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Research Paper

Indoor positioning: technology comparison analysis

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Abstract

A system that allows users to find and track a specific position is known as positioning system. Global Positioning System (GPS) is one of top known position tracking system that commonly used to find position and location of object outdoor. Tracking an object indoor using GPS is not highly recommended because the signals transmitted through a satellite to a device indoor gets blocked and resulted in weak signals. Thus, an indoor positioning system (IPS) that tracks and positions object indoor has been implemented to overcome the issues of signals multipath that resulted from GPS. The aim of this paper is to provide up to date indoor positioning technologies and compares the technologies according to its technical perspectives.

Keywords: *Indoor Positioning System; Indoor Positioning Technologies; Technical Perspectives; Signals*

1. Introduction

Tracking and locating objects within closed environments and inside buildings is known as indoor positioning system. Many surveillance applications and recognition activities mainly focused on this indoor positioning system. Indoor positioning system (IPS) uses communication technologies for object tracking in indoor environments. GPS technology has been wide spread implemented for outdoor tracking and detecting object. Although GPS technology has been the most efficient technology for outdoor environment tracking and detection, it has limited capability and usability to be used for indoor environment. GPS technology cannot be deployed for indoor purpose because GPS signal cannot reach indoor receivers. Complicated indoor environments such as building geometrics, the people movement and random effect of signal propagation makes GPS signals hard to perform and results in lower precision and accuracy of tracking and detecting ranges. Interference and noise from other device also plays an important role in degrading the accuracy of indoor positioning. Accuracy and precision of some 50 meters inside a commercial setting is useless with respect to a task such as locating specific merchandise on a shelf [1]. Thus, the need for specialized methods and technologies for indoor location systems has been widely accepted.

2. Related work

Studies conducted by [2] set up a classification scheme in order to help developers of location-aware applications to better evaluate their options when choosing a location-sensing system. At this particular time frame, the development of indoor positioning systems was one of the most researched topic. [15] systems were compared in terms of limitation, scale, precision, costs and accuracy. It is very hardly valid today if the quantifications given was 10 years ago. A new survey is required for every 3 to 5 years to represent a useful state-of-the-art guide for the rapid progress in this emerging networking field.

In [3] studied on an extensive survey of wireless indoor positioning techniques and solutions. Their survey focused on the state-of-the-art in 2005 and the efficiency of GPS, RFID, cellular based, UWB, WLAN and Bluetooth technologies. 20 systems parameter performance have been compared in terms of robustness, scalability, complexity, precision and accuracy. In [4] studies found a survey of the mathematical methods used for indoor positioning. The study aims on wireless positioning techniques and it is grouped into the four categories which are geometry-based methods, cost-function minimization and fingerprinting and Bayesian techniques.

In [5] presented a good review total number of 16 technologies were reviewed in a sequential order with no classification and with focus on high precision technologies operating in the mm to cm level, different indoor positioning solutions. The evaluation is carried out by the range of geodesist perspective and includes the criteria accuracy, range, signal frequency, principle, market maturity and acquisition costs. In this paper, certain technologies have been reviewed in sense of its opportunities, challenges and on its specific features.

3. Problems and challenges

This section discussed about the possible problems and challenges that need to be considered before selecting and implementing the best indoor positioning technologies. There are few criteria need to be considered such as accuracy, range of coverage, complexity, precision and cost [6].

3.1. Accuracy

Overall, an accuracy of a technology determines the reliability of the whole system. Accuracy in terms of indoor positioning technologies, it is evaluated by how accurate it gives the position information [5]. Different system provides different accuracies. For

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example, Wi-Fi system provide medium level accuracy that is 1.5 m and RFID technology provides high level of accuracy which is 1-5m in indoor positioning system. However, implementing an accurate indoor positioning system is still a challenging key area of research for most researchers [7].

3.2. Coverage

Range of coverage also main key factor to be reviewed during technology selection for indoor positioning system. Range of coverage described the area covered for accurate indoor localization. Different technology has different specification for range of coverage. Hence, short range technology might need more devices to cover the same area [8]. Ranges of existing systems can go from 5-50 meters. A system that covers more than 60 meters would a greatest effort to be found in the indoor localization research.

3.3. Complexity

Complexity of a system can be divided into three parts. It can be attributed to software complexity, hardware complexity or operation factors. Software complexity mainly focused on the computational algorithm. If the algorithm performed is centralized, the positioning could be calculated faster and more energy could be saved [9]. If the computational algorithm performed were complex and hard to perform, then it takes more energy to perform the calculation of location. Hardware complexity means the difficulty of installing the devices in the respected area. A small and weightless device is much more convenience to install compared a device that weighs a lot and big in size. Operation factors of complexity refers to the installation and maintenance part of the hardware device [10]. Easy installation and simpler maintenance of the device will be considered as less complexity.

3.4. Precision

Precision is close to the definition of accuracy but precision interprets the meaning that derivation of the distance error whereas accuracy means the mean error of distance. To be exact precision means how consistently the system works. Different system consists of different precision. It can be varying from 5m to 20 cm. In a technology comparison, when two technology have the accuracy level, then precision level will be take into count. The system with a higher precision consider better than the precision contains low precision [11]. For example, Bluetooth technology positioning precisions is tens of centimeters to tens of meters. While, UWB technology positioning precisions is a few centimeters to tens of centimeters.

3.5. Cost

Computational cost is an important criterion for evaluation of an indoor positioning system. More cost will result in more cost in the device and more consumption of power [12]. Cost factor can include space, time, money, energy and weight. Time factor can be related for the implementation and installation spend for the system. Energy is an important cost for the system. Some mobile units are completely energy passive, but some mobile units have a lifetime depend on the time have given for charging. In this cost factors, sunk cost also need to be considered. Overall, Bluetooth technology needs a higher cost compared to Wi-Fi technology.

4. Indoor positioning systems

Several numbers of technologies have been imposed by the researchers for indoor positioning systems within past years [13]. Among those technologies, there most common technologies have been identified such as visible light communication (VLC) that uses optical technologies, ultrasound which uses sound based technologies, Wi-Fi, Bluetooth, Radio Frequency Identification (RFID) and ultra-wideband that uses radio frequency technologies. In this section, a brief explanation on the technologies has been reviewed.

4.1. Visible light communication

Light signal can be classified in both infrared light and visible. Light signal also an electromagnetic signal same like the RF signal, but its associated technologies might not be same. The advantage and challenges for the optical technologies differs. For instance, line of sight are the main problem for optical signals.

Visible light communications (VLC), a technology in which the visible spectrum is modulated to transmit data. Due to the propagation distance of the light emitting diodes (LEDs), VLC is a short-range communication technology. VLC technology has been practiced for indoor positioning system purpose for past few years [14]. The system reuses current lighting infrastructures, thus can be deployed easily and fast inside buildings where LEDs are used for lighting.

Briefly, each light emitting diode has different flicker encoding, thus the sensors holds by the users will easily compares the modulation over the known encoding scheme. Then, it determines the presiding and associates the corresponding lamp [15]. There are few advantages of using VLC technology for indoor positioning system such as lamps are extensively and homogenously available in buildings, as well as beacons can complement the positioning in indoor environment. Furthermore, VLC Technology is considered as the one of the efficient technology to be implement for the indoor positioning system because the positioning technology does not depend on batteries. VLC Technology also can be considered precise because it is less than 1 meter and has a high range up to 8 meters. Studies conducted by [15] proves that all VLC projects has an accuracy below 20cm. Some commercial companies in light industry such AS Philips proposed that the accuracy of the system can be easily increased by adding more bulbs. The disadvantage of the system is back channel and tracking only possible with special hardware/app.

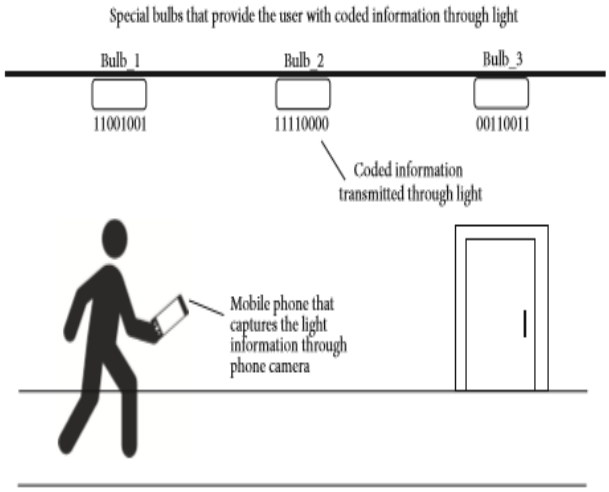

Fig. 1: VLC Technology in Indoor Positioning System.

4.2. Ultrasound

Sound signal can be divided into both audible and ultrasonic. Location based system that used ultrasonic sound need to have frequency of higher than the audible range to track and decide the location by determining the time taken for the ultrasound signal to travel from transmitter to receiver [16]. Ultrasonic mainly uses triangulation algorithm to take reflective distance and to determine the position of the objects in indoor environments [15]. Advantage of this technique is low in cost ability of reflection in indoor obstacles. The disadvantage are multipath signals may disturb the measurement distance between the receivers and the emitters.

A remarkable ultrasound positioning system can be identified as Bat System, refer Figure 2. Research conducted in [17] uses array of microphones and tags carries by the user to provide an active configuration on positioning. Using the information provided by the signal strength, it is possible to find out the position where the user is facing as well. Advantage of this system is it is easier to place more transmitter simultaneously and the precision is just in a few centimeters. The drawback was the location information might be leaked and resulted in security breach. The scalability of this ultrasound system, environment issues might be affected as well as its system performance due to too many tags that causes sound emission collide each other.

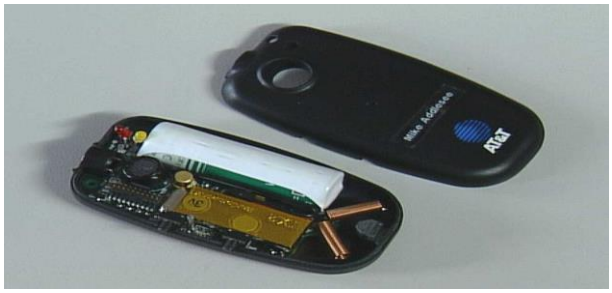

Fig. 2: BAT Ultrasonic Location System.

4.3. Wi-Fi

One of the most known wireless technology is Wi-Fi technology. Wireless Local Area Network (WLAN) is also can be utilize for location estimation within the network. WLAN also known as middle distance wireless technology. Past few years, it has been a very famous technology among public. Its dominant local wireless networking standard is IEEE 802.11. Since WLAN infrastructure quite famous among in most indoor environment, this approach is might be suitable for indoor positioning system.

Important advantages of this technique is it is less cost, since most all indoor infrastructure has installed the Wi-Fi enabled device. Apart from that WLAN also does not require Line of sight. There are three methods can be implemented to apply WLAN technology for indoor positioning. Firstly, distance calculation of a known base from a known antenna by using propagation model [18]. Secondly, the triangulation method where target position is calculated from signal strength information received from multiple location. Thirdly, fingerprinting method where mapping process takes place between signal strength of routers and the location information built in the offline database [19]

Accuracy of WLAN technology can be varied from 20m to 40m but improvements can take place by deploying wireless routers or by hybrid together with another technology. Power consumption known as major drawback of this technology. Small and battery power becomes the major constraint for the indoor localization. Signal attenuation from the indoor environment for example cupboards, cushion, and floors is the main limitation for this technology.

4.4. Bluetooth

Bluetooth technology classified into short distance wireless technology. It is also a personal area network standard. It is similar to Wi-Fi technology where it uses 2.4GHz and [5] GHz. Bluetooth also can be explained as a communication technology that that has been digitally embedded with information on radio frequency signal [20]. Bluetooth was mainly introduced to exchange information between mobile devices by minimizing the usage of cables mainly to implement wireless technology within short distance.

Bluetooth is also known as lighter standard, supports many other networking services and it is highly ubiquitous. Bluetooth is a small size transceiver with unique ID in it. This technology is perfect to implement in small size infrastructure such as rooms and not suitable for a larger environment such a big building with multiple floors [19]. Advantage of Bluetooth technology is its device is small in size and encourage easy integration among mobile device. The coverage of Bluetooth technology is 1-30 meters. Bluetooth technology also low in cost and requires low power technology.

On the other hand, Bluetooth technology also have few drawbacks. Each time Bluetooth performs finding, it repeats it finding steps and it resulted in latency and power consumption at the same time. It also provides low accuracy within 2m to 3m [11]. This accuracy considers very low compared to other technologies. Hence, this Bluetooth technology is not suitable for large localization infrastructure.

4.5. Radio frequency identification (RFID)

Radio Frequency Identification (RFID) holds a history of more than 40 years in history. This technology needs to divide into two part, which is reader localization and tags localization. RFID defines as electromagnetic transmission to an RF integrated circuit by retrieving and storing of data. The RFID reader reads the data obtained from the RFID tags. RFID can be classified as either passive or active. Passive RFID tags does not require battery supply. It is small in volume and cost effective compared to the other tag. Passive RFID tag have a very limited range [21]. The reading normally will be among 1-2m. Active RFID tags are tags that actively sends their ID. It is a small size transceiver. Advantages of active RFID tags are it has low range and it is small in size thus it is very convenient. It is suitable for high unite value products in an assembly process.

The radio waves signals have the ability of penetrating into solid object. This makes the RFID technology works without the presence of Line of sight. The drawback is its accuracy is often limited the strength of signal depends on the density of the object [22]. Frequency range in RFID technology can be divided into three parts such as Ultra-High Frequency (UHF) 860-960MHz, High Frequency (HF) at 13.56 MHz and Low Frequency (LF) at 125-134MHz [23]. Furthermore, RFID technology is less cost effective, compact, high data rate and secured overall. The limitation of this technology is LF and HF have ability for short reading range and UHF have drawbacks in absorption of RF signal in Liquid state or presence. Figure 3 shows a scheme of working RFID technology.

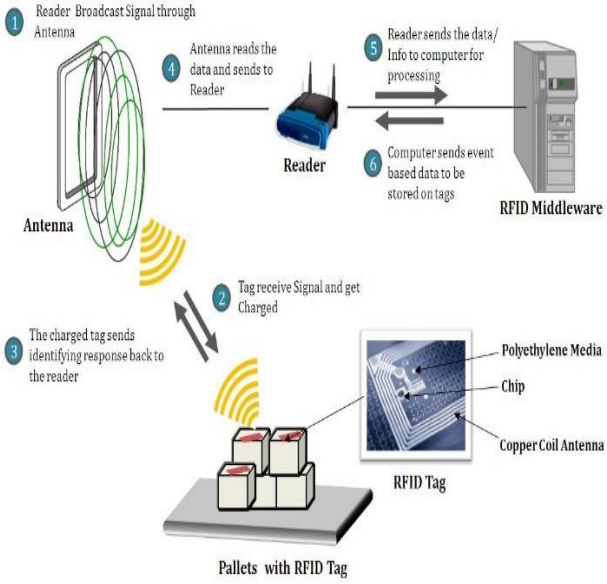

Fig. 3: A Scheme of Working RFID Technology.

4.6. Ultra-wide band (UWB)

UWB technology is a latest technology compared to other traditional technologies. UWB technology usually implemented for its precise indoor positioning. This technology uses a nanosecond radio pulse to transmit data in a wide bandwidth ranges from

greater than 500MHz [1]. Time of Arrival (TOA) and Time Difference of Arrival (TDOA) measures can be used together with this UWB technology to determine the distance between the target and reference point.

Studies conducted by [24] presented that Indoor Positioning System with UWB technology contains four transmitters and few mobile users. The transmitters were synchronized using time division scheme. The system proves an accuracy of 1meter when the UWB signal is at 528MHz.

There are few clear plus point of implementing this UWB technology such as it has penetrating powers and it consumes very low power consumptions. For instance, this technology uses small transmission power -41.4dBm/MHz which is limited by FCC, meaning the power consumption is low. Furthermore, it is immune to multipath effects and highly secured with less complex infrastructure. Due to this advantage of UWB technology, it is best to use in both stationary and moving indoor environment and it provides very accurate positioning accuracy.

5. Technologies comparison

A reliable Indoor Positioning System that benefits in every aspect can only be achieved by selecting the most suitable technologies to accomplish the whole system overall. Comparison among existing technologies for selecting suitable technologies for indoor positioning system is very crucial [25]. For a detailed technology comparison, few parameters were chosen such as accuracy, coverage cost, complexity, typical environment and power consumption were explained in Table 1.

Table 1: Comparison among Indoor Positioning Technologies

		TECHNOLOGIES					
		VLC	Ultrasound	Wi-Fi	Blue-tooth	RFID	UWB
PARAMETERS	Accuracy	10cm	1cm-2m	1.5m	30cm-m	1-5m	15cm
	Coverage	Multiple level Building	Room	Building	Building	Room	Building
	Cost	High	High	Low	Low	Low	High
	Complexity	High	Low	Low	Low	Low	Low
	Power Consumption	Low	Low	High	Low	Low	Low
	Strength	Cheap to user Uninstructive	Good precision	Low cost, good precision	Low cost, good precision	Low cost	High precision
	Weakness	Expensive infra-structure	High Cost	Vulnerable to access point changes	Low precision	Low precision	High cost

6. Conclusion

Indoor positioning system is being an eye catchy topic among researcher. This system not only benefits commercially but it helps the disabled people life quality as well can be used in emergency situation. The analysis that has been carried out explains the current indoor positioning technologies and its evaluating criterial. Different technologies have its own advantages and disadvantages. Each technological characteristic and specialized aspect need to be considers to match with the respective mathematical algorithm. To improve the performance of the indoor positioning system, hybrid integration of technology is highly encouraged.

Acknowledgments

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