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Efficient Services Management in Libraries using AI and Wireless techniques

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ABSTRACT

Radio Frequency IDentification (RFID) has been used in a wide variety of applications such as highway toll collection, building access control, animal tracking, remote keyless entry for automobiles and tracking assets. For example, RFID in libraries, with a modest investment, can improve the capabilities of both librarians and users. This paper presents a new use of RFID in libraries to help determining the physical location of a book within the library and to provide assistance to users to arrive to the desired locations.

Our initial prototype, named SIGUEME, has been extended and experimentally implemented in Meco's Public Library (Madrid, Spain). The application comprises three main systems: an electronic one – which detects users through a RFID sensors system; an AI-based system to plan and to monitor the users' requests according to their interests; and finally a screen-based information system that communicates visually the directions the users have to follow. We have developed a wireless communications system based on Zigbee technology to allow both, the information flow across the building and to connect the antennas to detect RFID users. This eliminates the need for using wires.

The application not only helps users to easily locate the books or the reading rooms inside the building, but also automates tasks manually performed by the library staff (i.e. generate statistics about books usage time, age-related usage, etc).

1. Introduction

Ubiquitous computing contexts rely on the convergence of wireless technologies and advanced electronics. Multiple sensor network applications can take advantage of the synergy resulting from the combined use of Radio Frequency IDentification (RFID) and Wireless Sensor Network (WSN) technologies. ZigBee is a wireless communications standard designed by the ZigBee Alliance[3] that fulfils most WSN requirements in a wide variety of applications (Zhang, Yang, & Chen, 2009).

RFID systems and WSNs represent two key technologies for ubiquitous computing that have attracted considerable attention in recent years because their use revolutionizes diverse application areas. RFID facilitates detection and identification of objects that are not easily detectable or distinguishable by using conventional sensor technologies. However, RFID does not provide information about the condition of the objects it detects.

WSN on the other hand, not only provides information about the condition of the objects and the environment but they are also networks of small, cost-effective devices that can cooperate to gather and provide information by sensing environmental conditions such as temperature, light, humidity, pressure, vibration and sound. It also enables multihop wireless communications. Hence, the integration of these technologies expands their overall functionality and capacity. An introduction to the taxonomy and challenges of this integration could be found in Liu, Bolic, Nayak, and Stojmenovic (2008). The resulting integrated technology will have extended capabilities, scalability, and portability as well as reduced unnecessary costs.

There are a lot of examples of applications, from highway toll collection, supply chain management, public transportation, controlling building access, animal tracking, developing smart home appliances, to remote keyless entry for automobiles, for locating children, etc. But, we can consider three big domains by the volume of applications:

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1. Healthcare: separation of Zigbee and RFID technologies has been very common in healthcare systems. However, recent applications integrate both technologies what boost their potentials. A healthcare example of this empowerment is the improvement of patient treatment quality. The patients location can be tracked using RFIDs, while their condition can be monitored using sensors. Critical errors such as those in treatments orders or inaccurate medical records, can be avoided with the use of an integrated RFID-sensor network (Mitsugi et al., 2007). Another example is the development of prototypes of human-monitoring systems using active RFID tags, which are integrated with sensors. These sensor-tags can be, for example, used to continuously monitor the temperature of the blood bank refrigerator as well as to track the location of a blood bag (Kim et al., 2006).
2. Logistics: RFID systems have widely been used in the supply chain for product tracking, inventory control, and asset monitoring, while WSNs are used for space and environment monitoring. RFID–WSNs integrated sensors have also been adopted by the U.S. Navy (Roberti, 2004) to track valuable aircraft parts in storage. The integrated sensors are able to measure humidity, temperature, and air pressure, and for a network with other RFID sensor-tags. Another example of an integration scenario of RFID and WSNs, and for a tour group system, was proposed by Chen et al.. Each group's guide holds a badge and each group's member carries a ticket with a passive RFID tag in which the group's ID is stored.
3. Libraries: RFID technology has been used originally in libraries to improve the available inventory of books (Ferrer, Dew, & Apte, 2010; Coyle, 2005; Thornley, Ferguson, Weckert, & Gibb, 2011; Wang, 2011) and to prevent theft (Young et al., 2004; Golding & Tennant, 2007). The first project implementing RFID in a library was deployed in 1998, in the Library of Rockefeller University in New York (Singh, Brar, & Fong, 2006). Shortly afterwards, in 1999, the Farmington Community Library was the first public library using RFID technology. Although RFID was initially conceived to streamline the inventory management (Suda & Rani, 2013), it can also help extending the library operating hours by means of the self-checkin and self-checkout stations (Singh et al., 2006).

This last domain is the focus of this paper. The combination of RFID and WSN, in the libraries field, could solve other problems than the well-known one mentioned above. For example, a common difficulty that users face in large libraries, which have multiple floors and rooms, is the correct location of the books and the orientation of people inside the building. One way to solve this problem is to provide the building with an intelligent system to guide the users towards the reading rooms. This also provides a way to know at any time the number of users in the building and the possibility of its localization within it.

This article presents the experiences and results of applying an extension of our initial prototype SIGUEME[4] (R-Moreno et al., 2011) to the Meco's Public Library (MPL) in Madrid. This application combines Artificial Intelligence (AI) techniques, RFID and Zigbee. RFID based indoor localization is a mature topic of research and researchers have proposed very interesting schemes to exactly locate the tags in a building with high accuracy (Hsu & Yuan, 2011; Ni, Zhang, & Souryal, 2011; Saab & Nakad, 2011). Our proposal does not pretend to propose any new method on how tags should be placed but how AI can be used to coordinate and monitor all the information about users, rooms and books. Some approaches use Wi-Fi for people tracking (Zhoua et al., 2014) but instead, we have decided RFID as the indoor location system (Tesoriero, Tebar, Gallud, Lozano, & Penichet, 2010). The reason was mainly influenced by the RFID infrastructure already available in libraries for books, that could be extended also for people.

The paper is organized as follows. Section 2 describes the new services provided by the system in the MPL. Then, the different components of the architecture are described. Section 4 presents the results derived from the experience and use of this system in a real environment. Finally, conclusions and future work are outlined.

2. Services provided in MPL

MPL is located 42 km Northeast of Madrid (Spain), in a small town with a population around 12,500 citizens. The library has four rooms distributed on two levels as shown in Fig. 1.

On the ground floor, the first spot is the main entrance with the information and check-out front desk that gives access to Room 1. Any user who wants to enter/exit the library has to go through this point where an RFID security gate is placed. Fig. 2 (left) shows the checkpoint of our application (set on the main entrance) and the RFID gate 1 along with the RFID security gate. Fig. 2 (right) shows the main entrance from the other side, where the users can search for the books thanks to a PC located before the front desk. Additionally, they can delegate this task to the information desk staff. In both cases, they can ask for the latest books or the availability of reading materials they are interested in and they can also obtain information about the availability and room location of particular books. In the case of the users who want to borrow a book from the library, they can only pop by this desk and present the book(s) to borrow, together with the library card.

Room 1 acts both as an entry and exit point to the library. Once in this room, one can access the other three rooms where all the books are located. Room 2 holds Children, shown in Fig. 2 (center), and Juvenile's literature and Room 3 hosts young adults books. On the first floor we can find Room 4, which can be accessed either by using the stairs or the elevator. This room holds Fiction and Non-Fiction books, Pamphlet/newspaper, local authors and regional collections books. All these rooms have a reading area, where the user can find tables and chairs to read the books comfortably.

Hitherto, we have described the common operation of any library. We have extended the functionality of the service by adding the following elements: four RFID gates to detect the people in the building, one for each room that we can access in the library, a Zigbee wireless communication network to transmit the information collected by the detection system to the central computer,

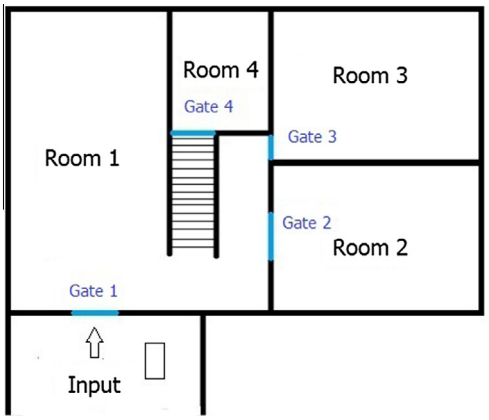

Fig. 1. Map of MPL.

[4] The letters stand for *Sistema Inteligente de GUiado para Entornos Multiusuario Extensos* – Intelligent Guidance System for multiuser extensive environments – that means *FOLLOW ME*