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A Survey Of Indoor Positioning Using Mobile Cellular Network

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Abstract: *The demand for Indoor Location Based Services (LBS) is increasing over the past years as Smartphone market expands. There's a growing interest in developing efficient and reliable indoor positioning systems for mobile devices. Smartphone users can get their fixed locations according to the function of the GPS receiver. This is the primary reason why there is a huge demand for real-time location information of mobile users. However, the GPS receiver is often not effective in indoor environments due to signal attenuation, even as the major positioning devices have a powerful accuracy for outdoor positioning.*
Keywords: *UWB,RFID,APs, RSS, WLAN, GPS*

I. Introduction

Indoor positioning systems locate and track objects within the buildings and closed environments. These systems use wirelessconcepts,opticaltrackingorultrasonictechniques. Object detection and tracking is the basis of many applications in surveillance and activity recognition. There are many solutions developed for position estimation of indoor or outdoor objects[1, 2].

Indoor localization systems employ a wide range of different technologies, these systems could use any combination of the following:

- Ultra-wideband (UWB)
- Infrared
- Radio frequency identification (RFID)
- Inertial sensors, magnetic sensors etc
- Sound (ultra-sound or audible sound)
- Wi-Fi
- Camera

The first five positioning systems in the above listing are able to localize users with high accuracies. However, these systems require the installation of additional hardware, which lead to high budget and labor cost, preventing them from having large-scale deployments.The use of Wi-Fi to estimate location is a great approach, since Wi-Fi Access Points (AP) are readily available in large quantities in today's indoor environment and it is possible to use available mobile devices on the users' side. This process of estimation involves capturing the strength of Wi-Fi signal received on the device’s end and then using it to do analysis regarding the user’s location. Let’s explore the different techniquesusing which we can determine the location of a user.

II. Indoor Positioning Techniques

IPS can be used to locate people or objects inside buildings, typically via a mobile device such as a smart phone or tablet. Although the technology is newer than GPS, services that leverage IPS are quickly gaining traction in places like shopping malls, hospitals, airports and other indoor venues where navigation and other location-based services (LBS) can prove to be indispensable.

In Table 1 below, the accuracy, key characteristics, main advantages and disadvantages of the various positioning techniques used in mobile devices are compared. GPS with a high accuracy has emerged as the leading technique to provide location information. Assisted GPS (A-GPS) is a system allowing global positioning system (GPS) receivers to obtain information from network resources to assist in satellite location. An GPS system is especially useful when the receiver is in a location where it is difficult for the satellite signals to penetrate. Both GPS and A-GPS techniques need the signal from the satellite to propagate without obstruction to the receiver, which is the line of sight (LoS), to support high accuracy positioning.

Wi-Fi positioning and INS can provide medium accuracy without LoS, thus they are more suitable to be used in indoor environments. However, high cost for infrastructure and limited coverage is a major issue for Wi-Fi positioning. INS also has some issues since it is prone to rapid accumulative errors.

Table-1: Comparison of Indoor positioning techniques based on their accuracy level, advantages and disadvantages.

Technique	Accuracy Level	Advantage/Disadvantage
GPS	Height(<10m)	Good accuracy/ Line of Sight (LoS) is needed
A-GPS	Height(10m)	Assisted GPS/ Network interaction is required and only effectively used for locating a particular place in a small area
Wi-Fi Positioning	Medium (10-100 m)	Good accuracy for indoor environments and no need LoS/ Medium cost for infrastructure and limited coverage
Inertial Navigation System(INS)	Medium (10 m)	Affordable/ Bias and drifting are a concern(accumulative error)
Cellular Network Position	Low-medium(1 km)	No requirement for infrastructure/ Problematic in low signal conditions

III. Typical Positioning Technique

a. The Global Positioning System (GPS)

GPS is the most popular system to find the location andthepositionoftheobjects[3]. GPS is a US satellite-based radio navigation system with a nominal constellation of 24 satellites. It was originally intended for military navigation applications, but in the early 1980s, the system was made available for civilian use. For example, for high accuracy positioning such as geodetic surveying and engineering surveys where millimeter- or centimeter level of accuracies is required. GPS is regarded as a popular tool/positioning utility to locate mobile objects that need basic position and navigation services. For example, GPS chips embedded smart phones become a standard component for the acquisition of its location information. For the determination of 2D position e.g. latitude and longitude (or easting and northing), a GPS receiver needs to track GPS signals from at least three satellites. With four or more satellites in view, the receiver can determine the 3D position (latitude, longitude and altitude) of the user. Once the user's location has been determined, the GPS-enabled Smartphone unit can provide navigation and some other information, e.g. the user's current speed, bearing, track, trip distance, distance to destination, sunrise and sunset time. One of the advantages of the GPS system is its 24-hour availability. In the below figure is a snapshot of GPS satellites' visibility in Melbourne on 3rd July 2013.[4]

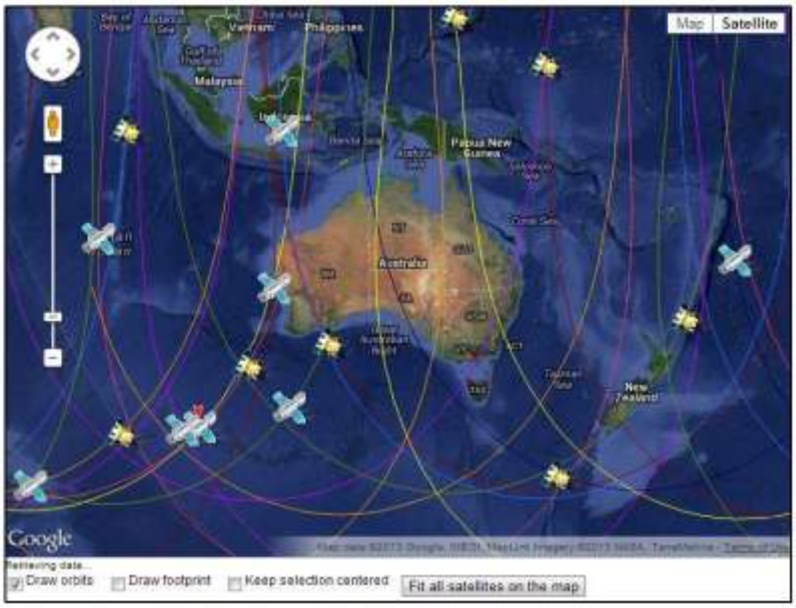

Figure 1: *GPS satellites' visibility in Melbourne on 3 July 2013*

b. Infrared Positioning Systems

These systems use infrared signals in order to transmit signals from sensor nodes to the BS. One of the most well-known infrared positioning systems is the active badges developed by AT&T Cambridge [5]. In this system, users carry an ID card equipped with infrared LED. The infrared LED sends a unique code every fifteen seconds. Furthermore, there are infrared sensors installed on a ceiling and if the IR badge is within six meters, the sensor is able to read the code. The BS receives the data from the IR sensors periodically. Finally, the BS is able to build a map of each badge location using the information retrieved from the sensors. Active Badges have mainly four commands, WITH, LOOK, NOTIFY, and HISTORY, each of which provides a different function. For example, WITH shows the badges that exists in the sensor area, LOOK is used to look for a badge by a sensor, NOTIFY is used to notify the BS when the badge is found and HISTORY shows the badges positions over a certain period of time.

c. Ultrasonic Positioning Systems

Ultrasonic beacons are used more often than infrared technology. Ultrasonic systems provide more accurate positions for objects. Ultrasonic based systems are more accurate than Radio Frequency based systems as we will see in the discussion section. However, Ultrasonic systems need to have a fixed structure of the system [6]. Examples of the systems developed based on Ultrasonic technology are the Active Bats [7] developed by AT&T Cambridge too. The Crickets system [8] developed by the Massachusetts Institute of Technology (MIT) is another well-known ultrasonic based indoor positioning system.

The Cricket system has two types of nodes, beacons and listeners. Beacons' locations are fixed and they are attached to the ceiling while the listeners are attached to the target objects and people.

d. RSSI positioning systems

ReceivedSignalStrengthInformation(RSSI)wasemployed toestimatethedistancesbetweentransmittersandreceivers. UsuallyRFsignalsareused[10].Thelocationoftheobjects are determined by calculating the distance of the object from the transmitters using triangulation or tri-lateration techniques. Initially a test run can be accomplished in indoors to determine the RSSI database for various transmitters[11-].

One weakness is that the radio signals attenuates from the walls and the receivers perform poorly in indoor environment.Typicalindoorenvironmenthavemanywalls and obstacles which are made of various materials. As a result,RSSIvalueschangesanditbecomesunreliable. Many sensors are developed to measure signal strengths andanglesofsignalorientations.Manyalgorithmsarealso developedforbettersignalacquisitionandtracking.There is a trend for integrating various sensors and data sources. They also use the triangulation, trilateration and data matching techniques.RF signal based systems can be split into WaveLAN, Ultra Wide Band and RFID. ,

e. Ultra Wideband (UWB)

In UWB, ultra short-pulses with time period of 500MHz), in the frequency range from 3.1 to 10.6GHz, using a very low duty cycle [12] which results in reduced power consumption. The technology has been primarily used for short-range communication systems, such as PC peripherals, and other indoor applications. UWB has been a particularly attractive technology for indoor localization because it is immune to interference from other signals while the UWB signal increasing the number of tags deployed in any can penetrate a variety of materials, including walls.RFID Technology

f. **RFID based indoor localization system**

Shirehjini et al. [16] propose an RFID based indoor localization system that relies on a carpet of RFID tags and the readers on mobile object to calculate the location and orientation of the mobile device. The proposed system uses low-range passive RFIDs and various other peripherals that help in interpreting the sensor data. The readers on the mobile object read the information from the RFID tags on the carpet and then use the information to calculate its position. The RFID reader communicates with the passive RFID tags that are embedded in the floor tiles. The author do not highlight the localization accuracy that their system attained. The user shoe is integrated with an RFID reader that can communicate with user device using Bluetooth. An RFID tag grid, programmed with spatial and ambiance related information, is placed on the ground so that the reader in user shoes can read the position related information and convey it to the blind users. Wang et al. [17] use active RFIDs for localization in an indoor environment. The mobile user device has an RFID reader while fixed RN (RFID tags) are distributed in the environment. The authors use a two-step approach. In the first step, the strength of the signal in overlapping spaces is analyzed while in the second phase, the user's movement pattern is analyzed using the signal strength. The proposed system relies on the RSSI to obtain the location of different entities in an indoor setting. RFID tags can be installed within a room, with which the tagged users or entities can communicate and obtain their relative location with respect to each other. SpotON can also be used for absolute location, however the absolute position of the RFID tags should be known.

g. Trilateration method

This method is widely used in conventional surveying and GPS positioning. It uses the distances of an object from three or more known fixed points, to determine the position of an object. As shown in the below figure there are three APs to send signals which is received by the mobile device. Now the received signals (RSS values) are converted into spatial distances, which are used as the radii of circles i.e. d1, d2, d3 etc. Since

the complexity of indoor space can have a great impact on the signal, when one converts the signal strength to a spatial distance, it can inevitably produce errors. To reduce the error, researchers have suggested a variety of methods to assist trilateration. If you want to explore more in this area of research, read here
This method has been used for indoor positioning for several years. Its main advantage is that it can use existing WLAN infrastructures or other network environments. Compared to techniques like Trilateration, Fingerprinting technique is more suitable for indoor environments and is relatively simple to deploy. There are no specific hardware requirements, so any existing WLAN infrastructure can be used for positioning.

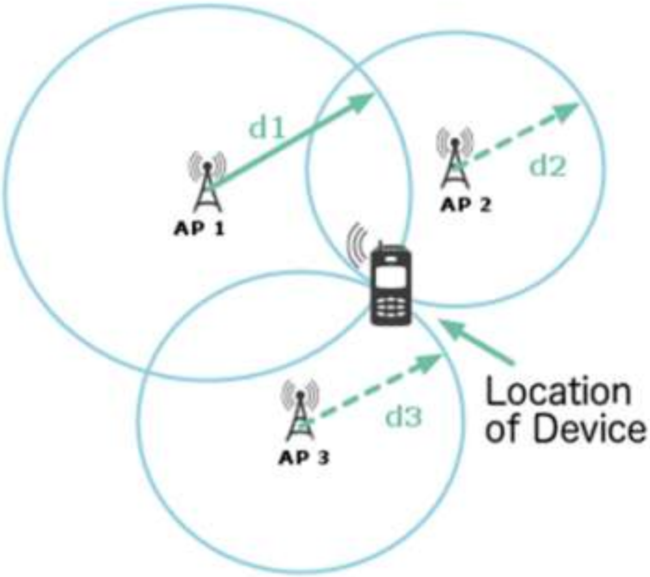

Figure 2: *Simple design of Trilateration method for Indoor Positioning Fingerprinting method*

IV. Conclusion

In this paper, we have presented a detailed description of different indoor localization techniques andtechnologies. The paper also provided a thorough survey of various indoor localization systems that have been proposed in the literature with particular emphasis on some of the recent systems. Using our proposed evaluation framework, the paper evaluated these systems using metrics such as energy efficiency, accuracy, scalability, reception range, cost, latency and availability. We provided a number of use case examples of localization to show their importance particularly after the rise of the IoT and the improved connectivity due to different sensors. The paper also highlighted a number of challenges affiliated with indoor localization and provided general directions and solutions that can help in tackling these challenges.

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