Towards a Smart Campus for Qassim University: An Investigation of Indoor Navigation System

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ABSTRACT

With the advancements in technology, smart entities are becoming increasingly intelligent, therefore, increasing their interaction capabilities with their surrounding environment. Apart from the traditional smart low profile devices, these entities now involve cars, mobiles, televisions, and extend to universities and smart cities. One of the bi-product of the smart cities is the emergence of the concept of smart campus. The smart campus is a teaching environment, where dynamic interaction between students/users and the surrounding devices takes place using the paradigm of the Internet of Things (IoT). The Qassim University (QU) is considerably a large university having thousands of students and hundreds of functional units in the central building and also spread across the different cities of the Al-Qassim province. Therefore, the QU can be considered as a small city where many elements need to be connected and decisions be made. The QU thus represents an optimal and practical scenario for the concept of smart campus. With this spirit, the goal of this research is thus to investigate an Indoor Navigation System (INS) as a suitable platform for the QU. As such, the paper reviews the current technologies and opt for the best available and optimal options. For implementation and simulation, the BLE beacon is selected and user data is analyzed to design a mobile application that includes all the services requested by the users. The system architecture in addition to a 2D map presented in this research will help in identifying the locations of BLE beacons to cover the specific area. The work in this paper is conducted on the main campus of the QU; however, the extension to other setups involves minimum or similar infrastructure.

1. Introduction

Over the last decade, a smart city is one of the emerging concepts that aims to provide a smart livable environment for the resident. Cities as Singapore, Barcelona, San Francisco, London, etc., is an example of cities that apply the concept of smart cities. In [1], the author defined a smart city as “A city well performing built on the ‘smart’ combination of endowments and activities of self-decisive, independent and aware citizens”. The Internet of Things (IoT) paradigm allows cities to manage and control every aspect of the city from buildings, roads, railways, to airports and traffic in a smart manner. IBM smarter planet project adopted the term of the smart city [2]. The smart city relies on six key factors: smart governance, smart people, smart economy, smart environment, smart life, and smart traffic [3]. Nowadays, the typical universities are considered as small cities that include most of the services available in the cities. The advancement of new technologies such as Artificial intelligence, IoT, and the availability of High-speed internet plays a big role in changing the living environment to be smart than ever before [3]. Smart universities also called smart campuses to compose one of the branches of the smart city concept that concern about every aspect inside the university; students, staff, visitors, classrooms, buildings, equipments, etc.[4]. Due to the popularity of the term of smart campus, we will use it in this research to refer to smart university. The smart campus concept can offer many benefits such as save cost and time, automate maintenance, protect the environment, automate students and staff attendance, track occupancy as well and many other benefits [5]. Several
applications have been developed to make our campuses smart such as smart buildings, smart parking, smart learning, smart campus management, and maintenance, etc. [3].

Navigating inside large buildings, such as malls, hospitals, airports, and campuses, using an INS to help users to reach their preferred destination is highly required. INS is investigated in this research due to the huge size of QU main campus that has a similar interior design where finding places is a very difficult task for visitors and even for students and staff as well. The available infrastructures at the QU campus encourage us to explore this idea to make campus life easier and smarter. The main problem of INS is the signal unavailability of a Global Positioning System (GPS) inside buildings because of the walls and other barriers [6]. Smartphones, smart glasses, smart watches are widely spread and used heavily for INS because of the different sensors that is equipped with. Therefore, the aim of this paper is to investigate and identify the obstacles and barriers that could stand against devolving suitable INS for QU main campus.

2. Background

Smart cities with their different technologies and services are one of the active research areas where many survey papers have been published recently [1-5, 7, 8]. The Kingdom of Saudi Arabia is among the countries that apply this concept to change its traditional cities to become smart cities [9]. The smart campus is a concept where many universities working on several projects to adopt this concept such as King Fahd University of Petroleum and Minerals[10], Lancaster University [11], University of Malaga [12], University of New South Wales in Australia [13], etc. The services and applications offered by smart campus are varied. These services aim to make the universities surrounding smart includes but not limited to buildings, laboratories, libraries, classroom, attendance system, grid, learning, parking, navigation, waste and water management and etc. For more information about the smart campus, services refer to [3, 4, 14-15]. Due to the complex mixture of elements and devices to be connected, many expected and unexpected problems might appear and need to be addressed. For instance, internet coverage [16], energy consumption [17], sensory network [18], location-based services [19] etc.

In [20] researchers discussed different types of INS in the literature and highlighted the accuracy problem. In [21], the researchers give recommendations for the user interface design of INS based on the case study conducted by them. They found that it is important not to put heavy details in the map and to simplify the graphical layout. In [22] an android-based application is introduced for indoor navigation inside public buildings using Near Field Communication NFC and Quick Response codes QR. Several features include finding a destination with the shortest path, store the location of car parking, finding the nearest toilet, etc. Smart phones used for INS as in [23] where mobiles used for navigation using wireless access point fingerprints help an individual to get their direction with the indoor space using navigation application. Researchers in [24] Proposed Vision-based approaches for mobile indoor localization based on the combination of Virtual Reality (VR) and Augmented Reality (AR) in order to help in ensuring the accuracy of the localization.

Since the focus of this paper is to develop an Indoor Navigation platform for QU, in the following section we will review the current technologies used for INS. The researches in INS is still active, several survey papers published currently to explore it in detail as in [6, 25-27]. As the signal of GPS cannot reach the devices in indoor areas, several telecommunication technologies were introduced to overcome this problem. For example, Wireless Fidelity (Wi-Fi) [28, 29], Radio Frequency Identification (RFID) [30], Infrared technology (IR) [31], Ultra-Wide Band (UWB) signals [32] and Bluetooth low energy (BLE) beacons[33].

BLE beacons are a relatively new technology with the advantage of low energy consumptions that small batteries can be used for months up to years [34]. Based on the research conducted by [35] to study the localization accuracy between BLE and WIFI. The findings show that BLE was more accurate than WIFI at identical places. According to [36] BLE is a promising technology that has a low deployment cost and appropriate for most mobile devices. iBeacon is the name of Apple’s brand of BLE technology based on the micro-localization and the interaction of a mobile device [34]. BLE beacons need to care about the radiation pattern of a given device and possible attenuation element in the chosen places [37].

3. Data Collection and Analyses

User preferences are very important to build effective systems. Therefore, a questionnaire developed and published to collect the user preferences and other necessary data to get insight into the difficulties they faced inside the QU campus. Responses collected from 454 students, lecturers, and general staff. The questions dedicated to familiar and unfamiliar users for the QU campus. The main services and tools requested by the respondend to be available in the QU INS application are presented in table 1.

Table1: The percentage of each place & service required by users

| No. | Places & Services                                      | %   |
|-----|--------------------------------------------------------|-----|
| 1   | Places and services around current location (Prayer room, toilet, cafeterias, garden, shops, Photostat, parking, students clubs, gardens etc.) | 98% |
| 2   | Timetable and office hours information of staff        | 96% |
| 3   | Search by name, Map and around current location       | 95% |
| 4   | Announcements                                          | 93% |
| 5   | Laboratories                                            | 91% |
| 6   | Location of new events                                 | 91% |
| 7   | Classrooms location                                    | 90% |
| 8   | Examination room location                              | 90% |
| 9   | Staff members offices                                   | 87% |
| 10  | Emergency exits                                        | 81% |
| 11  | Library                                                | 74% |
| 12  | Administration offices                                  | 31% |

The gender, age, user type (student, lecturer, staff, or visitor), preferred services to be available in the system, and other questions been asked and responses obtained. The collected data have been analyzed and important information extracted as follows, refer to Figure 1 and Figure 2:

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1- 91% Preferred to have an application that can help to ease the indoor navigation inside the QU campus.
2- 73% of respondents are facing some difficulties in finding locations especially when they visit the QU main building.
3- 100% of respondents never used an INS before.

The second section is for the developers, where they can develop the INS software, upgrade hardware, add locations, and its information to the database and update the navigation map.

Figure 4 presents the system flowchart for the users where they can search for a location, positioning their selves, and navigate to the desired location. Searching can be through the map our using keyword. For positioning service where it shows the current location of the user in addition to the nearest services around. The navigation service used to guide the users from their location to a specific location inside the building. Based on the literature, BLE beacons are a new, cheap, and popular technology for INS. This encourages us to use BLE beacons to assist in navigation and positioning the users. BLE beacons broadcast their identifier to the nearby devices.

In order to deploy the minimum number of BLE beacon devices, Figure 5 shows the device's location that is enough to cover a single location at the Department of IT, where each beacon covers approximately 62 maters. Each BLE beacon has its own unique ID and for every wall, a boundary segmentation starts from 0 for the first wall, 1 for the second, and so on.

Walls need to determine the sides either left or right. To calculate the position of an object in indoor areas, at least three timestamps from different BLE beacons are needed. A mobile application is designed based on the gathered requirements from the users. Figure 6 shows some examples of screen shots for QU INS. The users can search by names, on a map, or around their current location.
Figure 3: Framework for INS at QU

Figure 4: Users' flowchart.
Figure 5: BLE beacons in 2D map at the department of Information Technology at QU

Figure 6: Screenshots of QU Indoor Navigation System
5. Conclusion

The QU is considerably a large university having thousands of students and hundreds of functional units in the central building and spread across the different cities of the Al-Qassim province. Therefore, the QU can be considered as a small city where many elements need to be connected and decisions are made. The QU thus represents an optimal and practical scenario for the concept of a smart campus. As such, we addressed the INS at the QU in this work. We presented a literature review for smart campuses in general and smart universities in particular. In the INS, several technologies are explored for solving navigation and positioning in indoor areas. For an implementation and simulation perspective, the BLE beacon is selected because the BLE beacons are cheap, reliable, having a longer battery life. As such 454 user data is analyzed and is used to design a mobile application that includes all the services required by the users. The system architecture in addition to a 2D map helps in identifying the locations of BLE beacons to cover the whole area of the Information Technology Department at the College of Computer in QU. The system architecture is scalable in order to accommodate any building size. The work in this paper is conducted on the main campus of the QU; however, the extension to other setups involves minimum or similar infrastructure.

Conflict of Interest

The authors declare no conflict of interest.

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