamed V University, Rabat, Morocco in 2009; his thesis concerns the Filtering of illegal sites on the Internet: Contribution to the type of image recognition based on the principle of Maximum Entropy.

Jamal EL Mhamdi Professor at Ecole Normale Supérieure de l'Enseignement Technique de Rabat, Morocco. Major: Computer Science and Telecommunication. His interest in teaching motivates him to work hard in teaching, working on the conception of systems concreting his expertise in software Engineering, System design and telecommunication.