Low Cost & Easy to Deploy Real Time Location System Based in Radio Frequency Identification

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Abstract. Real Time Location Systems (RTLS) provide great benefits to society in safety and can lead to sensitive information to optimize resource planning in public facilities and major events. The current cost of people locator systems and deployment difficulty hinders installation in multiple scenarios despite the potential benefits posed therein. In this paper we present a low cost and easy deployment RTLS based on RFID technology and active tags. The proposed system can be optimal for scenarios where location accuracy is not a key factor, being enough to know an approximation of the position and mainly the presence or absence of a person in the area monitored.

Keywords: Real Time Location Systems, RTLS, RFID, Active Tag, Smart Antenna, Assets and individuals tracking

1 Introduction

The cost and difficulty of installing the current real-time location systems (RTLS) hinders its deployment in environments where ROI cannot be measured from an economic standpoint. However to locate people in a bounded area or even verify their presence provides very clear benefits to society from the point of view of safety and leisure.

In that sense, providing a RTLS easily deployable on any installation and low cost in both infrastructure and tracking devices can be extremely advantageous in many scenarios. To ensure the presence of a person with a tendency to cognitive problems in orientation or memory, such as Alzheimer's disease or senile dementia in elderly within a controlled area for their care and detect when they leave the same or enter into a hazardous area, improves the quality of life not only of the monitored person but also staff in care assistant [1]. In parallel, the implementation of a system of this nature in big areas designated for children's entertainment, combined with new apps compatible with smartphones can be used to notify caregivers when a child leaves the monitored area or even to facilitate location when it's time to go home. In addition, the proliferation of social networks raises new possibilities of social interaction with geo-located individuals. Facilitate the location of friends and acquaintances in multitudinous events or estimate the flow of people in a particular installation can open a wide range of marketing possibilities and help optimize the management and planning of resources.

The aim of the work presented in this paper is to develop a real time location system based on radio frequency identification (RFID) and low cost active tags that allows easy deployment in indoor and outdoor areas for the provision of telematics services aimed at increasing the safety of people and offer new opportunities for leisure and resource planning.

In the following paragraph is contextualized the scope of the proposed system in comparison with other alternatives, section 3 shows the system architecture and describes the implementation of the main elements that make it up. Later section 4 describes the real scenario where the system is to be tested, where a detailed radioelectric analysis has been performed for the proper deployment of the system. Finally conclusions of the system will be presented and future lines opened by the proposed system.

2 Context of the Work

The main challenge of the proposed system in this paper is to develop a system capable of monitoring real-time people in indoor and outdoor scenarios with significant size, with the minimum possible cost. Currently there are multiple technologies used in indoor real time location systems [2]. Existing commercial location systems provide location accuracy varies from a few inches in systems based on proprietary microwave solutions (UWB) (e.g. Ubisense), accuracies below 1 meter by systems based infrared sensors technologies (e.g. Firefly) or systems that provide a lower accuracy using wireless technologies such as WLAN, Bluetooth, ZigBee or DECT (e.g. Ekahau). These systems employ multiple schemes to estimate the location. Many systems employ techniques and algorithms based on measurements on the Angle of Arrival (AoA), Time of Arrival (TOA) or Time Difference of Arrival (TDOA) that require additional hardware, increasing the cost of deployment [3]. Other systems, mainly those based on RFID technology, are based on the Received Signal Strength Indication (RSSI) to optimize the location estimate [4]. According to the characteristics of the scenario and considering the economic factor as main feature of the system, the chosen technology has been active Radio Frequency Identification [5]. The consolidated statement of this technology and the proliferation of manufacturers facilitates finding reader units and bracelet shaped tags at very low cost. In this sense multiple Asian manufacturers have launched numerous identification solutions in different ranges. From integrated units including directional antenna, the reader and the embedded platform for managing the acquired information, to simple readers that only provide located tags. The proposed system is based on those bottom range devices that considerably help to get a cheaper solution but difficult to estimate the location not providing any analyzable measure as those previously identified (RSS, AOA, TOA, TDOA). Therefore, the proposed system is based primarily on the location of the antennas and the order in which the reader provides the identified tags.

3 System Architecture

The system architecture is shown in Fig. 1. The proposed solution presents a distributed RTLS system based on three distinct levels.

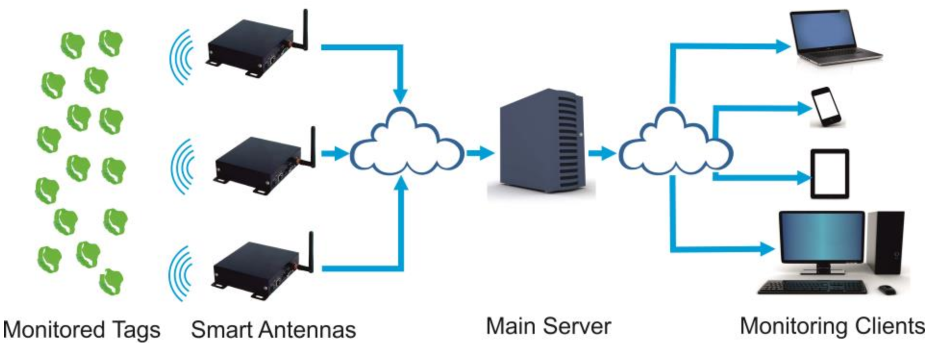

Fig. 1. System Architecture

3.1 Smart Antennas

It is the main component of the system. The implementation of this element is carried out by integrating a 2.4GHz RFID omni-directional active reader with a reading range up to 80 meters (MR3002A from Marktrace®) and a low-cost embedded platform with Internet connectivity (Raspberry Pi). The total cost of this item, including the reader (175€), the embedded platform (30€), an IP66 enclosure (Fig. 2) and all necessary accessories, does not exceed €400. The cost of implementing the system depends directly on the number of smart antennas to ensure proper coverage of tags monitored in the controlled environment. In chapter four discusses in detail the optimum antenna number and positioning of these for the chosen test scenario. A public 13,000 square meters area can be covered with five smart antennas. The low cost of the hardware deployed, together with the low cost of active tags compatible with the system (4 €) and the use of mobile platforms as monitoring clients, facilitates the implementation of the system.

The embedded platform, connected via Ethernet to the RFID reader constantly query RFID tags that are in the coverage range. The embedded platform manages a list of tags that are in the area of coverage. For each tag the platform stores the identifier and a sensing factor. When the reader identifies a tag that had not previously been identified, the antenna sends a SOAP POST request to the server, indicating the entry of the individual associated with that label in the coverage area. Each time a tag is identified, the sensing factor is restored to a pre-set value. When a tag in the list is not received after a query, the sensing factor is decremented. If the sensing factor reaches zero, the label is removed from the list and a SOAP POST request is sent to the server indicating the exit of the monitored person out of the coverage area of the antenna.

The configuration of each antenna to be deployed in the system requires two actions: setting the IP address and the HTTP port of the main server in the embedded platform (1) and inserting the positioning information and the transmission power into the database of the main server (2).

Fig. 2. MR3002A 2.4GHz RFID reader, raspberry Pi an prototype of the smart antenna.

3.2 Main Server

The main server is responsible for analyzing the information sent from the smart antennas and monitor proper people in the user interfaces of the clients.

A database stores the physical location of the antennas installed, links the RFID tags with the users of the system and stores each alteration in the people locations referred by each antenna. Microsoft SQL Server 2008 DBMS has been used in this context

All data transfer between smart antennas, monitoring clients and the main server are performed through asynchronous web services in order to facilitate scalability of the system and improve reliability. The implementation of this distributed architecture has been developed using .NET technology and Windows Communication Foundation (WCF).

Although tests of the system have been carried out on a development server, the technologies used in the development facilitate the deployment of the system in a cloud platform during the production stage. The estimated monthly cost of the system hosted on the Windows Azure platform including a Extra small Virtual Machine, 1Gb SQL Azure storage and bandwidth of 30Gb is € 20.76

3.3 Monitoring Clients

According to the nature of the test scenario, which is presented in the next section, it has been developed a native application for iOS compatible devices that enables to locate people who wear tags. The link between people and tags is performed from within the application via QR code printed over the tag. In addition to displaying the estimated location of the monitored person the application receives PUSH notification when the person leaves the controlled area.

4 Test Scenario

The proposed system will be deployed in a playground for children of recent construction. The park located in the town of Getxo in northern Spain, has 13000m2 and provides different recreational areas as three zones of swings, a bar, a soccer field, a basketball court and open area for free play (Fig. 3). The proposed system must allow tutors to monitor the estimated location where are children under their responsibility and report immediately when they leave the park.

Fig. 3. Scenario under consideration with the representation of the deployment of five readers RFID.

The most important requirement for the proper functioning of the system is the correct positioning of the antennas, which requires a complete radio-electrical analysis of the controlled area.

4.1 Radio-electrical Analysis

The effects of radio wave propagation are highly important in order to analyse the behaviour of the wireless communication system. The assessment on electromagnetic spectrum is of importance to model overall performance of the system under analysis in terms of coverage and capacity analysis. In this work, a deterministic method based on an in-house developed 3D ray launching code [6-8] is used to analyze the performance of the wireless communication system of the considered scenario. This scenario is depicted in Fig. 3 with the representation of five transmitters which have been analyzed in terms of coverage, capacity and sensitivity.

The use of deterministic modeling leads to a previous radio planning analysis in order to achieve an optimal configuration of sensors to bear a competitive, flexible and scalable solution. Firstly, the whole scenario has been created, taking into account the material parameters of all the elements within it in terms of conductivity and dielectric permittivity. Electromagnetic phenomena such as reflection, refraction and diffraction have been taken into account based on Geometrical Optics (GO) and the Uniform Geometrical Theory of Diffraction (GTD). The commitment between accuracy and computational time is acquired with the number of launching rays and the cuboids size of the considered scenario. Several transmitters can be placed within the scenario and parameters such as frequency of operation, radiation patterns of the antennas, number of multipath reflections, separation angle between rays and cuboids dimension are introduced.

3D ray launching simulation results have been obtained for the whole volume of the simulation scenario (Fig. 3). The positions of the transmitters have been chosen in order to simulate a possible morphology of a real wireless network.

Fig. 3 shows the obtained received power levels for the bidimensional plane at height 1m for different number of transmitter. For each of the represented planes (from Fig. 3a to Fig. 3c), two new transmitters have been added consecutively, starting with a single transmitter (Fig. 3a) and finishing with a wireless network composed by five transmitters (Fig. 3c).

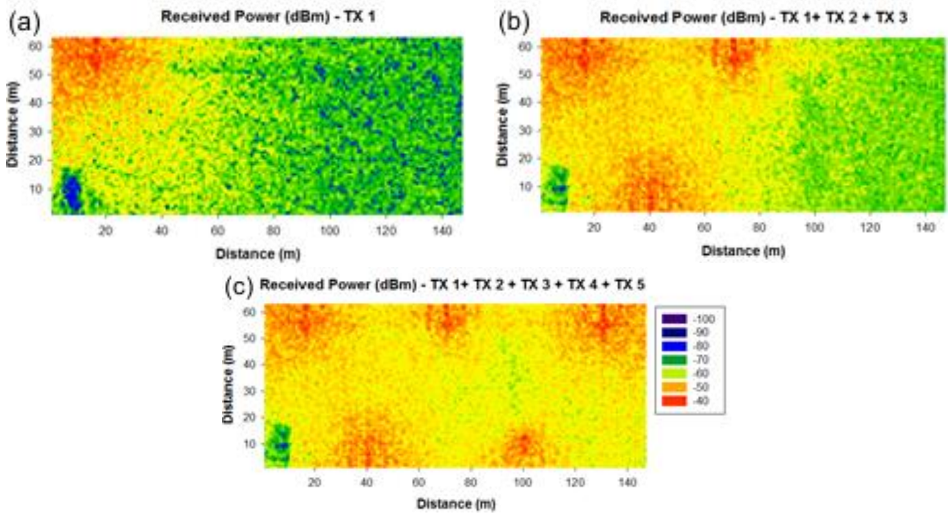

Fig. 4. RSSI 3D-ray simulation results obtained at a bidimensional plane at a height of 1m for different number of transmitters (a) TX 1 (b) TX1,TX2,TX3 (c) TX1,TX2,TX3,TX4,TX5.

As it can be seen from the previous figure, received power level is strongly dependent on the position of the potential receiver element and the morphology of the wireless network. Variations can be in order of 10dB within 1 meter when the number of transmitters is low, which has a strong impact on the performance of the sensors, not only in terms of receiver sensitivity limits but also on overall system capacity, which is dependent on signal level as well as on signal to noise ratio.

The multipath propagation is absolutely noticeable in this type of complex environments; hence, to appreciate the variability of estimated received power level more accurately, Fig. 4 represents the power delay profile for a single point at the center of the considered scenario. As it can be seen, there are a large number of echoes in the scenario in a time span of approximately 0.10 to 2.10µs.

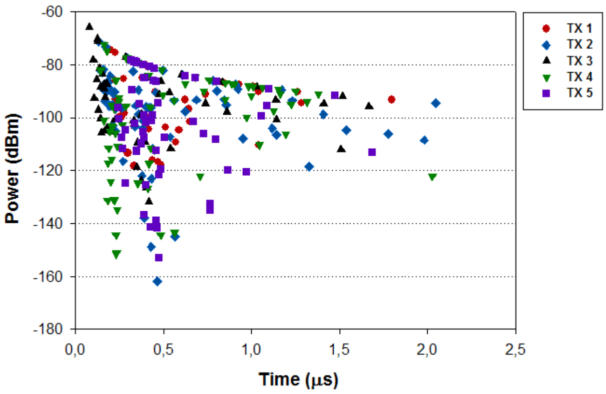

Fig. 5. Power Delay Profile in the central point of the scenario for a height of 2.75m.

5 Conclusions and Future work

The constant advancement in RFID technology and the general fall of prices on readers and tags allows the development of low cost RTLS lacking high location accuracy but able to detect the presence of people who should be monitored in large indoor and outdoor areas. These systems generate new application scenarios improving the safety of public facilities and major events and promoting leisure between users.

In the coming months the presented system will be deployed in Guernica Park, in the town of Getxo in northern Spain.

As future work, we will consider the application of fuzzy finite state machines (FFSMs) and fuzzy rule based classifiers (FRBCs) in order to obtain relevant information from data collected in the environment. Thanks to the near-human rules generated under the field of fuzzy logic, it is expected to be able to filter large amounts of data in the form (time + ID + Location) in order to obtain valuable information in the way: “at about 5pm, most of the parents are in the cafeteria, while their kids are in the play-zone 1”. This information is quite valuable in order to program maintenance operations in the environment as well as for to improve its characteristics.

To this purpose, FFSMs allow us to abstract the environment as a finite state machine, where events are responsible in changes of the state. The use of fuzzy logic allows dealing with imprecisions and uncertainties derived from the environment or the sensors. In the other hand, FRBCs provide the classification of such states and transitions in a formal way. Finally, by using computational perceptions techniques and expressions constructors it is expected to ”translate” obtained results in a set of human-like sentences, to be sent to the environment’s operator or manager.

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