A Comparative Analysis on Technologies Available for Localization in Indoor Navigation

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ABSTRACT

Indoor positioning systems have become very popular in past decades. These systems have been successfully used in many applications such as asset tracking and inventory management systems. This paper provides an overview of the existing indoor positioning solutions and attempts to classify different techniques and its usage for the localization. Two typical localization methods are addressed in this research work and studied estimation schemes of triangulation and fingerprinting, so analyzed in detail since it is used in the indoor environment. Furthermore, examine the set of performance matrices, and apply evaluation methods to survey some existing systems. Therefore performance comparisons include accuracy, precision, complexity, scalability, robustness, and cost. The experiment result discusses the above mention performance matrices.

Keywords **– Indoor navigation, RSSI, RFID, BLE, Fingerprinting**

1. INTRODUCTION

Localization is the technique to determine the position of an object or a person with the location. According to researchers Indoor localization system is a system that attempts to find the accurate position of the object inside a building, mall, hospital, and so forth [1]. Due to the popularity of mobile computing simulates extensive research on the localization of person or assets. In the present era of mobile devices, location information is crucial in a wide range of applications. In order to meet the user's need, the location information of persons or assets is required which can be provided by the indoor localization system. The position helps for the navigator to navigating, tracking, monitoring the known and unknown environment. The localization is still a challenge for the researchers to find the proper methods for identifying location in both indoor and outdoor environment due to following mentioned reasons:

- Indoor environment are more complex [2], [3].
- There is a signal interference and reflection inside building [2], [3].
- It is highly dependent on the environment such as the position of objects, the behavior of the person [4], [5].
- An indoor communication link is unreliable and inaccurate [4], [5].

Many indoor location-based algorithms are proposed and implemented by researchers, but design and deployment of a system for obtaining location and spatial information in an indoor environment is a challenging task for several reasons mentioned below:

- User privacy [8], [9].
- Management overheads [8].
- System scalability [10].
- Harsh [9], [10].

GPS based sensors play a major role in outdoor localization but due to poor signal strength it cannot be deployed inside buildings, so the cost of GPS device is high for indoor environment, and GPS signals are not available in the confined environment or high-rise buildings [8], [9], [10]. According to research findings, it requires line-of-sight transmission, clear sky-view for proper working, However there are many options are available for the design of positioning system in indoor environment such as infrared, ultrasound, radio frequency identification (RFID), sensor networks, audible sound, light, colour of walls, Wi-Fi access points, BLE beacon sensors, sensors (Accelerometer, gyro, compass, etc.), Magnetic Field, Low orbit satellites, Camera technology. There are some hybrid approaches which combine advantages of two or more different techniques [4], [10].

2. PROBLEM IDENTIFICATION

Indoor Localization System (ILS) defined as "A system that continuously and in real-time can determine the position of object or obstacle in the indoor environment" [13]. Most of the ILSs work in two steps.

- "Where the person is" [4].
- "How to reach to the target person" [13].

According to the [4], [14] an ILS consist three types of location information challenges as mentioned below:

- The absolute location information system should specify the exact location of the end user. Hence, the map of the typical area should be available as an ILS, so to provide localized information. Therefore as a system, it has large computation overheads and more memory [13].
- The relative position information measures the motion of the individuals and reachability to the destination. In [13] stated that the fixed positions are already stored in ILS and changes are noticed related to the fixed position information. It is helpful in tracking a particular object [13].
- The proximity location information specifies relatively known and unknown infrastructure [13].

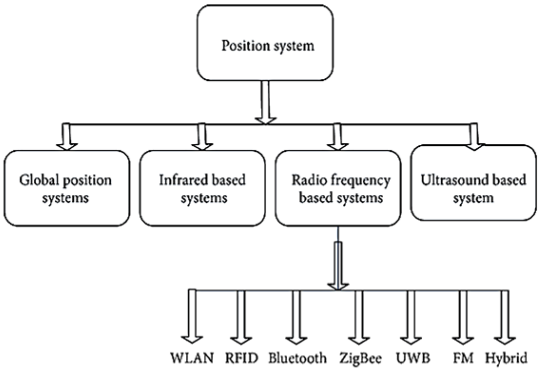

Figure 1: Taxonomy of position systems [14], [16].

Although there are many systems are available as mentioned in Figure 1.This paper addressed both Blue Tooth Low Energy Bluetooth (BLEB) and Wireless systems (WS) as a companied technologies and recommendation based on the performance analysis of the mentioned technologies.

3. RELATED WORK

In spite of the fact that there are advancements, writing survey considered just for the Bluetooth and Wireless frameworks as well-known innovations for the current confinement frameworks.

a. Wireless Local Area Network Based Indoor Localization

J. Padhye, V. Firoiu, and D. Towsley stated that the midrange wireless local area networks (WLAN) are operating in the 2.4-GHz. With a typical gross bit rate of 11, 54, or 108 Mbps and a range of 50–100 m, IEEE 802.11 is currently the dominant local wireless networking standard. Therefore, researchers have been asked to use an existing WLAN infrastructure for indoor localization, by adding a location server [11], [15]. The accuracy of typical WLAN positioning systems using Received Signal Strength (RSS) is approximately 3 to 30 m [11], with an update rate in the range of few seconds. Therefore Wi-Fi positioning systems have become the most widespread approach for indoor localization [15]. Most positioning systems based on WLAN (Wi-Fi) are available as commercial products as prototypes based on measurements on the RSS [11]. Wi-Fi-based positioning systems have two important advantages according to [17], [21], [22].

i. Regarding cost effect, WLAN infrastructures implementation of position algorithms does not need any additional hardware as network interface cards (NICs) measure signal strength values from all wireless access points in the range of the receiver. Therefore, signals needed for positioning can be obtained directly from NICs available on most handheld computing devices. Due to the ubiquity of WLANs, this mode of positioning provides a particularly cost-effective solution for offering LBS in commercial and residential indoor environments [21], [22].

ii. WLAN positioning systems offer scalability in two respects: first, no costly requirement of infrastructure and hardware and second the number of mobile devices subscribing to positioning services [17], [21].

There are several techniques to implement this Wi-Fi positioning system as shown in the Fig. 2 [17]. Authors have studied several triangulation methods under direction and distance based. This paper discussed Signal Property Based Method, under direction based triangulation. The Sri Lanka Institute, the 7th-floor research area, used as a test environment for the experimental results.

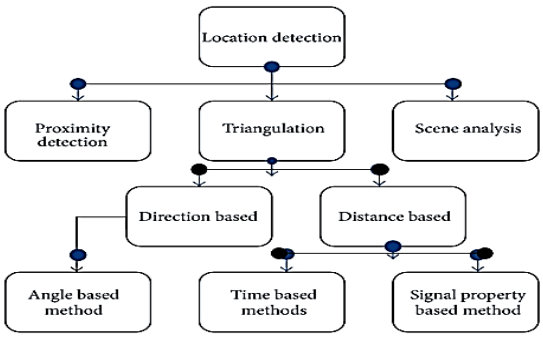

Figure 2: Location detection based classification

1) *Triangulation:* Triangulation uses the geometric properties of triangles to determine the target location. It has two derivations: alteration and angulation. Techniques based on the measurement of the propagation time system (e.g., TOA, RTOF, and TDOA) and RSS-based and received. Signal phase methods are called alteration technique [8], [9]. The AOA (Angle-of-Arrive) estimation technique is also known as an angulation technique.

2) *Signal Property Based Method*: The majority of wireless localization systems compute the distance to the positioning device using either timing information or angle based. In both scenarios, they are influenced by the multipath effect. Due to this, the accuracy of estimated location can be decreased [17]. The substitute method is to estimate the distance of an unknown node to reference node from some sets of measuring units using the attenuation of emitted signal strength [3], [12]. This method can only be possible with radio signals.
Mostly wireless localization systems positioning device using properties of the received signal, with received signal strength indicator (RSSI) being the most widely used signal-related feature. RSSI measurement estimations depend heavily on the environmental interference, and they are also nonlinear [23], [24]. These methods work with the Wi-Fi technology. As this system needs a server for implementation, this technique can work using only access points which are cheaper than Wi-Fi routers.

b. Bluetooth Based Indoor Localization

Bluetooth is a short-range, wireless, cable replacement protocol operates in the 2.4-GHz ISM band [20]. Compared to WLAN, the gross bit rate is lower (1 Mbps), and the range is shorter (typically 10–15 m). On the other hand, Bluetooth is a "lighter" standard, highly ubiquitous (embedded in most phones, personal digital assistants (PDAs), etc.) and supports several other networking services in addition to IP. Bluetooth tags are small size transceivers [20], [25]. Like any other Bluetooth device such as BLEB, beacons has a unique ID. This ID can be used for locating the Bluetooth device. Bluetooth technology is mainly used in small-scale positionings, such as single-room or warehouse. Bluetooth indoor positioning technology of the biggest advantages is the device small and easy to integrate the PDA, PC, and mobile phones, so it is easy to popularize. Indoor localization using Bluetooth beacons is attractive because of the low cost and high spatial selectivity of Bluetooth devices [25]. The beaconing permitted in the BLEB standard enables a very short, unsolicited message at very flexible update rates. These messages can be used to allow a device to detect proximity to a specific location based on the RSS. BLE advertising beacons are particularly attractive to retailers because of the promise of long battery lives of many years, and so low maintenance requirements. In this way, location specific triggers, adverts, vouchers and information can be provided to the user [24], [25]. Long battery lives are expected to require low radio power output and/or low beaconing rates. While this does not affect their use for proximity detection it does affect their usefulness for providing fingerprint-based positioning throughout an entire indoor environment [20] – [25].
Fingerprinting: Fingerprinting is currently the state-of-the-art indoor positioning scheme readily available on standard smartphones [25]. The main theme is to collect features of the scene (fingerprint) from the surrounding signatures at every location in the areas of interest and then build a fingerprint database. The location of an object is then determined by matching online measurement with the closed location against the database [24], [25].

Figure 2: Fingerprinting based positioning [24].

This technique is composed of two phases: Training (Offline) phase and Tracking (Online) phase. During the training phase, signal strengths from Access Points (APS) are collected at pre-identified locations, which are called reference points (RPs). The objective of this operation is building the fingerprint database which will be used in the tracking phase. For the reason that mobile user's location is determined based on the surrounding RPs, they should be distributed in the target area evenly and homogenously [24]. In the tracking phase, Mobile user's surrounding AP RSSs are compared with the RPs dataset collected in the training phase to identify the best matching RPs. The tracking phase could use deterministic and

probabilistic algorithms to match real-time RSS readings with RPs signal data [8], [9], [20] – [24].

4. TESTING AND RESULTS

The examination did on both frameworks which are actualized utilizing Wi-Fi and Bluetooth advances. Formulas:

For Wi-Fi :

$$Distance = 10^{\left[\frac{27.55-(20*\log_{10} frequency)+signal\ levlel}{20}\right]}$$

For Bluetooth :

$$RSSI\ (dBm) = (-10 * n * \log d) + A$$

d- distance in meters
A-received signal in dBm at 1m
n- propagation constant (n=2 for free space)

In this analysis, the researchers assessed the signal strength of the framework utilizing concentrated on situating strategies. The test outcomes appeared in table 1, and the aftereffect of assessment of execution measurements are portrayed in Table 2.

Table I – Test results

	Signal Strength	
Actual Distance	Wi-Fi (Triangulation)	Beacon (Fingerprinting)
0.1m	-38dBm	-15dBm
1.0m	-41dBm	-26.5dBm
2.0m	-46dBm	-28dBm
3.0m	-49.5dBm	-28.5dBm
4.0m	-52dBm	-28.5dBm
5.0m	-54dBm	-28.5dBm
6.0m	-55dBm	-28.5dBm
8.0m	-58dBm	-32.5dBm
10.0m	-60dBm	32.5dBm

Table II – Comparison of implemented system used for indoor localization

	Systems	
	Wi-Fi	Bluetooth
Accuracy	1 m – 5 m [8]-[10].	2 m–5 m [20]-25]
Principles used for localization	proximity, ToA, TDoA, RSSI Fingerprinting, and RSSI theoretical propagation model [8], [9].	RSSI is fingerprinting and RSSI theoretical propagation model [20]-[25].
Coverage	Building level [1]-[8]	Indoor [1]-[8]
Power consumption	High [8]-[10]	Low [20]-[25]
cost	Low [8], [9]	High [20], [21]
Remark	1) Infrastructure available everywhere [14], [20]. 2) Initial deployment is expensive [14]-[16].	1) Data transfer speed is high [17],[18]. 2) Limitation in mobility [17], [18].

5. DISCUSSION AND CONCLUSION

This paper reviews the current most prominent indoor situating strategies and frameworks. Diverse execution estimation criteria are talked about, and a few exchange offs among them are watched. For instance, the one amongst multifaceted nature and accuracy needs watchful thought when to pick situating frameworks and procedures for various applications situations, for example, warehousing, mechanical autonomy, or crisis. The assessment of this examination outlines that an area Bluetooth method is better for little ranges while Wi-Fi strategy is reasonable for substantial situations. At long last, this exploration study has demonstrated regarding signal quality, power utilization and information exchange speed Bluetooth situating methods and frameworks altogether expanding the granularity and precision of the area data contrasted with Wi-Fi.

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