 ISSN : 0976-8491 (Online) | ISSN : 2229-4333 (Print)

A Survey on Various Wireless Indoor Localization Techniques and Technologies

[1]Priya Darshini, [2]Suchitra V

[1,2]Dept. of Electronics and Telecommunication, Siddaganga Institute of Technology, Tumkur, India

Abstract

Wireless indoor positioning systems have become very popular in recent years. IPS have been designed to provide location information of persons and devices. These systems have been used in many applications such as asset tracking and inventory management. IPS uses sensors and communication technologies to locate objects in indoor environment. IPS are attracting scientific and enterprise interest because there is a big market opportunity for applying their technologies. This paper provides an overview of existing indoor positioning techniques such as Angle of Arrival (AoA, Time of Flight),Time of Arrival (ToA), Time Difference of Arrival (TDOA), Round-trip time of Flight (RTOF), Received Signal Strength (RSS), based on technologies such as WiFi, Radio Frequency Identification Device (RFID), Ultra-Wideband (UWB), Bluetooth and systems.

Keywords

Indoor Positioning Systems, Location Techniques, Fingerprinting, Localization

I. Introduction

In the past couple of years, the mass proliferation of mobile phones and other portable devices has resulted in a wide variety of facilities, including indoor localization. Over the last few decades, the localization of indoor devices has been extensively studied primarily in industrial settings and for wireless sensor networks and robotics. It is, however, only less than a decade ago that the wide-scale proliferation of smartphones [6] and wearable devices with wireless communication capabilities made the location and tracking of such devices synonymous with the location and tracking of the corresponding users and enabled a wide variety of related applications and services.

Localization of users and apps has wide-ranging applications in the health sector, manufacturing, disaster management, building security, surveillance and a range of other industries. Some emerging technologies [4] such as the Internet of Things (IoT), smart networks (such as smart cities, smart buildings, smart grids) and Machine Type Communication (MTC) can also benefit.

Global positioning system (GPS) is the most widely used satellite-based positioning system, which offers maximum coverage. However, GPS cannot be deployed for indoor use, because line-of-sight transmission between receivers and satellites is not possible in an indoor environment. Some interference and noise sources from other wired and wireless networks degrade the accuracy of positioning. The building geometry, the mobility of people and the atmospheric conditions result in multi-path and environmental effects. Considering these issues, IPSs [9] for indoor applications raise new challenges for the future communications systems. Some papers give an overview of the numerous technology choices available for IPS [9] design such as infrared (IR), ultrasound, radio frequency identification (RFID), wireless local area network (WLAN), Bluetooth, sensor networks, ultra-wideband (UWB), magnetic signals, vision detection and audible speech.

The remainder of this paper is organized as follows. An overview of localization techniques is presented in Section II. In Section III, we describe the technologies used for localization. Performance metrics used to evaluate ant localization system is explainer inSection IV. Section V will be discussed about possible applications of localization. Finally, Section VI concludes the paper and gives possible future directions for research.

II. Localization Techniques

In this section, we are going to discuss some of the techniques that are used for localization. Equipped with one or more location technologies, IPSs use positioning techniques [4-5], [9] to locate objects and deliver position information of absolute, relative and proximity. Mainly there are four indoor location estimation techniques: triangulation, fingerprinting [1], [8] proximity and vision analysis.Positioning techniques for triangulation, fingerprinting, and vision analysis may provide information on the absolute, relative and proximity position. The proximity positioning technique can offer information only about the proximity position.

A. Triangulation Technique

Triangulation uses the triangular geometric properties to estimate the destination position. There are two derivations to it: lateration and angulation. The lateration calculates an object's location by calculating its distances from many reference points. Instead of measuring distance directly by means of received signal strengths (RSS), arrival time (TOA) or arrival time difference (TDOA) is typically calculated, and the distance is determined by calculating the attenuation of the transmitted signal intensity or by multiplying the radio signal velocity and travel time. Angulation locates an object by measuring angles with respect to several reference points.

1. Lateration Technique

(a). Time of arrival (ToA)

Time of Arrival (ToA) or Time of Flight (ToF) is used to measure the distance between the Tx transmitter and the Rx receiver. In fig. 1, the distance from the mobile target to the measuring unit is directly proportional to the propagation time. TOA [8] measurements must be made with respect to signals from at least three reference points for calculating the device's position regarding the access points. The time of one-way propagation is determined for TOA-based systems, and the distance between the measurement device and the signal transmitter is estimated.

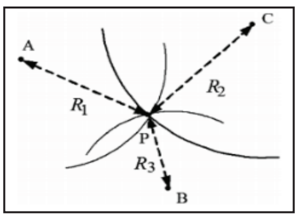

Fig. 1: Positioning based on TOA/RTOF Measurements

(b). TDOA

TDOA's idea is to determine the relative position of the mobile transmitter by examining the difference in time at which the signal reaches multiple units of measurement, rather than TOA's absolute arrival time. A 2-D target location, as shown in Fig. 2 can be estimated from the two intersections of two or more TDOA measurements [8]. Two hyperbolas are formed from TDOA measurements at three fixed units of measurement (A, B, and C) to provide a point of intersection, locating target P.Usage of correlation techniques are the standard methods for estimating TDOA in computation. TDOA can be determined fromthe cross-relation between the obtained signals in a pair of units of measure.

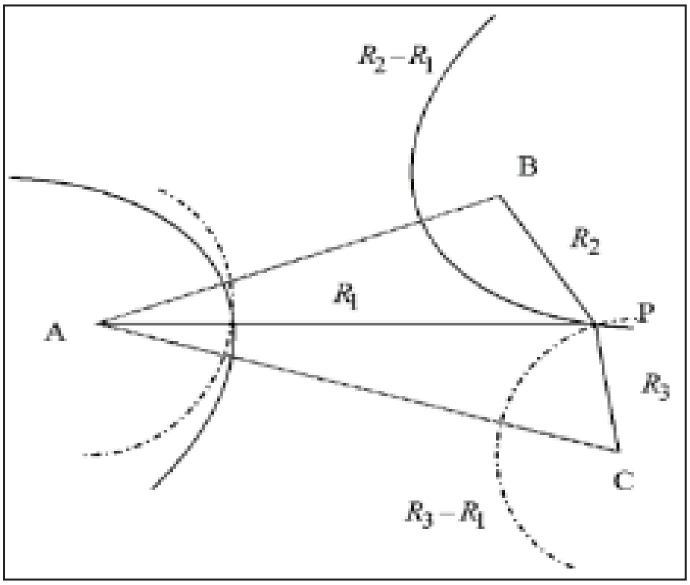

Fig. 2: Positioning based on TDOA measurements

(c). RSS-Based (or Signal Attenuation-Based) Method

The above two schemes have some drawbacks. It is difficult for indoorenvironments to find a LOS channel [7] between theSender, and receiver. In these conditions, the propagation of radio will suffer from multipath effects. Multipath effect would affect the time and angle of an arrival signal; thus, the accuracy of the estimated location could be diminished. Signal-based attenuation methods attempt to quantify the loss in signal direction due to propagation [8]. Theoretical and empirical models are used to convert into a range estimate the difference between the transmitted signal intensity and the received signal strength as shown in Fig. 3.

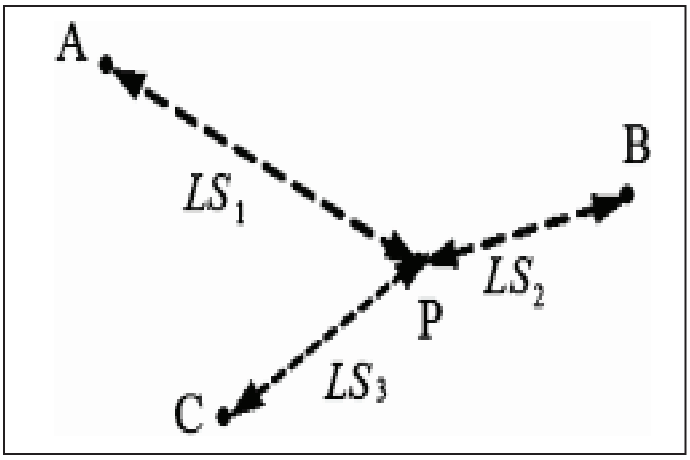

Fig. 3: Positioning based on RSS, where LS1, LS2, and LS3 denote the measured path loss.

(d). Round Trip Time of Flight (RTOF)

This method is to measure the flight time of the signal which travels from the transmitter to the measuring unit and back, called the RTOF (see Fig. 1). For RTOF a milder criterion for relative clock synchronization replaces the above criterion for synchronization in TOA. Its measuring mechanism of range is identical to that of the TOA. A target transponder responds to the radar signal being tested, and the entire propagation time of the roundtrip is determined by the units of measurement.

(e). Received Signal Phase Method

The method used for the received signal phase uses the carrier phaseto estimate the range. This method is also known as the arrival phase (POA). The signal transmitted from each transmitter to the receiver requires a finite transit delay, assuming that all transmitting stations emit pure sinusoidal signals that are of the same frequency f, with zero phase offset, in order to determine the phases of signals received at a target point.For an indoor positioning system, the signal phase method can be used in conjunction with the TOA [8] / TDOA or RSS method to fine-tune the positioning of the location.

2. Angulation (AOA Estimation) Techniques

In AOA you can find the position of the desired target by the intersection of several pairs of angle direction lines, each shaped from the base station or beacon station to the mobile target by a circular radius. As illustrated in Fig. 4, AOA methods [4-5], [8] can use at least two known reference points (A, B) and two measured angles (A, B) to derive target P's 2-D location. The advantages of AOA are that a position estimate may be determined with as few as three measuring units for 3-D positioning or two measuring units for 2-D positioning, and that no time synchronization between measuring units is required.

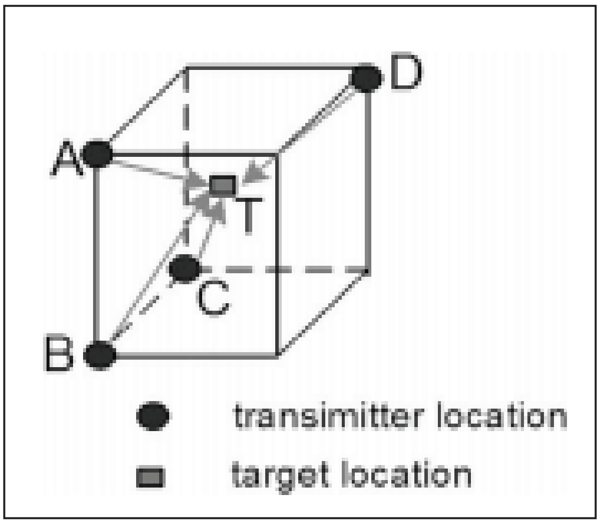

Fig. 4: Positioning based on AOA measurement

B. Fingerprinting/Scene Analysis

RF-based scene analysis refers to the type of algorithms that first collect a scene's features (fingerprints) and then estimate an object's position by comparing online measurements with the nearest fingerprints located a priori. RSS-based [8] fingerprinting of positions is widely used in scene analysis. Location fingerprinting [1], [8] refers to techniques that suit any feature of a location-dependent signal fingerprint.The fingerprints or features are normally collected in RSSI or CSI format. There are a variety of algorithms available which can be used to suit the online measurements offline. The main challenge to the techniques based on location fingerprinting is that the received signal strength could be affected by diffraction, reflection, and scattering in the propagation indoor environments.

There are mainly five location fingerprinting-based positioning algorithms [8] using pattern recognition technique: probabilistic methods, k-nearest-neighbor (kNN), neural networks, support vector machine (SVM), and smallest M-vertex polygon (SMP).

1. Probabilistic Methods
One method considers positioning as a classification problemin addition to the histogram approach, kernel approach is used in calculating likelihood. Assuming that the likelihood of each location candidate is a Gaussian distribution, the mean and standard deviation of each location candidate can be calculated. If the measuring units in the environment are independent, we can calculate the overall likelihood of one location candidate by directly multiplying the likelihoods of all measuring units. Therefore, the likelihood of each location candidate can be calculated from observed signal strengths during the online stage, and the estimated location is to be decided by the previous decision rule.Other probabilistic modeling techniques for location-aware and location-sensitive applications in wireless networks may involve pragmatically important issues like calibration, active learning, error estimation, and tracking with history.

2. kNN
The kNN averaging uses the online RSS to search for k closest matches of known locations in signal space from the previously-built database according to root mean square errors principle. By averaging these k location candidates with or without adopting the distances in signal space as weights, an estimated location is obtained via weighted kNN or unweighted kNN. In this approach, k is the parameter adapted for better performance.

3. Neural Networks
During the offline stage, RSS and the corresponding location coordinates are adopted as the inputs and the targets for the training purpose. After training of neural networks, appropriate weights are obtained. Usually, a multilayer perceptron (MLP) network with one hidden layer is used for neural-networks-based positioning system. The input vector of signal strengths is multiplied by the trained input weight matrix, and then added with input layer bias if bias is chosen. The result is put into the transfer function of the hidden layer neuron. The output of this transfer function is multiplied by the trained hidden layer weight matrix, and then added to the hidden layer bias if it is chosen. The output of the system is a two-element vector or a three-elements vector, which means the 2-D or 3-D of the estimated location.

4. SVM
SVM is a new and promising technique for data classification and regression. It is a tool for statistical analysis and machine learning, and it performs very well in many classification and regression applications. Support Vector Classification (SVC) of multiple classes and support vector regression (SVR) have been used successfully in location fingerprinting [1], [8].

5. SMP
SMP uses the online RSS values to search for candidate locations in signal space with respect to each signal transmitter separately. M-vertex polygons are formed by choosing at least one candidate from each transmitter. Averaging the coordinates of vertices of the smallest polygongives the location estimate. SMP has been used in MultiLoc.

C. Proximity
Proximity algorithms offer details about the symbolic relative location. It usually relies on a dense grid of antennas, each of which has a well-known position. When a single antenna detects a mobile target, it is treated as being collocated with it. When the mobile target is detected by more than one antenna, it is considered to be collocated with the one which receives the strongest signal. This approach is based on the idea that mobile cellular networks can classify a mobile handset's approximate location by knowing which cell site the user will be using at a given time.

D. Vision Analysis
The vision analysis estimates a location, from the image received by one or several points. Vision positioning brings the users comfort and efficiency, as no extra tracked devices are needed for the tracked people to carry. In the tracking area of an IPS [9], one or more cameras are usually fixed to cover the entire place and take images in real-time. The observed target images are searched in the pre-measured database to make estimations of the position. The technique of vision positioning can provide a useful location context for services based on the images taken.

III. Technologies for Localization
In this section, there will be presented and discussed several existing technologies that have been used to provide indoor localization services. Digital networking technologies [4], such as IEEE 802.11(WiFi), Bluetooth, Zigbee, RFID and Ultrawideband (UWB), will be introduced first, followed by technology focused on visible light and acoustics.

A. WiFi
The IEEE 802.11 standard, also known as WiFi, operates in the Manufacturing, Science, and Medical (ISM) band and is mainly used to provide networking capabilities and Internet access to various devices in residential, public, and commercial environments. Initially, WiFi had a reception range of about 100 meters which has now increased to about 1 kilometer (km).WiFi is enabled for most of the current smartphones [6], laptops and other portable user devices, making WiFi an ideal candidate for indoor localization [2]. Since current WiFi access points can also be used as reference points for simple localization systems for signal collection without the need for additional infrastructure.Current WiFi networks are usually deployed for communication purposes rather than for localization purposes and thus new and efficient algorithms are needed to improve their accuracy of localization. The techniques of RSS [8], CSI, ToF and AoA [4], [8] may be used to provide WiFi-based localization services [2].

B. Bluetooth
Bluetooth consists of the requirements of physical and MAC layers for connecting various fixed or moving wireless devices within a particular personal space. Bluetooth's new version, i.e. Bluetooth Low Energy (BLE), also known as Bluetooth Smart, will offer an enhanced 24Mbps data rate and 70-100-meter coverage range with better energy efficiency. Although BLE may be used with various localization techniques such as RSSI, AoA, and ToF, most of the current BLE-based localization solutions [4] are less complex

based on RSS-based inputs as RSS-based systems.While BLE can be used for localization in its original form, two protocols based on BLE,primarily for context-conscious proximity dependent services.A fundamental limitation of iBeacons [3] is that the user interface receives only the average RSSI value per second, even though the sos are transmitted at 50 ms intervals. This is to take into account differences in the consumer device's instantaneous RSS values.

C. Zigbee

Zigbee is based on the IEEE 802.15.4 standard for low cost, low data rate and energy-efficient personal area networks, which is concerned with the physical and MAC layer. Zigbee defines the higher protocol stack rates and is primarily used in wireless sensor networks. The Network Layer in Zigbee is responsible for routing multihops and managing networks while the application layer is responsible for distributed communication and application growth. Although Zigbee favors sensor localization in WSN, it is not readily available on most consumer devices, so it is not desirable for consumer indoor localization.

D. Radio Frequency Identification Device (RFID)

The primary purpose of RFID is to transfer and store data using electromagnetic transmission from a transmitter to any circuit compatible with Radio Frequency. The RFID tags emit data that can be read by the RFID reader using a predefined RF and protocol, both a priori known to the reader and tag.There are two basic types of RFID systems: First one is Active RFID, that work within the frequency spectrum Ultra High Frequency (UHF) and Microwave. They are linked to a local power source, transmit their ID regularly and can work from the RFID reader at hundreds of meters. Second one is Passive RFID, limited in range of contact (1-2 m) and able to work without power. They can work at frequency ranges low, high, UHF and microwave. Despite being able to be used as an alternative to bar codes, their restricted range renders them unsuitable for indoor venue.

D. Ultra-Wideband (UWB)

In UWB, in the frequency range from 3.1 to 10.6GHz, ultra short pulses with time periods of < 1 ns are transmitted over a bandwidth of > 500MHz using a very low duty cycle resulting in reduced power consumption. The technology was mainly used for short-range communication systems, as well as other indoor applications. UWB has become an especially attractive indoor localization technology because it is resistant to interference from other signals because the UWB signal can penetrate a variety of materials increasing the number of tags deployed in any area.

E. Visible Light

Visible Light Communication (VLC) is an evolving high-speed data transfer technology, using visible light between 400 and 800THz, mainly modulated and emitted by LEDs. Visible light-basedlocalization strategies use light sensors to determine the LED emitters' location and direction. In other words, the LEDs transmit the signal which can be used for location when picked up by the receiver / sensor [3], [5]. AoA is considered the most effective localization method for visible light.

F. Acoustic Signal

The acoustic signal-based localization technology uses the omnipresent microphone sensors in smartphones to detect acoustic signals generated by sound sources / RNs and estimate user positions with respect to RNs. The traditional method used for acoustic-based localization was the transmission of modulated acoustic signals, used for ToF estimation by microphone sensors [3]. While acoustic-based systems have been shown to achieve high localization accuracy, only audible band acoustic signals can provide accurate estimates because of the smartphone [6] microphone limitations.

G. Ultrasound

To calculate the distance between a transmitter and a receiver node, the ultrasound-based localization technology mainly relies on ToF measurements of ultrasound signals and sound velocity. Providing fine-grained indoor localization accuracy with centimeter level accuracy and monitoring multiple mobile nodes simultaneously with high energy efficiency and zero leakage between rooms has been demonstrated.Finally, although complex algorithms for signal processing can filter out high levels of environmental noise that can degrade the accuracy of the localization, permanent noise source can still significantly degrade device performance.

IV. Conclusion

This paper surveys the current techniques and technologies for indoor localization. The location fingerprinting scheme is typically best for open areas while the Active RFID is ideal for dense environments. Such positioning methods and systems have their own essential characteristics when implemented in specific environments in terms of scalability and availability. The researcher's attention to indoor localization is still a very strong core field of study. Increasing efforts and need to be done to come out with supporting and effective technologies. The aim of this paper is to provide a better understanding of technologies and stimulate new research efforts in this field. The choice of technique and technology significantly affects the granularity and accuracy of the location information.

References

[1] S. Alraih, A. Alhammadi, I. Shayea, Ahmed M. Al-Samman, "Improving accuracy in indoor localization system usingfingerprinting technique", 2017 IEEE International Conference on Information and Communication Technology Convergence (ICTC).

[2] Xiang He, Shirin Badiei, Daniel Aloi, Jia Li,"WiFi iLocate: WiFi based indoor localization for smartphone", Conference Paper, 2014.

[3] Han Zou, Zhenghua Chen, Hao Jiang, Lihua Xie and Costas Spanos, "Accurate Indoor Localization and Tracking Using Mobile Phone Inertial Sensors, WiFi and iBeacon", March 2017.

[4] M. Usman, M. Rizwan, Imran Shafique Ansari, Fabrizio, Khalid A. Qaraqe, "Technologies and Solutions for Location-Based Services in Smart Cities: Past, Present, and Future", Vol. 6, 2018.

[5] Xinrong Li, Kaveh Pahlavan, Mika Ylianttila, Ranvir Chana, and Matti Latva-aho," An Overview of Wireless Indoor Geolocation Techniques and Systems", Conference Paper, January 2000.

[6] Eladio Martin, Oriol Vinyals, Gerald Friedland, Ruzena Bajcsy, "Precise indoor localization using smart phones", conference paper, October, 2010.

[7] Katsuyuki Haneda, Lei Tian, Henrik Asplund, Jian Li, Yi Wang, "Indoor 5G 3GPP-like Channel Models for Office and Shopping Mall Environments" IEEE International

ISSN : 0976-8491 (Online) | ISSN : 2229-4333 (Print)

Conference on Communications, May, 2016.
[8] Hui Liu, Houshang Darabi, Pat Banerjee, and Jing Liu, "Survey of Wireless Indoor Positioning Techniques and Systems", IEEE Transactions on Systems, Man, and Cybernetics—part c: Applications and Reviews, Vol. 37, No. 6, November 2007.
[9] Yanying Gu, Anthony Lo and Ignas Niemegeers," A Survey of Indoor Positioning Systems for Wireless Personal Networks", IEEE Communications Surveys & Tutorials, Vol. 11, No. 1, First quarter, 2009.

Priya Darshini received her bachelor's degree in Electronics and Communication Engineering from Kalpataru Institute of Technology, Tiptur, recognized by Visvesvaraya Technological University, Belagavi, Karnataka, India, in 2018 and pursuing Master's degree in Digital Electronics and Communication system from Siddaganga Institute of Technology (Autonomous), Tumkur, Karnataka, India recognized by Visvesvaraya Technological University, Belagavi, Karnataka, India.

Mrs. Suchitra V received her B.E degree in Electronics and Communication Engineering from Basaveshwara Engineering College (Autonomous), Bagalkot, Karnataka, India in 2011, the MTech degree in Digital Communication from Acharya Institute of Technology (Under VTU), Bangalore, Karnataka, India in 2013. Presently, working Assistant Professor in Department of Electronics and Telecommunication Engineering, Siddaganga Institute of Technology (Autonomous), Tumkur, Karnataka, India since 2015 till date. Her research interests include Wireless Networking, MANETs, Wireless Sensor network, and antenna designing technique.