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WiFi and Bluetooth Low Energy Beacons for Indoor Positioning System

Nurul Fatehah Zulkpli, Nor Azlina Ab. Aziz*, Noor Ziela Abd Rahman and Rosli Besar
Center for Engineering Computational Intelligence, Faculty of Engineering & Technology, Multimedia University, Melaka, Malaysia.
*azlina.aziz@mmu.edu.my
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***Abstract* - Indoor Positioning System (IPS) is used to locate a person, an object or a location inside a building. IPS is important in providing location-based services, which has recently gain much popularity. The services ease visitors' navigation at unfamiliar premises. Location-based services depend on the capability of IPS to accurately determine the location of the user, which is a challenging issue in indoor environments. Several wireless technologies are available. In this paper, two of the most widely used IPS technologies are reviewed which are, WiFi and Bluetooth low energy (BLE). Their advantages and disadvantages are reviewed and reported here. Comparison of the systems based on their performance, accuracy and limitations are presented as well.**

Keywords*— *Indoor positioning system, Bluetooth low energy, beacons, WiFi, navigation

I. INTRODUCTION

Time is valuable. Spending a lot of time to find something can be stressful. Entering a shopping complex for the first time while looking for a recommended restaurant or searching for the shortest escape path in emergency situation are examples of frustrating scenarios in which location positioning is highly desirable. The search for the location of an object or a person can be defined as positioning. There are two categories of positioning, namely outdoor and indoor with many variations of enabling technologies [1]. Figure 1 shows some of the positioning technologies.

Global Positioning System (GPS) is the most common technology for outdoor positioning. It is a satellite navigation system. GPS provides the location of a person or object on earth using latitude and longitude [2]. It is adopted in many applications like military intelligence and transport navigation. GPS signal travels through the atmosphere, and this weakens the satellite signal. The signal is also inaccessible indoor and under dense foliage as it can be blocked by physical obstacles like building, forest, etc. which causes poor line of sight to the satellite [3, 4]. Hence, GPS is unsuitable for indoor positioning. Additionally, lack of GPS interface in user's device could also hinder the effectiveness of GPS for indoor positioning [5]. Due to this, there is a need for other technologies to cater for indoor positioning.

There are many technologies available for indoor positioning, such as WiFi, BLE, Ultra-Wide Band (UWB), visible light communication (VLC) [6-10], etc. These technologies may differ in accuracy, implementation and installation cost and maintenance [10].

This paper focuses on the WiFi and BLE in IPS. WiFi is an attractive option due to its widespread usage in most of the buildings. This reduces the cost of IPS [3]. WiFi works well for indoor positioning due to its frequencies and standard protocols of 802.11 networks [10]. On the other hand, BLE has a lot of attractive characteristics such as low power, high range, and 1-2meter accuracy which makes it good for indoor positioning. Due to their advantages, these two technologies are frequently used in the research of indoor positioning [11-12].

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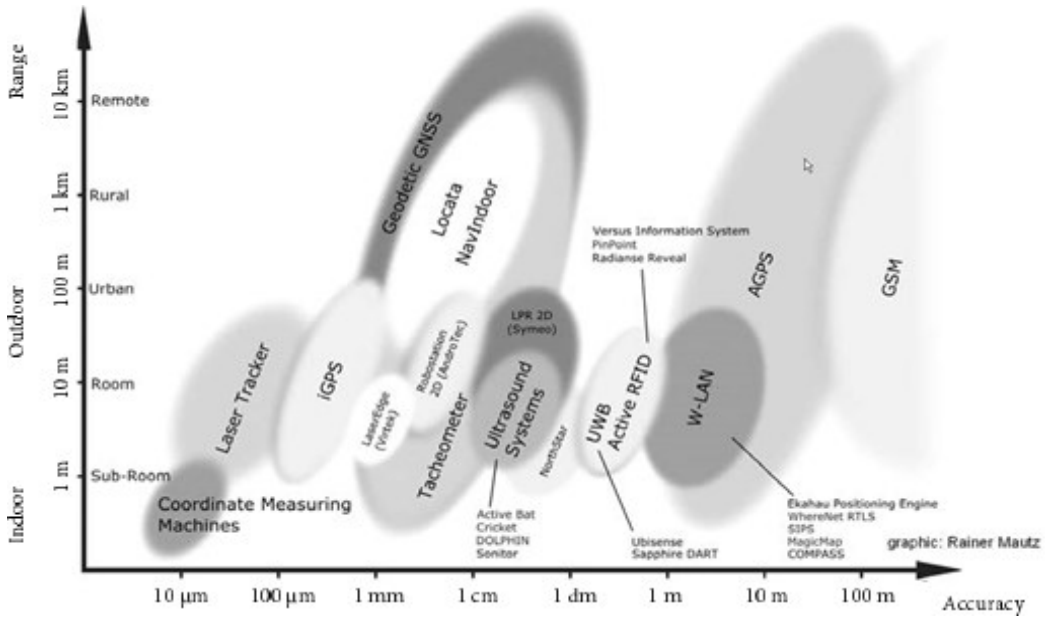

Fig. 1. Existing technologies for positioning with accuracy and coverage area [1].

This paper is organized as follows. Section II depicts the indoor positioning system. WiFi-based indoor positioning system is introduced in Section III. Section IV provides the details on BLE-based indoor positioning system. In Section V, hybrid indoor positioning system is described. This work is finally summarized in Section VI.

II. Indoor Positioning System

Indoor positioning, in essence, is a process of detecting or identifying location of a person or an object in an enclosed interior area [14]. Various signals from location devices and motion sensors as well as other sensors on mobile devices are used by IPS [10].

Nowadays indoor positioning system is in demand. As stated in the 2016 survey involving 301 respondents from United State, United Kingdom, Australia, Singapore and Hong Kong [15], it is expected that IPS market value, will rise to $4.4 billion by 2019. It is also reported that the top five IPS deployment are at airport (38%), hotel and resort (28%), hospital (24%), office (24%) and malls (24%). Figure 2 below shows example of indoor positioning application, the *sensewhere*.

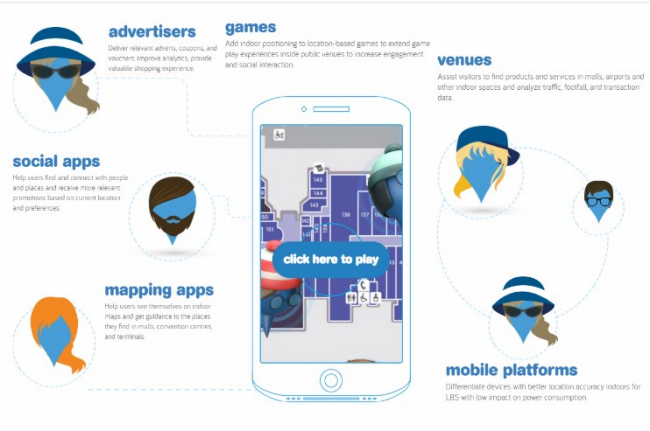

Fig. 2. *sensewhere* platforms.

The IPS works similarly as GPS when searching for direction in terms of outdoor positioning. However, IPS does not rely on satellite signals [15]. In IPS, signals are exchanged between the location devices and smart devices' sensors instead of retrieving satellite signal. The GPS is unsuitable for IPS due to several reasons [16]:

1. The effects of multipath and fading caused by reflection and diffraction around items, walls and floors within the area.
2. Failure of transmission due to solid obstacles like walls, floors and many more.
3. Transmission of energy in passages at high frequencies.
4. Movement of human bodies and items in the coverage area.

Figure 3 illustrates problem number 1 and 2 above.

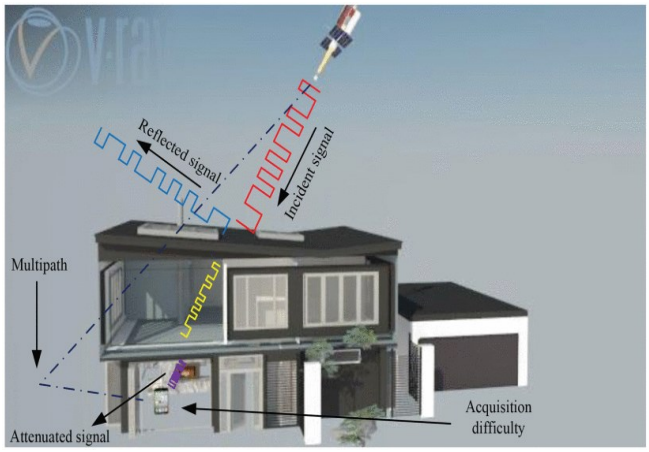

Fig. 3. GPS signal does not work indoors [17].

III. WiFi-based Indoor Positioning System

WiFi is the most extensively used technology for IPS because of its massive availability and existence at many infrastructure [9]. In [15], it is found that 47% from the respondents who had IPS used WiFi. An example of Wifi access point is shown in Fig. 4.

Fig. 4. One of WiFi access points in Multimedia University, Melaka.

The word WiFi stands for Wireless Fidelity, a wireless technology that allows communication using a wireless signal. It is also known as IEEE standard 802.11, which uses a centralized router device to share WiFi signal with additional standards like 802.11a, 802.11b and 802.11n [18].

In a WiFi-based system for indoor positioning, WiFi transmitters are called as tags. The tags send simple packets to the available access points in a building or facility. For indoor localization in mobile devices, common range for accuracy is from 3-5 meters. WiFi is able to give a reasonably high level of accuracy because the system uses difference of the time of arrival with large scale bandwidth. However, at least three access points are needed for each transmission of tag. As long as the WiFi connection is enabled, there is no need for the device to be connected to a WiFi network. In order to track a location indoor, there are several methods used by WiFi, such as the proximity time of arrival (TOA), time different of arrival (TDOA), receive signal strength indication (RSSI), theoretical propagation model and lastly fingerprinting [3,17-18]. Primarily, fingerprinting and RSSI are used the most.

WiFi is reported to be better than Bluetooth [18]. It uses greater protocols and algorithms to improve performance. More security mechanisms are provided as well in WiFi compared to Bluetooth, like the WiFi Protected Access (WPA) and Wired Equivalent Privacy (WEP).

Although WiFi is a popular choice, there are several issues to be considered. The WiFi network is designed for data communication instead of positioning purposes [14], and because of this, the WiFi enables IPS has been reported as not accurate enough [10]. In order to achieve 10 m accuracy, a lot of access points need to be installed [15]. Although, dense implementation of wireless routers can upgrade the accuracy, but it raises the issue of power consumption and signals attenuation [21].

When designing WiFi based IPS, the number of access points need to be as minimum as possible to reduce the cost of building and operating the system [22]. Therefore, new and powerful algorithm for optimal access point placement is required to ensure that the setting is optimal without compromising the localization accuracy.

WiFi could not be implemented in some mobile devices, particularly, iOS devices as they do not provide WiFi scanning results [10, 23].

IV. BLE-BASED INDOOR POSITIONING SYSTEM

BLE is one of the protocols of Bluetooth 4.0, which appears in mid-2010 [10]. Bluetooth works in the 2.4GHz ISM band. A unique ID exists for each Bluetooth Tag to locate the tags [19]. The tags are originally from the beacons (sensors). Figure 5 portrays some example of beacons produced by *estimote*. Its framework consists of access points between wireless and wired networks, they are called as terminal networks. For indoor positioning, usually the range of the terminals is smaller, typically a few dozen meters [21]. As far as BLE is concerned, only two things are required, BLE beacons and BLE-enabled devices [23]. Most of the smart devices nowadays have the Bluetooth or BLE. In indoor positioning, the BLE transmits signals from transmitters (beacons) that use batteries. The BLE-enabled devices detect the signal from the beacon and notify the nearby devices on their presence. Roughly, the distance to it can be calculated and thus location of the devices can be estimated. Those nearby devices can receive various contents and being subscribed to notifications of the beacons. It is important for the devices to activate the BLE, or else no location can be detected. Beacons are able to send out signals, but they cannot receive them. In order for the signals to be sent, there are two categories of positioning methods used mainly in BLE, fingerprinting-based and range-based [23]. For fingerprinting-based methods, reference fingerprinting map (RFM) is a must. As for range-based methods, the positions of the beacons should be known before positioning. Therefore, a path-loss model of built-in radio frequency is applied in order to evaluate the interval between the users and beacons. There are several placement standards of Bluetooth beacon for IPS, where in between of the beacon and end station, no obstacles ought to exist and density of beacon should be increased. As for the placement space of the beacons, 4-6 meter is an ideal preference.

Fig. 5. Estimote beacons.

There have been multiple findings on the advantage and disadvantage of BLE in indoor positioning. BLE can be used for both Android and iOS, provided that Bluetooth or BLE is turned on [23]. BLE has a low deployment cost and able to operate endlessly for a long time due to low power consumption of the beacon nodes. In [24], BLE and WiFi are compared based on the accuracy and power consumption using the results of investigation done by previous research. It is found that BLE is better especially in terms of power consumption. Meanwhile, for accuracy, it is unclear, as the coverage is not as big as WiFi. Nevertheless, the localization accuracy can be maximized by increasing the beacons' density in the indoor area.

Similarly, the researchers in [9] reported that BLE is better than WiFi technology in indoor positioning even though they work within the same spectrum range and similar range of transmission.

Based on the findings, BLE is seen to be a more accurate positioning technology than WiFi even though the placement of access points is similar. The superiorities of BLE are, the higher scan rates, lower power as well as cheaper transceivers which makes bigger deployments possible. As mentioned by [25], BLE beacons operate using batteries, thus, their placement can be anywhere. In other words, BLE has the freedom to place beacons in order to ensure excellent signal configuration [26]. In [19], it is revealed that the main advantage of using BLE is due to its high reliability and low power consumption, no extra infrastructure is needed and the transceivers of the tag is small in size. It is also beneficial for the BLE when the applications involved are using low bandwidth to transfer data [18].

However, it is quite difficult to figure out the RFM or beacon positions in practice. Besides, additional hardware is needed for the positioning process in BLE, where both [27] and [28] prove that particular inertial sensors are required in their research for the positioning of foot-mounted or waist-mounted, respectively.

Indoor positioning by BLE is not about exact location, it is all about proximity[15]. In [2], the authors highlighted that, BLE is inappropriate for real-time positioning due to its accuracy of 2-3 meters with time delay of 20 seconds. The authors of [20] discussed a few disadvantages of BLE which are, its cost and smaller area coverage, about 10-15 meters.

Table I below lists the common features of WiFi and BLE from the reviews conducted.

Table I. WiFi versus BLE.

	WiFi	**BLE**
Installation Cost	Higher, since high-traffic router is expensive	Lower, as beacons usually cost lower than WiFi routers
Power Consumption	High power usage	Low power usage
Range	Longer, typically 200 ft	Shorter, about 50 ft
Requirement	WiFi access points and wireless adaptors on devices	Bluetooth connection

V. Hybrid Indoor Positioning System

Some IPS use hybrid technologies, for example *sensewhere*, uses both WiFi and BLE for its Android version while its iOS, it is more dependent on the BLE beacons due to the reason discussed before [29].

Hybrid system of indoor-outdoor seamless positioning is also explored in [6]. The study is done in Tokyo Station which is underground and involves WiFi, BLE, UWB, Pedestrian Dead Reckoning (PDR) and GPS. A simple switching algorithm comparing the technologies implemented is also proposed. The effectiveness of the system is claimed to be within 2 meters. However, this might change once the area is surrounded by many tall buildings. The fusion of GPS and UWB for indoor positioning in a gymnasium is proposed in [30]. The proposed method is able to provide exact and real-time positioning.

In [31], a new trend of Bluetooth IPS technology is introduced, which combines with Inertial Navigation System (INS). However, it is not fully implemented yet as most of the investigations focuses on the positioning process techniques rather than the characteristics of INS.

The integration of two wireless technologies has its perks [32], where one of the technologies used can help to outweigh the shortcomings of the other. On the other hand, in [10] it is reported there is no significant advantage in terms of performance for the fusion of WiFi and BLE. In fact, several IPS functionalities of the hybrid techniques cannot be used when the technologies are separated [10].

VI. Conclusion

This paper looks into the pros and cons of using BLE and WiFi as well as the hybrid technologies. Based on the findings of the literature review, it can be concluded that none of the technologies can guarantee the best performance in indoor positioning. Between WiFi and BLE, each one of them has their own strengths and weaknesses.

For the case of WiFi, the main strength is no new infrastructure deployment is needed since the WiFi access point has been made available in many properties. Compared to BLE, it has a longer range but in terms of new installation cost, it can be slightly higher. Even though existing WiFi access points can be found, more deployment might be necessary so that reliability can be increased. As for BLE, its major fortes lie on its low energy usage and low cost. Despite that, BLE has a shorter range compared to WiFi.

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