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Wireless Indoor Localization Systems and Techniques: Survey and Comparative Study

Ahmed Azeez Khudhair[1,2*], Saba Qasim Jabbar[1], Mohammed Qasim Sulttan[1], Desheng Wang[1]
[1]School of Information and Communication Engineering, Huazhong University of Sceince and Technology, Wuhan, China
[2]General Directorate of Electricity Distribution for Middle Euphrates, Ministry of Electricity, Iraq
*Corresponding author, e-mail: engahmedazeez1@yahoo.com

Abstract

The popularity, great influence and huge importance made wireless indoor localization has a unique touch, as well its wide successful on positioning and tracking systems for both human and assists also contributing to take the lead from outdoor systems in the scope of the recent research works. In this work, we will attempt to provide a survey of the existing indoor positioning solutions and attempt to classify different its techniques and systems. Five typical location predication approaches (triangulation, fingerprinting, proximity, vision analysis and trilateration) are considered here in order to analysis and provide the reader a review of the recent advances in wireless indoor localization techniques and systems to have a good understanding of state of the art technologies and motivate new research efforts in this promising direction. For these reasons, existing wireless localization position systems and location estimation schemes are reviewed. We also made a comparison among the related techniques and systems along with conclusions and future trends to identify some possible areas of enhancements.

Keywords: wireless indoor localization, triangulation, fingerprinting, proximity and vision analysis

1. Introduction

Localization is a heterogeneous part of the field wireless communication networks that play a vital role in modern life. Its importance make it one of the pioneer for the research areas and make it also the technique to determine the position of an object or a person [1]. Indoor localization system is a system that attempts to find the accurate position of the person and object inside a building, mall, ... etc. The popularity of mobile computing [2] stimulates extensive research on the localization of persons or assets. In present era of mobile devices, location information is crucial in a wide range of applications such as manufacturing, healthcare etc. In order to meet the user's needs, the location information of persons or assets are required which can be provided by indoor localization system.

The localization systems try to identify the position of moving devices with the help of some fixed nodes and some mobile computing devices. The position information can be used for navigating [3, 4], tracking [5], monitoring [6], ... etc. We cannot use same localization methods for identifying location in both indoor and outdoor environment because (1) indoor environments are more complex, (2) there is signal interference and reflection inside building (3) it is highly dependent on the environment such as position of objects, behavior of person, (4) indoor communication link is unreliable [7]. Many location based protocols and services are proposed by authors for outdoor and indoor environment.

The design and deployment of a system for obtaining location and spatial information in an indoor environment is a challenging task for several reasons like user privacy, management overheads, system scalability and harsh nature of indoor wireless channel (i.e. metal reflection, interference with noise) [4, 6]. For outdoor environment, we can use fixed sensors or GPS based sensors [8]. GPS is the most widely used satellite based positioning system, which offers maximum coverage [1]. GPS cannot be deployed inside buildings, because: (1) It requires line-of-sight transmission between receivers and satellites which is not possible in indoor environment, (2) It requires clear sky-view for proper working, (3) Cost of GPS device is high for

indoor environment; (4) GPS signals are not available in confined environment or high rise buildings.

Many options [5, 8] are available for the design of positioning system in indoor environment such as infrared, ultrasound, radio-frequency identification (RFID), sensor networks, audible sound, light, color of walls, etc. Depending on the priority of the user, different positioning systems are developed. Some of the centralized schemes include the use of self-organizing maps (SOM) [9] to concurrently estimate node locations given hop counts over entire network. There are some hybrid approaches which combine advantages of two or more different techniques.

The remainder of this paper will be organized as follows; wireless indoor localization techniques is presented at section 2. In section 3, we describe wireless indoor localization algorithms. Section 4 illustrates the existing wireless indoor localization systems. Section 5illustrates the performance criteria of evaluating wireless indoor localization systems and in section 6 illustrates some of the wireless indoor localization technology applications. Section 7 discusses the wireless indoor localization techniques which summarizes our work and presents recommendations for future works.

2. Wireless Indoor Localization Techniques

The modeling for the radio propagation in the indoor environment, is difficult to do because ofthe environment circumstances of not line of sight that can be tracked there due to sever multipath and specific site parameters such as; floor layout, moving objects, and numerous reflecting surfaces. There is no good model for indoor radio multipath characteristic so far [10]. Except using one of the five indoor positioning estimation triangulation, Trilateration ,fingerprinting, proximity and vision analysis [2, 11]. Triangulation, fingerprinting and vision analysis positioning techniques can provide absolute, relative and proximity position information. The proximity positioning technique can only offer proximity position information. In the design of IPSs, some IPSs use one positioning techniqueothers combine some of these positioning techniques to compensate for the limitations of single positioning technique.

2.1. Triangulation Technique

The use of geometric characteristics of triangles to achieve or estimate the location of person or objects its called-Triangulation and can be divided into: lateration and angulation as shown in Figure 1. Lateration estimates the position of an object by measuring its distances from multiple reference points. So, it is also called range measurement techniques. Instead of measuring the distance directly using received signal strengths (RSS), time of arrival (TOA) or time difference of arrival (TDOA) is usually measured, and the distance is derived by computing the attenuation of the emitted signal strength or by multiplying the radio signal velocity and the travel time. Round trip time of flight (RTOF) or received signal phase method is also used for range estimation in some systems. Angulation locates an object by computing angles relative to multiple reference points.

2.2. Fingerprinting Technique

Another technique is position finger printing which have Two methods: Training (Offline) phase and Tracking (Online) phase. During the training phase, RSS is used as fingerprint (Figure 2(a)). From 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. Because mobile user's location is determined based on the surrounding RPs, they should be distributed in the target area evenly and homogenously. In the tracking phase (Figure 2(b)), MU'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. based indoor localization is that for each position in area the features of signals are different. By relying on the difference of signals in different position, the current location can be obtained. For fingerprint based indoor localization.
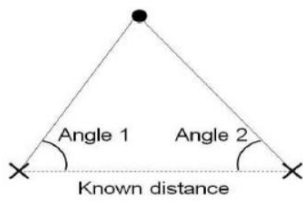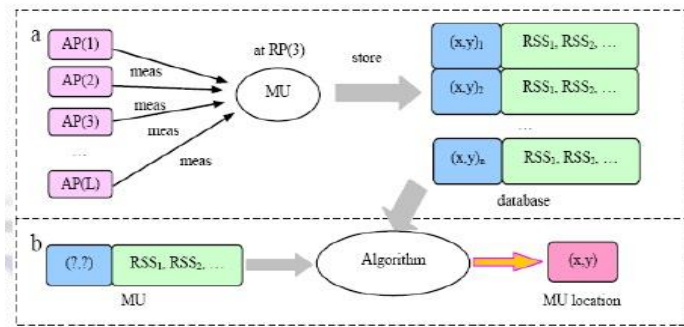
Figure 1. The Angulation Method

Figure 2. Two Phases Of Fingerprinting (a) Training Phase and (b) Tracking Phase
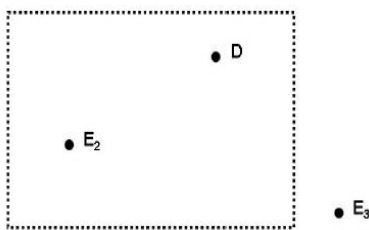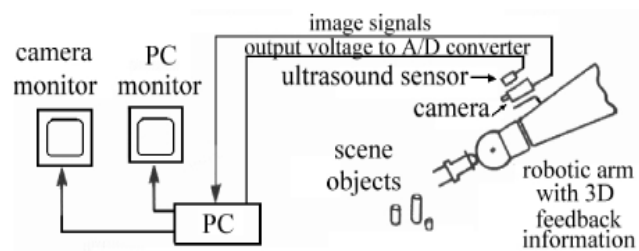

Figure 3. Proximity Positioning Techqnique

Figure 4. An Example Of Using Vision Position Technique

2.3. Proximity Technique

This technique is considered as the simple method for localization, its based on examines the location of a target object with respect to a known position or an area. The proximity location technique needs to fix number of detectors at the known positions. When a tracked target is detected by a detector, the position of the target is considered to be in the proximity area marked by the detector.

As shown in the Figure 3, E2 and E3 are the tracked targets. A proximity area of the detector D is specified and shown by the dotted square in the Figure 3. E2 and E3 are located by monitoring whether they are in the proximity area or not. Thus the target E2 is in the area of D and E3 is not. Thus the proximity location sensing technique cannot give absolute or relative position estimations as with the other three positioning techniques. The proximity location information provided is useful for various location-based services and applications. Most GSM based localization use this type of method for localization. It achieves the accuracy between 50-200m which corresponds to the size of the GSM cell [3]. Proximity based method has a high variance which sometimes might not satisfy the need for localization. Hence this method no longer appears in recent literatures.

2.4. Vision Analysis Technique

This technique involves the monitoring of a wide area around the subject of interest from a specific vantage point. The commonly deployed sensors have broad coverage area and range. Examples include ceiling-mounted video cameras or passive infrared (PIR) sensors. as shown in Figure 4. Vision positioning brings the comfort and efficiency to the users, since no extra tracked devices are needed to be carried by the tracked persons. Usually, one or multiple cameras are fixed in the tracking area of an IPS to cover the whole place and take real-time images. From the images, the tracked targets are identified. The observed images of the targets are looked up in the pre-measured database to make the position estimations. In addition, vision positioning technique can provide useful location context for services based on the captured images.

2.5. Lateration / Trilateration / Multilateration

(Lateration, Trilateration, and Multilateration), Allthreetermsrefer to a position determined from distance measurements. Lateration or trilateration determines the position of an object by measuring its distance from multiple reference points see Figure 5. Thus, it is also called range measurement technique. In trilateration, the "tri" says that at least three fixed points are necessary to determine a position. 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 lateration techniques.
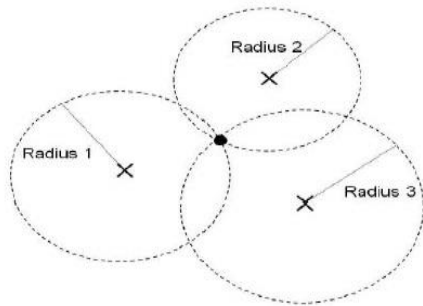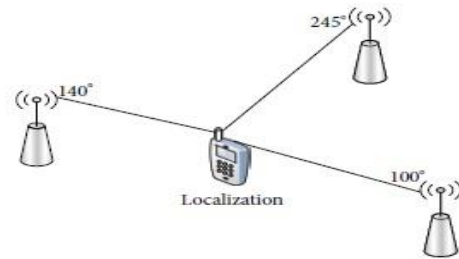

Figure 5. The Latertion Position Method

Figure 6. Angle-of-arrival Positioning Method

3. Wireless Indoor Localization Algorithms

Different techniques for calculating used which classified dpending on the method used for calculation so there are three basic indoor positioning algorithms; the time based methods such as Time Of Arrival (TOA), Time Difference of Arrival (TDOA), Round-Trip Time of Flight (RTOF), Angle Based or Angle of Arrival (AOA), and Received Signal Strength (RSS) [5, 7, 10]. Each of which has its own pros and cons as shown in Table 1.

Table 1. Advantages and Disadvantages of Indoor Positioning Algorithms

Algorithm	Advantages	Disadvantages
TOA	It is the most accurate technique, which can lter out multipath effects in the indoor situations	It is complex to implement [5], it requires precise time synchronization of all the devices which is high cost
TDOA	It needs only to synchronize the base stations participated in the positioning, without the precise synchronization between the targetand the base station as in TOA [3], [12]	It needs some prior knowledge to eliminate the position ambiguity[3], it is affected by multipath of signals [3].
AOA	Since, all of the required transmitter timing information is encodedin the signal, an objects receiver does not need to maintain phase coherence with the time source of any beacon	It requires additional antennas with the capacity to measure the angles which increases the cost of the AOA system implementa tion,it is affected by multipath and NLOS propagation of signals,and reflections from walls and other objects. Due to these factors,it can significantly change the direction of signal arrival and thus degrade the accuracy [3], AOA calculations are very susceptible to range. As the distance from the source increases, the position accuracy decreases [13].
RSS	It is simple to deploy compared to the techni ques that use angle of arrival (AOA) and time difference of arrival (TDOA), there is no need for specialized hardware at the mobile station (MS) besides the wireless network interface card [14].	Existence of obstacles indoors may cause the different attenuation coefficient for RF signals. So the establishment of accurate indoor propagation model is very difficult . [12], building site survey is time-consuming, labor intensive, and easily affected by environmental dynamics [15].

3.1. The Angle Based Triangulation

This technique also can be called angle *of of Arrival (AoA)/AngulationAoA* due to the use of angles so we say its a technique that determines the angle of arrival of the mobile signal coming from a known location at which it is received at multiple base stations [6]. To estimate position in a 2D dimension plane, AoA approach requires only two beacons. To improve accuracy, three beacons or more are used for location estimation (triangulation). For finding direction, it requires highly directional antennas or ntenna arrays. Geometric relationships can then be used to estimate the location of the intersection of two lines of bearing (LoBs) from the known reference points as shown in Figure 6 below. AOA-based techniques have their limitations. AOA requires additional antennas with the capacity to measure the angles which increase the cost of the AOA system implementation In indoor environments, AOA-based methods are affected by multipath and NLOS propagation of signals, along with reflections from walls and other objects, so it is not good for indoor implement tation. Due to these factors, it can significantly change the direction of signal arrival and thus degrade the accuracy of An indoor AOA-based positioning system.

3.2. Time Based Methods

For calculation the time is the major player so Time based triangulation is one of the method that use distance for triangulation. The assumption under time based triangulation is that the time used from beacon to user point can be used to infer the distance between the two points. Since the travel speed of wireless signal is known which approximately equals the speed of light in air. For time based triangulation there are three types of methods: ToA (Time of Arrive) and TDOA (Time Difference of Arrive) and Round Trip Time (RTT).

3.2.1. Time of Arrival (ToA)/Time of Flight (ToF)

Time of Arrival(ToA) systems are based on the accurate synchronization of the arrival time of a signal transmitted from a mobile device to several receiving beacons as shown in Figure 7. With TOA, the distance between the transmitting node andthe receiving node is deduced from the transmission time delayand the corresponding speed of signal as follows:

$$R = time \times speed \tag{1}$$

Where speed denotes the traveling speed of the signal, time the amount of time spent by the signal travelling from transmitting to the receiving node, and R the distance between the transmitting node and the receiving node. Since speed canbe regarded as a known constant, R can be computed byobserving timein ToA, the mobile device transmits a time stamped signal towards receiving beacons. When it is received, the distance between the mobile node and the receiving beacons is calculated from the transmission time delay and the corresponding speed of the signal.
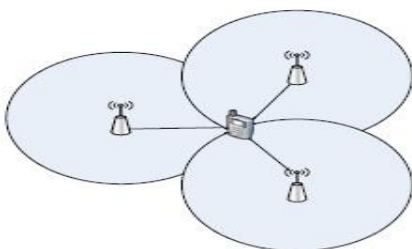
Figure 7. Positioning based on TOA/RTOF Measurements

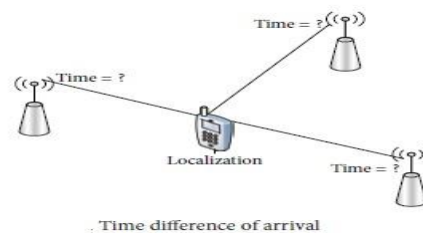Figure 8. Time Difference of Arrival (TDoA)

ToA method needs precise knowledge of the transmission start time(s). Due to this, all receiving beacons along with mobile devices are accurately synchronized with a precise time source. ToA is the most accurate technique used in indoor environment which can filter out multi-path effects [16]. One of the disadvantages of TOA approach is the requirement for

precise time synchronization of all the devices. For time delay measurement, an additional server will be needed which will increase the cost of the system. Along with this, increased delay can also be propagated by a denser environment, in terms of more people.

3.2.2. Time Difference of Arrival (TDoA)

Time Difference of Arrival (TdoA) techniques are measured between multiple pairs of reference points with known locations and use relative time measurements at each receiving node in place of absolute time measurements illustrated in Figure 8. The time difference between these two kinds of signals is used to reconstruct the transmitting node's position. The calculation is based on the following by:

$$\frac{R}{c_1} - \frac{R}{c_2} = t_1 - t_2 \tag{2}$$

In (2), c_1 denotes the speed of one kind of signal, c_2 thes peed of another kind of signal, t_1 and t_2 the time for these two signals travelling from one node to the other respectively, and R still the distance between the transmitting node and the receiving node. TdoA does not need the use of a synchronized time source of transmission in order to resolve timestamps and find the location. With TdoA, a transmission with an unknown starting time is received at various receiving nodes, with only the receivers requiring time synchronization [16]. Each difference of arrival time measurement produces a hyperbolic curve in the localization space on which the location of the mobile node lies.The intersection of multiple hyperbolic curves specifies thepossible locations of the client. Localization using TDOA is called multilateration.

3.2.3. Round Trip Time (RTT)/Round-Trip Time of Flight (RtoF)

It measures the time of flight of the signal pulse traveling from the transmitter to the measuring unit and back [6]. This measurement method emerges with the goal of solving the problem of synchronization incurred by TOA. With RTT, the distance is calculated as follows:

$$2R = tRT - \Delta t \times speed \tag{3}$$

Where tRT denotes the amount of time needed for a signal totravel from one node to the other and back again, Δt the predetermined time delay required by the hardware device to operate at the receiving node, and speed the speed of the transmitting signal. It is clear that RTT is a reciprocal technology [1, 17]. Instead of using two local clocks in both nodes to calculate the delay (as TOA technology does), it uses only one node to record the transmitting and arrival time. Therefore, to some extent, this technology solves the problem of synchronizatio InTOA, calculating the delay is by using two local clocks inboth nodes, while in RTT, it uses only one node to recordthe transmitting and arrival times. Because of this advantage,this technology solves the problem of synchronization to some extent. One of the drawbacks of this method is range measurements to multiple devices that need to be carried out consecutively which may cause precarious latencies for applications where devices move quickly. Positions setting and the flour plan, the model based estimation can save deployment cost. However the change of the furniture or walking people might also somehow change the propagation of the wireless signal, and hence will effect the accuracy of the result

3.3. Received Signal Strength (RSS)

RSS estimates the distance of unknown node to reference node from some sets of measuring units using the attenuation of emitted signal strength. This method can only be possible with radio signals [3]. RSS localization method could be using either a propagation model algorithm or a fingerprinting algorithm. Propagation model algorithm (PMA) establishes the model between RSS and the distance. to calculate the distance according to signal propagation is asfollows:

$$p(R) = p(R_0) - 10n \log\left(\frac{R}{R_0}\right) - \begin{cases} nW \times WAF & (nW < C) \\ C \times WAF & (nW \geq C) \end{cases} \tag{4}$$

The attenuation formula can be expressed in (4), where R denotes the distance between the transmitter and the receiver, R0 a reference distance, p(R) and p(R0) the signal strength received at R and R0 respectively, nW the number of obstacles between the transmitter and the receiver, WAF the attenuation factor of the wall, C the maximum number of obstacles between the transmitter and the receiver, and n the routing attenuation factor which could be determined by both theoretical and empirical calculations. Generally, the lager of the RSS values the closer from the access point (AP). Attenuation of signal strength is inversely proportional to the distance from AP in the outdoor. In contrast, it is complex in the indoor environment because of the existence of many obstacles such as the furniture, equipment windows and doors which may cause multiparty propagation, such as reflection and refraction diffraction [10]. Fingerprinting algorithm follows the way stated earlier in the fingerprinting technique.

3.4. D- OTHERS
3.4.1. Phase of Arrival (PoA)/Phase Difference (PD):
This type of algorithm depend on PoA uses the received carrier phase to determine the distance between two devices. In order to mitigate phase wrapping, the received signal phase is evaluated on multiple frequencies. The distance is then determined by the rate of phase change.

3.4.2. Near-Field Electromagnetic Ranging (NFER):
The term NFER refers to any radio technology employing near- field properties of radio waves. The principle is that the phase of an electro-magnetic field varies with the distance around an antenna. NFER has potential for range measurements in the accuracy range of 30 cm to 1 m and operating distances up to 300m.

Table 2. Wireless Indoor Location Systems - Principal Classification

Taxanomybasics	Categories
Need for hardware	Technologies that require hardware in the building, and self-contained ones
Existence of network	Network-based and non-network-based technologies
System architecture	Self-positioning architecture, infrastructure positioning architecture, and selforien ted infrastructure-assisted architecture
Main medium used to deter mine positions	Ultra-sound, radio frequency, magnetic, vision-Based, and audible sound technologies
Installed system in a building	Fixed indoor positioning and indoor pedestrian positioning
Prior knowledge	Parametric and non-parametric technologies

4. Existing Wireless Indoor Localizaytion Systems
Systems for the indoor localization have different designing and classification approachesas shown in Table 2. In this work, we will consider the most three approachesused; the first approach depends on the frequency of the used electromagnetic waves and can be classified into (long-middle-short) range Wireless technology, while the second approach is to develop a signaling system and a network infrastructure of location measuring units focused primarily on wireless location application. The third approach is to use an existing wireless network infrastructure to locate a target. The advantage of the second approach is that the designers are able to control physical specification and, consequently, the quality of the location sensing results. The tag with the target can be designed as a very small wearable tag or sticker, and the density of the sensor can be adjusted to the required positioning accuracy. The advantage of the third approach is that it avoids expensive and time-consuming deployment of infrastructure. To use more intelligent algorithms to compensate for the low accuracy of the measured metrics. Several types of wireless technologies are used for indoor location. It is beyond the scope of this work to provide a complete overview of systems available till now .We focus on the wireless positioning systems primarily for indoor situations. There are some classification approaches to surveying the indoor positioning system, such as application environments (such as 2-D/3-D positioning in office, warehouse, etc.), positioning algorithms, and wireless technologies. In this paper, we adopt the wireless technologies scheme, also addressing their positioning algorithms and their application situation.

4.1. Global Positioning System (GPS/High Sensitive GNSS/Assisted GNSS /iGPS)

Global positioning system considered a short distance wireless technology and a one of the significant and reliable system for the outdoor positioning and its very successful but for the indoor positioning its unsuitable because of the limited coverage of satellite signal in indoor environment decreases its accuracy due to the presence of obstacles between in the line of sight between the satellite and the receiver and electromagnetic waves is spread and attenuated by the buildings and outdoor obstacles [8]. But it's the most popular and World wide navigation system. As people spend most of their time in a closed environment (indoors), GPS is not well suited for indoor positioning tracking a GPS technology uses a location server with a reference GPS receiver that can simultaneously detect the same satellites as the wireless handset (or mobile station) with a partial GPS receiver, to help the partial GPS receiver find weak GPS signals. The wireless handset collects measurements from both the GPS constellation and the wireless mobile network. These measurements are combined by the location server to produce a position estimation. Performance of indoor GNSS using high sensitivity technologies has been shown to be severely degraded, as compared to the level of performance achievable in outdoor environments. GNSS can be used inside buildings made of wood or bricks at accuracies in the order of 10 m when accepting acquisition times around 20 s. However, HSGNSS is not yet ready to be used for pedestrian navigation in most public buildings and therefore the market of emerging location based services cannot be served with satisfaction based on HSGNSS alone. However, HSGNSS can be a useful component of an IMU multi-sensor fused indoor navigation system to provide sparse position updates. Recently, Atmel2 and U-blox3 announced the availability of a new GPS weak signal tracking technology, called Super Sense. With this new GPS software, GPS navigation becomes possible in building interiors and deep urban canyons because of its tracking sensitivity beyond −158 dBm4, for precision positioning both indoors and outside. Also an iGPS is a laser-based 3D measurement system which can be used for high precision industrial measurements. This technique iGPS consists of two or more static transmitters which continuously send out two rotating fan- shaped laser beams and a reference infrared pulse see Figure 9. Based on Time Difference of Arrival (TDoA) between the three signals, the relative horizontal and vertical angles with respect to a receiver are determined.
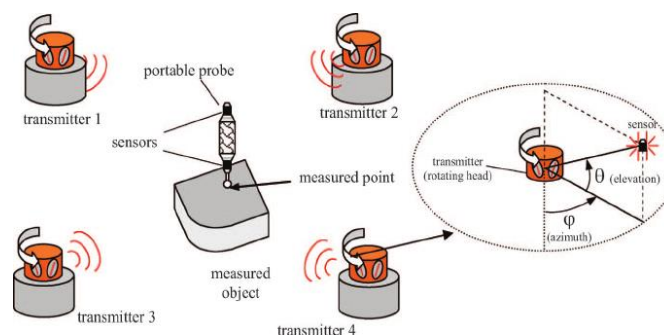

Figure 9. iGPS Scaledetermination

4.2. Infrared (IR)

This technique use wireless communication technology considered most commonly used in localization systems it makes use of the invisible spectrum of light just below red edge of the visible spectrum, which makes this technology less intrusive compared to indoor positioning based on visible light [10, 18]. The three general methods of exploiting infrared signals are: (a) use of active beacons, (b) infrared imaging using natural (i.e. thermal) radiation or (c) artificial light sources. Also IR can be used in two different ways; direct IR and diffuse IR. IrDA (Infrared Data Association) is an example of direct IR which used point-to-point ad-hoc data transmission standard designed for very low-power communications. IrDA requires line of sight communication between devices over very short distance and up to 16 Mbps. On the other hand, diffuse IR has stronger signals than direct IR and therefore, it has longer reach (9-12)

meters. Diffuse IR uses wide angle LEDs which emit signals in many directions. Thus, it allows one to many connections and does not require direct line of sight [19]. The main advantage of using IR based system devices is being small, lightweight, and easy to carry out. The IR systems undertake an indoor positioning determination in a precise way. Besides these, IR based indoor positioning systems have some disadvantages like security and privacy issues. IR signals have some limitations for location determination, like interference from fluorescent light and sunlight [16]. Beside this, the IR based indoor system has expensive system hardware and maintenance cost.

4.3. RFID

Radiofrequency identification considerd a simple technology that has a history to 50 years ago, its commonly used to location position systems of some advantages; for example, radio waves can penetrate through obstacles like building walls and human bodies easily. Due to this, the positioning system in RF based has a larger coverage area and needs less hardware comparing to other systems.

The RFID technology is based on the use of an RFID reader equipped with one or more reader antenna and active or passive transceivers (i.e., tags). A summary scheme that shows how this technology works is reported in Figure 10. Active RFID tags contain a battery and can transmit signals autonomously, whereas passive RFID tags have no battery and require an external source to emit a signal transmission [20]. Typically, the data in the tag consist in a univocal serial number but also additive information (e.g., positional information) can be stored in a tag. The amount of data that can be stored in a tag depends on the size of its memory. The features of this technology make it the ideal candidate for the traceability of several products, such as food or drugs [17, 21] along the supply chain, but it is also used for many other purposes, including the indoor localization.
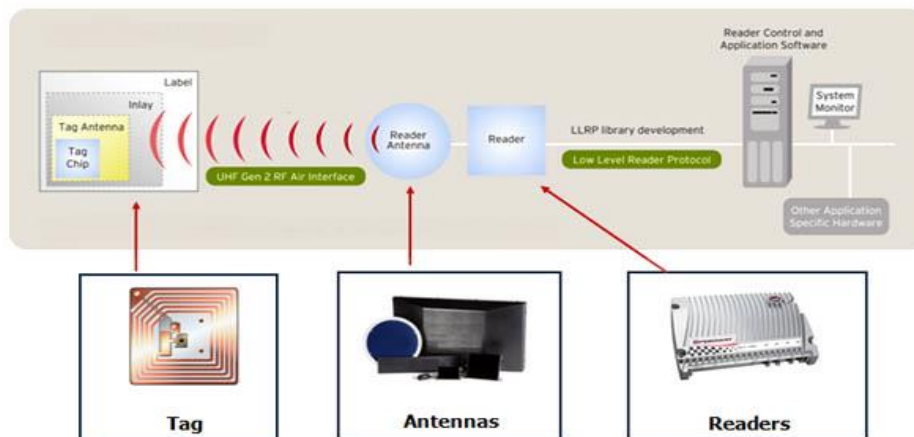

Figure 10. A schema of the RFID Technology Working

The RFID localization can be categorized into two types, i.e., reader localization, and tag localization depending on what, between reader and tag, needs to be localized. In the reader localization, the accuracy of the RFID system is highly depending on the density of tag deployment and the maximal reading ranges. In a probable localization context, a large number of RFID tags, which contain location information, can be deployed to cover an entire indoor environment. A person with a hand held reader could read the closest tag and obtain information about his/ her position. The disadvantage of this approach is the large number of RFID tags, which need to be used, and prerecorded with location information. Alternatively, the RSSI can be used for a coarse range estimation in order to apply multilateration techniques. On the contrary, the tag localization requires several RFID reader spread in the environment in known positions. Obviously, this method is more expensive and the cost increases with the increase in the number of used RFID readers The RFID technology works without direct LoS

since the radio waves have the ability to penetrate solid materials, but strength of the signal depends upon the density of the objects in the building, and then accuracy is often limited. The typical frequency ranges used in RFID are categorized as: (i) Low Frequency (LF) at 125-134 kHz; (ii) High Frequency (HF) at 13.56 MHz; (iii) Ultra-High frequencies (UHF) at 860-960 MHz.In addition to the possibility to work in NLoS environment, other advantages of the RFID technology are high data rate, high security, cost effectiveness, and compactness. Main limitations of LF and HF RFID technology are related to a short reading range and to the ability to read only a few tags at the same time. Instead, regarding the UHF RFID technology, its drawbacks are mainly due to the absorption or reflection of RF waves in the presence of liquids or metals, respectively the main advantages of this technology, is that non-contact is required and not need direct vision (N-LOS) [6]. Therefore RFID systems have been widely adopted as an attractive technology for many significant applications such as asset tracking and industrial automation.

4.4. Cellular-Based

This technique make investment of the wide world usage of GSM\CDMA mobile phones and it has three techniques: i- GSM Fingerprinting ii- Distance Based GSM Positioning iii- Angle Based GSM Positioning. Unlike WLAN, GSM operates in the licensed bands which prevent interference from other devices operating at the same frequency [9]. Indoor positioning based on mobile cellular network is possible if the building is covered by several base stations or one base station with strong RSS received by indoor mobile clients [11]. The most common method of GSM indoor positioning is fingerprinting based on the power level (RSS) [18, 22]. Indoor positioning based on mobile cellular network is possible if the building is covered by several base stations or one base station with strong RSS received by indoor mobile clients. Otsasen, et al., presented a GSM-based indoor localization system in Their key idea that makes accurate GSM-based indoor localization possible is the use of wide signal-strength fingerprints. The wide fingerprint includes the six strongest GSM cells and readings of up to 29 additional GSM channels, most of which are strong enough to be detected but too weak to be used for efficient communication. The higher dimensionality introduced by the additional channel dramatically increases localization accuracy. They present results for experiments conducted on signal-strength fingerprints collected from three multifloor buildings using weighted kNN technique. The results show that their indoor localization system can differentiate between floors and achieve median within-floor accuracy as low as 2.5 m. The same method could be applied in IS-95 CDMA and 3G mobile network.

4.5. UWB

Ultra-Wide Band is a new communication technology and has great differences with traditional communication technologies. The Positioning Methods Using UWB can be classified to: 1-Passive UWB Localization, 2-UWB Virtual Anchor, 3-UWB Direct Ranging, 4-UWB Finger printing. It does not require the use of traditional communication unlike other technology, uses a sub-nanosecond radio pulse to transmit data in a wide range of bandwidth (normally greater than 500 MHz). Its transmission can be regarded as background noise to other wireless technologies, hence in theory, it can use any spectrum without interfere with other users. It uses small transmission power -41.4dBm/MHz (which is limited by FCC) meaning the power consumption is low. Another advantage of UWB is it immune to multi-path problems.it considered short-range, high-bandwidth communication holding the properties of strong multipath resistance. Widespread use of UWB in a variety of localization applications requiring higher accuracy 20–30 cm than achievable through conventional wireless technologies (e.g., radio frequency identification (RFID), wireless local area networks (WLAN), etc.) [23]. A typical UWB setup structures stimulus radio wave generator and receivers which capture the propagated and scattered wave. Moreover, UWB hardware is expensive, making it costly for wide scale used.

4.6. WLAN (IEEE 802.11)

Wireless local area network (WLAN) standard which are midrange and, has become very popular in public hotspots and enterprise locations during the last few years. The IEEE 802.11 WLAN standard was ratified in June 1997. The standard defines the protocol and compatible interconnection of data communication equipment via the air in a local area network

(LAN) using the carrier sense multiple access protocol with collision avoidance (CSMA/CA) medium sharing mechanism [23]. With a typical gross bit rate of 11, 54, or 108 Mbps and a range of 50 to 100 meter, IEEE 802.11 is currently the dominant local wireless networking standard [19]. Using WiFi in indoor positioning and navigation systems depends on knowing a list of wireless routers that are available in an area in which the system operates in. The most popular WLAN positioning method is RSS (Received Signal Strength) which is easy to extract in 802.11 networks and can run on offthe- shelf WLAN hardware [1]. Time of Arrival (ToA), Time Difference of Arrival (TDoA), and Angle of Arrival (AoA) methods are less common in WLAN due to the complexity of time delay and angular measurements. The accuracy of typical WLAN positioning systems using RSS is approximately 3 to 30 meters, with an update rate in the range of few seconds.

4.7. Bluetooth (IEEE 802.15)

Bluetooth is a wireless standard for wireless personal area networks (WPANs). In contrast to ZigBee, Bluetooth standard is a proprietary format managed by Bluetooth Special Interest Group (SIG) [18]. Bluetooth is designed to be a very low power technology for peer-to-peer communications which operates in the 2.4-GHz ISM band. Compared to WLAN, the gross bit rate is lower (1 Mbps), and the range is shorter approximately from 10 cm to 10 meters [11] [24]. Local Positioning group, is one of the Bluetooth SIG groups, which investigates the use of Bluetooth wireless technology for positioning. Bluetooth tags are small size transceivers. As any other Bluetooth device, each tag has a unique ID. This ID can be used for locating the Bluetooth tag [3]. The BlueTags tag is a typical Bluetooth tag12.

The Topaz local positioning solution13 is based on Tadlys Bluetooth infrastructure and accessory products. This modular positioning solution is made up of three types of elements: positioning server(s), wireless access points, and wireless tagsas shown in Figure 11. The system's performance makes it suitable for tracking humans and assets. This system provides room wise accuracy (or, alternatively, 2-m spatial accuracy), with 95% reliability. The positioning delay is 15–30 s. The performance is further enhanced in their new generation Topaz system that integrates infrared and other transducers, with the Bluetooth positioning and communication capabilities.
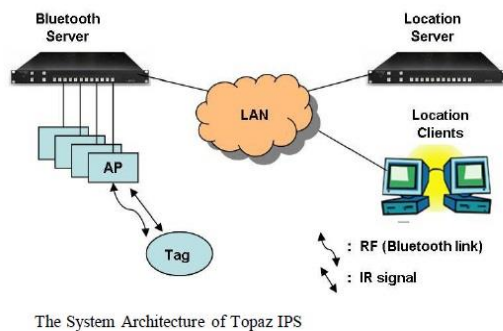

Figure 11. The System Architecture of Topaz Local Positioning Solution
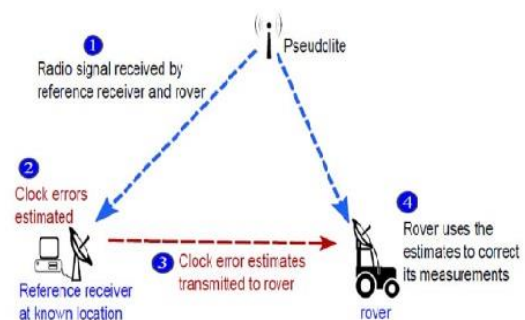
Figure 12. Pseudolites Operation Priciple

4.8. ZigBee

This technology is typical for indoor localization system, its emerging wireless technology standard st for PAN/LAN intended for applications which do not need significant data throughput, but require low-power consumption so it will provides solution for short and medium range communications due to its numerous benefits [25]. It is mainly designed for applications which require low-power consumption but do not require large data throughput. The signal range coverage of a ZigBee in indoor environments is between 20m to 30 m. Distance calculation between two ZigBee nodes is usually carried out from RSSI values. ZigBee is open to interference from a wide range of signal types using the same frequency which can disrupt

radio communication because it operates in the unlicensed ISM bands. Many researchshas deployed a ZigBee based localization algorithm for indoor environments [26]. Beside this proposeing a ways to improve the position determination in an indoor location system (ILS) based on the power levels (RSSI) of an ad hoc ZigBee network.

4.9. FM

FM (Frequency Modulation) technology considerd as a Long Distance Wireless Technologies used world-wide for regional radio broadcasts. In most regions, it uses 87.5 to 108.0 MHz radio spectrum. Using the VHF (very high frequency) which is far less than the WiFi and other modern wireless technology, FM is less affected by weather or obstacles like walls. Since the ubiquity of FM, there is no need to build extra beacon infrastructure using FM for indoor localization. And FM receiver is cheap and has lower power consumption hence better battery life. However, the FM station is very far away and FM has large wave length (around 3m), which means that the signal strength of FM signal does not dramatically change in short distance. Hence FM works better for large area. Since different FM stations use FDMA to share the spectrum, multiple channel signals can be used to reduce the variance or error introduced by single channel signal.

4.10. Dead Reckoning

By knowing the last position, dead reckoning estimate the present position and incrementing that position based on known or estimated speeds over elapsed time. An inertial navigation system which provides very accurate directional information Position estimation is commonly based on accelerometry and gyroscopy uses dead reckoning and is very widely applied [21]. One of the disadvantages of dead reckoning is that the inaccuracy of the process is cumulative, so the deviation in the position fix grows with time. The reason is that new positions are calculated entirely from previous positions.

4.11. Image Based Technologies/Cameras Based Technology

One of the efficient technologies and can be called Visual positioning systems. The vision analysis method estimates a location from the images received at one or multiple points.it can be divided to these sub technologies; 1-Reference from 3D Building Models, 2-Reference from Images, 3-Reference from Deployed Coded Targets, 4-Reference from Projected Targets, 5- Systems without Reference Usually, one or multiple cameras are fixed in the tracking area of an IPS to cover the whole place and take real time images. From the images, the tracked targets are identified. The observed images of the targets are looked up in the pre-measured database to make the position estimations. In addition, vision positioning technique can provide useful location context for services based on the captured images or by use low cost 2D tags (e.g., barcodes) with the encoded information that can be recorded and processed by a mobile device with a built-in camera, as in the system proposed in [21]. The symbolic location of a device is estimated by finding the tag's identifier and associated location in a deployment database, or by decoding the location information embedded in the tag itself [14]. Positioning systems based on video scene analysis are based on computer vision technology to recognize tracked objects in video data. Easy Living by Microsoft Research provides one example of this approach [1] where a video surveillance system tracks moving objects recognized in the video scenes. Also, the mobile device can use video scene analysis to estimate its location by comparing a snapshot of a scene generated by itself with a number of pre-observed simplified images of the scene taken from different positions and perspectives. An improved performance and sub-meter (1 cm – 1 m) accuracy of camera-based localization systems has promoted them as promising positioning solutions for applications in industry, as well as robot and pedestrian localization and navigation.

4.12. Pseudolites

This technology is similar to GNSS in idea but different in application. And can make use from GNSS waves. The illustration of the operation is shown in Figure 12 for thesystem overview of pseudolite. Pseudo-satellites are the cause of nomination. Which are land-based beacons that generate pseudo-noise codes similar to those transmitted by GNSS. A pseudolitesystem also includes mobile receiver units (rovers) whose positions are estimated from distance measurements to the pseudolite beacons which are usually deployed at known

positions. The main purpose of pseudolites is to support GNSS with additional ranges in situations where satellite signals are blocked, jammed or simply not available, e.g. in indoor environments. Originally pseudolites included only systems that transmit at GPS frequencies L1 (1575.42 MHz) and/or L2 (1227.6 MHz) to enhance the satellite geometry for the usage of customary GPS receiver. For the use in indoor environment it has Several error sources are intrinsic for pseudolite based indoor positioning: i-Multipath is a big concern when using signal structures similar to GNSS indoors ii-The near-far problem arises from signal interference of pseudolites with large differences in the distance to a receiver iii-Time synchronization remains a costly and complex task for pseudolite range measurements iv-A solution for carrier phase ambiguities is not found straightforwardly for pseudolite systems relying on phase measurements as we see Several difficulties have limited pseudolite systems to few applications in GNSS-challenged environments such as open pit mines. These difficulties arise primarily from the need for multipath mitigation, time synchronization and ambiguity solving. The tempting approach to broadcast the GPS L1 signal or to use GNSS repeaters is impeded by regulatory restrictions. Therefore, pseudolites of commercial systems always broadcast their own signal structure. While an area of several kilometers can be covered outdoors, the indoor application is limited to a single room or part of a building.

4.13. Others

There is many systems that cannot comprised due to the huge need and use of localization so here a mention of some other system:

1. Radar

This technology has three techniques to for localization; 1) FMCW Radar, 2) Chirp Spread Spectrum (CSS), 3) Doppler Radar. The term is come from (RAdio Detection and Ranging) is a technique to determine the range and angle of incidence to an object. The original principle of radar was to measure the propagation time anddirection of radio pulses transmitted by an antenna and then bounced back from a distant passive target (primary radar). If the object returns a tiny part of the wave's energy to the antenna, the radar device measures the elapsed time. The angle of incidence is estimated from a directional antenna. This original concept of radar assumes passive object reflection and involves only one station which comprises both, transmitter and sensor. This concept has two disadvantages: most of the signal energy gets lost by the reflection and the use of steerable directional antennas is impracticable. Therefore, the concept of radar has been extended to include more than one active transmitter (secondary radar). Instead of passive reflection, the single-way travel time of the radar pulse is measured by ToA and then returned actively.

2. WhereNet

One of the technologies which has a special purpose its a real-time locating syste(RTLS), uses the same 2.4 GHz band as the IEEE 802.11 and Bluetooth systems, but it uses a dedicated standard protocol (ANSI 371.1) optimized for low-power spread-spectrum location. It works by timing the signals transmitted from tags to a network of receivers. 3D-ID is a commercial location system produced by PinPoint. Pinpoint uses RTOF to do ranging. It uses an installed array of antennas at known positions to perform multilateration.

3. Commercial indoor positioning

For the purpose of localization of trading assets or products, it using mesh network techniques such as MeshNetwork positioning system (MPS)15 are also worth to mention. The MPS technology leverages the patented position location and determination methods built into MeshNetwork Quadrature Division Multiple Access (QDMA) radio technology, which uses direct sequence spread spectrum (DSSS) and operates in the ISM 2.4-GHz bands. It is reported that MPS position location information, accurate towithin 10 m, is generated in less than 1 s at mobility speeds of up to 200 mi/h.

4. Wireless Sensor Network Techniques

A great benefits and use for the technology in the wild world its Dramatic advances in RF and microelectromechanical (MEMS) IC design have made possible the use of large networks of wireless sensors for a variety of new monitoring and control applications [6, 8]. Accurate and low-cost sensor localization is a critical requirement for the deployment of wireless sensor networks in a wide variety of applications, including indoor location positioning. Such systems using wireless sensor network have been described as "cooperative, "relative," "multi-

hop," "GPS-free," or "network" localization; "ad-hoc" or "sensor" positioning; and "self-localization" in various papers.

5. DECT Phones

The world wide use of mobile and the fast develop of programs and systems make it perfect for indoor localization. Phones based on Digital Enhanced Cordless Technology (DECT) are common devices for talking wirelessly around the house. DECT phones communicate with a single base station within a typical distance of 200 m to 500 m. the feasibility of using DECT phones for positioning in urban indoor and outdoor scenarios. His fingerprinting method on DECT RSSI outperformed that of WLAN due to the high number of DECT stations (12 to 17) which could be received at a single sub-urban location. After taking fingerprints of 1 to 3 m separation, a localization accuracy of up to 5 m was achieved.

6. Digital Television

This technology also can be used for indoor localization Broadcast signals of digital television stations can be utilized for positioning in urban areas including deep indoor environments with accuracy of about 10 m. Since digital television had started in 1998, most countries have established a network of terrestrial broadcast stations (10 km to 100 km distance between stations). The unmodified digital video broadcast is suited for pseudorange estimation and multilateration in indoor environments due to several reasons: digital television has a signal power advantage over GPS of 40 dB allowing reception in deep indoor environments, the signals have a wide bandwidth of 5 MHz-8 MHz facilitating multipath mitigation, demodulation of the data is simplified by a guard interval in the message, emitters of digital television are synchronized with GPS time allowing to timestamp the data and determine TOA pseudoranges.

7. Performance Criteria of Evaluating Indoor Position System (IPS)

To evaluate the IPSs, various important system performance parameters and deployment criterias are proposed and described in this section. We should ask why we need positioning and then explain the evaluation, so we will start in explain the need for localization.

Outdoor positioning have characteristics that made it very useful in the wide world but in the other hand There are many characteristics that make indoor positioning different from outdoor positioning [18]. In comparison with outdoor environments, indoor environments are more complex as there are various objects (such as walls, equipment, and people) that reflect signals and lead to multipath and delay problems. Also, due to existence of various objects, indoor environments typically rely on Non-Line-of-Sight (NLoS) propagation where signal can not travel directly in straight path from an emitter to a receiver which causes inconsistent time delays at the receiver. Furthermore, the existence of objects and obstacles leads to high attenuation and signal scattering. Typically, indoor positioning applications require a higher precision and accuracy in comparison with outdoor positioning applications in order to deal with relatively small areas and existing obstacles.On the other hand, there are some characteristics of indoor environments that facilitate positioning [20]. For example, small coverage area makes it relatively under control in terms of predetermined infrastructure, corridors, entries and exits, small temperature and humidity gradients, and slow air circulation. Also, indoor environment is less dynamic due to a slower moving speed within.

After the clarity of indoor localization(positioning, tracking) needed for,so we must focus on the other factors that have great influence on designing and using the indoor localization systems so IPSs use numerous positioning approaches that vary greatly in terms of accuracy, cost, precision, technology, scalability, robustness, and security [11, 14, 18]. Some applications may require less cost IPS while others may require high accuracy IPS such as medical tracking, industrial environmental tracking, indoor navigation system for blind. In this section, we describe different performance metrics of IPSs we provide the following performance benchmarking for indoor wireless location system: accuracy, precision, complexity, scalability, robustness, and cost. Thereafter, we make a comparison among different systems.

5.1. Accuracy

The term accuracy it means that you must be 100% confident, or can be defined in the Joint Committee for Guides in Metrology (JCGM) as the closeness of agreement between a measured quantity value and a true quantity value of a measured. Therefore, the accuracy of an IPS is the average Euclidean distance between the estimated position and the true position [11]. The accuracy is still a very challenging area for many researchers in the field [10]. Although the

accuracy of an IPS is the key driver for most applications, some compromises might be needed between accuracy and other performance metrics.

5.2. Robustness

To make sure that localization system is still operate normally even thought some measuring units could be out of function or damaged in a harsh environment and it faced great malfunctioned or some of devices run of battery The positioning techniques have [5] to use this incomplete information to compute the location positioning technique with high robustness could function normally even when some signals are not available.

5.3. Cost

The term cost in positioning system has many aspects or factors on consideration. Important factors include money, time, space, weight, and energy. The time factor is related to installation and maintenance. Mobile units may have tight space and weight constraints. Measuring unit density is considered to be a space cost. Sometimes, we have to consider some sunk costs. For example, a position positioning system layered over a wireless network may be considered to have no hardware cost if all the necessary units of that network have already been purchased for other purposes. Energy is considered as a critical resource in IPSs to avoid service disruption and provide higher mobility solutions. Some mobile units (e.g., electronic article surveillance (EAS) tags and passive RFID tags, which are addressed later) are completely energy passive. These units only respond to external fields and, thus, could have an unlimited lifetime. Other mobile units (e.g., devices with rechargeable battery) have a lifetime of several hours without recharging.

5.4. Scalability

Since indoor localization (positioning, tracking) defined and developed for the needs of users, the IPSs should consider the users' requirements of the tracked devices, so The scalability character of a system ensures the normal positioning function when the positioning scope gets large. Usually, the positioning performance degrades when the distance between the transmitter and receiver increases. A location system may need to scale on two axes: geography and density. Geographic scale means that the area or volume is covered. Density means the number of units located per unit geographic area/space per time period. As more area/space is covered or units are crowded in an area/space, wireless signal channels may become congested, more calculation may be needed to perform location positioning, or more communication infrastructure may be required. Another measure of scalability is the dimensional space of the system. The current system can locate the objects in 2-D or 3-D space. Some systems can support both 2-D and 3-D spaces.

5.5. Complexity

Complexity of a positioning system is extremely important to individuals using IPSs, where a strong access control over how users personal information is collected and used is crucial can be attributed to hardware, software, and operation factors. In this work, we emphasize on software complexity, i.e., computing complexity of the positioning algorithm. If the computation of the positioning algorithm is performed on a centralized server side, the positioning could be calculated quickly due to the powerful processing capability and the sufficient power supply. If it is carried out on the mobile unit side, the effects of complexity could be evident. Most of the mobile units lack strong processing power and long battery life; so, we would prefer positioning algorithms with low complexity. Usually, it is difficult to derive the analytic complexity formula of different positioning techniques; thus, the computing time is considered. Location rate is an important indicator for complexity. The dual of location rate is location lag, which is the delay between a mobile target moving to a new location and reporting the new location of that target by the system.

Table 3. Some of Applications of Localization Technologies and Methods

Application domains	Indoor localization technologies	Accuracy
Asset tracking	RFID, Infrared (IR), Barcode Scanning	Very high
Location-based advertising	Bluetooth beacons (iBeacon)	Low
Shopping assisstance system	Bluetooth, WiFi	High
Museum, fairs, airports, guided tours	Wi-Fi fingerprinting ,Bluetooth LE	Medium
School, university campus	Wi-Fi fingerprinting, Wi-Fi TOA/TDOA	Medium
Hospitals, healthcare, Ambient Assistant Living (AAL)	Wi-Fi fingerprinting, RFID, IR	High
Emergency response and rescue management	Ultrasound, dead eckoning	Medium
Robotics	Dead recko ning,infrared, UWB,Vision sensors	Very high
Indoor sports	Bluetooth LE	Very high
Smart home	ZigBee	High
Augmented reality	LLA Markers(barcodes), INS	High

Table 4. The important characteristics of indoor localization systems and related technologies

System	Technique	Methods	Accuracy	Calculated at Mobile device	Calculated at Infrastraucture	Scalability	Complexity	Cost	Typical Environment
GPS	Trilateration	ToA	6m–10m	√		Low	High	High	Indoor/Outdoor
Wi-Fi	Proximity Trilateration Angulation Scene anal	Cell-ID TOA TDOA AOA RSSI	10-100 m (Prox.) 1-10 m	√ RSSI	√ TOA TDOA AOA Prox.	High	Low	low	Indoor
UWB	Trilateration Angulation	RSSI TOA, TDOA, AOA	1cm-1 m		√	Low	Low	high	Indoor
Bluetooth	Proximity Scene anal. Trilateration	Cell-ID RSSI TOA	1-5 m	√ TOA RSSI		High	Low	high	Indoor/Outdoor
RFID	Proximity Trilateration Scene anal	Cell-ID RSSI	1-5 m	√	√	Medium	Low	low	Indoor
Zigbee	Proximity Trilateration	Cell-ID RSSI	1-10 m	√RSSI	√Prox.	Low	Low	medium	High
Infrared	Proximity Trilateration	Cell-ID TOA	1cm-5m	√TOA	√Prox.	Low	Low	medium	High
Ultrasound	Trilateration	TOA, TDOA	1cm-1m		√	Low	Low	high	Indoor
FM	Trilateration	RSSI fingerprint	2m–4m		√	Low	Low	Low	Indoor/Outdoor
Video scene analysis	Scene anal. Angulation	Computer vision	1cm-1m	√	√	Low	High	high	Indoor
Barcodes	Proximity Angulation	Pattern recognitin	1-10 m	√	√	Medium	Low	high	Indoor
Sensor networks	Proximity Trilateration	Cell-ID RSSI	10 cm-1 m		√	Medium	High	medium	Indoor/Outdoor
INS, PNS	Dead reckoning		1-10 m	√		High	Low	low	Indoor

6. Indoor Localization Technology Applications

The need for indoor localization is not limited since there is huge progress in knowledge systems and industry and normal live benefits so its become emerging to be modified and to be more flexible and reliable and easy to use and keep pace with progress. The most used applications are such as (Location Based Services in Indoor Environments, Private Homes, Context Detection and Situational Awareness, Medical Care, Social Networking, Environmental

Monitoring, Police and Firefighters, Intelligent Transportation, Industry, Museums, Financial Institutions, Logistics and Optimization, Guiding of the Vulnerable People, Structural Health Monitoring, Surveying and Geodesy, Construction Sites, Underground Construction, Scene Modeling and Mapping, Motion Capturing, Applications Based on Augmented Reality). We will show here some of the applications of localization technologies and methods in various indoor available on the market are reviewed in Table 3, along with the accuracy required by a particular service (Very high, from 0-1m; High, from 1-5m; Medium, from 5-15m; and Low, greater than 15m).

7. Summary and Conclusions

This work gives a brief overview of the wild world used in daily life the indoor localization technology, it trends was to cover all the systems and methods and comparison of the system used and some advantages and disadvantages technologies and also some of the application. Despite the great progress made in recent years, there are a number of open issues that need to be addressed. Examples include e.g continuously tracking people travelling between indoor and outdoor environments its only one step forward in this field to help the persons how will investigate in this research area. the future tends for the coming research topics, a) new innovative applications for mobile after the 5G is know had been existed in which provides more possibilities for indoor location information can be used to improve the quality of users' experience and to add value to existing services offered by wireless providers also, b) the advance in WPAN networks it will make a space for further research. c) the un stopped hybrid system innovative applications. d) the need for more unsophisticated infrastructure and high accuracy with un limited coverage area also the benefits of dual using in the inside and outside environments or adequate acquisition for the robustness and cost all these will open the fields of further knowledges. Finally, the important characteristics of indoor localization systems and related technologies are reviewed in Table 4.

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