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Indoor Positioning Based Ranging: A Review and Literature Survey of UWB and Li-Fi Technologies

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Abstract: Why IPS (Indoor Positioning Systems)? This issue is one of the most challenging things to solve in wireless localization due to the lack of a Global Positioning System (GPS) and the existence of distinctive radio propagation characteristics. Although there are different localization options available, the accuracy of localization cannot satisfy customers' requirements. Positioning algorithms could be grouped into two groups, including range-based and range-free techniques. Before actually putting a localization technique into practice, the accuracy of those techniques is of the utmost importance. Range-based methods can often attain great accuracy with the help of specialized hardware, and this accuracy can be dependent on either the distances between nodes or the angles between them. In this paper, a comparison of different strategies utilized for positioning is presented, as well as an analysis of the pros and cons associated with supporting technologies for each strategy. A literature survey of the recent IPS technologies range-based with focuses on Ultra-Wide Band (UWB) and Light Fidelity (Li-Fi) is presented with significant recommendations. This literature considered the accuracy, complexity, scalability, cost, latency, deployment, and usability, as well as strengths, shortcomings, approaches, and issues determined by each work. This paper highlights the most recent research gaps and reviews the most promising findings, with recommendations to the reader and researcher, in UWB and Li-Fi indoor positioning systems over the last five years based on range-based techniques. In addition, this paper serves as a guide that discusses all of the measures that may be utilized in the process of evaluating localization technologies, and it could be considered a roadmap for existing and new researchers to identify and characterize suitable technologies for creating innovative systems and apps via stand-alone range-based positioning.

Keywords: IPS, localization, range-based, localization, IoT, indoor positioning

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1. INTRODUCTION

There has been a recent uptick in interest in having localization-based services made available to consumers all over the world. The majority of mobile and wireless networks necessitate the use of localization as an essential component. For instance, wireless sensor networks are frequently set up in an ad-hoc manner, which implies that the precise positions of the sensors are not determined in advance [1]. The process of obtaining information regarding various reference points within a predetermined area is referred to as localization or position. This information can be used to establish where tracked items are located. In other words, it is an attempt to determine the position of movable or fixed devices (such as smartphones, unmanned vehicles, navigation, drones, patient monitoring, and emergency response systems, watches, beacons, and vehicles) by utilizing specific fixed nodes and mobile computing devices [1-3]. Additionally, the information on the location could be utilized in a variety of services such as navigation, tracking, monitoring, and so on. At the moment, location information is an essential component of the majority of IOT apps. In addition to this, more recent advances in technology are able to provide numerous alternatives to guarantee that the data includes location information for IoT (Internet of Things) solutions.

The GPS [4] is the satellite-based localization system that is utilized most frequently in outdoor environments. However, the GPS does have some restrictions when used in enclosed spaces like buildings. This is owing to the fact that the GPS device suffers significant power loss when used indoors as a result of signal attenuation caused by a variety of building materials [5] or that the GPS signals will be suppressed in the deeper parts of the interior [6]. To address these challenges in an indoor environment, a number of different solutions that make use of a variety of technologies have been proposed. Examples of these technologies include ultra-wideband (UWB) [7], ZigBee [8,9], radio frequency identification (RFID) [10], wireless fidelity (Wi-Fi) [11], Bluetooth [12], frequency modulation (FM) [13], and cellular networks (including LTE and 5G) [14–16], wearable devices, and inertial sensors [17]. In addition, some hybrid strategies combine the positive aspects of two or more technologies in order to improve the accuracy of indoor localization [18]. Positioning accuracy, scalability, precision, cost, dependability, complexity, seamlessness, power efficiency, scalability, and security are among the most crucial evaluation indicators to consider when deciding on choosing a localization approach and technology. Due to the fact that indoor positioning is one of the most complicated issues in localization, it has attracted the attention of a large number of researchers from both the private sector and academic institutions. The numerous properties of localization systems, such as their network architecture, computational technique, use of anchors, and capacity to manage mobility (whether it be the anchors or the mobile targets), can be used to further differentiate or classify these systems. On the other hand, localization algorithms will generally fall into one of two categories: range-based or range-free. Taking readings of a signal allows range-based localization methods (like GPS and other forms of cellular-based location) to achieve great precision but at the expense of implementation and computational complexity. On the other hand, range-free localization techniques (such as simple cell-based localization) can deliver a less precise position (but maybe "good enough" for specific purposes) with a far less complex implementation. The location of a node is determined in a range-based method by comparing it to the sites of other nodes that are close by. Before attempting to identify the location of the mystery node, it is necessary to take accurate measurements of the distance or angle (range information) between the nodes. It is possible to achieve this goal with the help of the Received Signal Strength Indicator (RSSI) [19], the Time of Flight (TOF) [20], the Time of Arrival (ToA) [21], the Time Difference of Arrival (TDoA) [22], and the Angle of Arrival (AoA) [23]. Range-based localization is a costly option, but in the meantime, it provides accurate information about the positions of sensor nodes. This expense is a result of the supplementary equipment that is necessary for the measurement, with increased energy consumption due to these hardware measures. On the other hand, range-free approaches do not take into account the various strategies for range measuring [24].

One of the primary motivations for preparing this work is that the majority of people spend a significant amount of time each day in a variety of interior environments for a variety of reasons; the identification of locations becomes an attractive research field for the sake of emergency, security, and safety measures. In light of this, the reason for carrying out this survey is to study the localization perspective in terms of utilizing numerous strategies and technologies within the context of the era of the IoT. The IoT provides positioning-based applications that affect nearly every facet of human life. For instance, (1) fall detection in the healthcare system would enable rapid assistance to be provided in the event that an old or disabled people were to fall [17]. (2) automobile accident detection [25], (3) An interactive and technologically advanced museum [26]. (4) Real-Time Surveillance of Vehicle Parking Lots and Autonomous Payment [27]. (5) Estimation of available parking spots using the Smart Parking System [28]. (6) Firefighters work under dangerous conditions, such as dust, smoke, and fires [29]. (7) Management of Intelligent and Location-Based Resources [30]. (8) Access control is determined by the user's location, which gives users permission to access resources according to that location [31]. (9) Navigation in Shopping Centre [32]. (10) Inventory and asset tracking in the warehouse [33,34]. (12) identification of interior items, such as doors [35]. The main contributions presented in this paper are:

1) This work offers a systematic review of the many localization technologies, approaches, algorithms, and strategies that have been suggested, with a focus on indoor ranged-based localization.
2) The survey illustrates several localization metrics and criteria in addition to comparisons between all of IPs aspects in terms of performance and strong and weak points.
3) The IPS challenges and difficulties that researchers in this field encounter are highlighted in an effort to shorten their journey.
4) Finally, this study is a roadmap for existing and new researchers to identify and characterize suitable technologies for creating innovative systems and apps via stand-alone ranged-based positioning.

The rest of the paper is organized as follows: Section 2 discusses the most often employed radio frequency range-based localization parameters. Section 3 presents a brief review of common positioning algorithms. Recent advances in UWB and Li-Fi positioning technology literature are stated in Section 4. Section 5 contains an analytical critique based on the recent literature survey. The recommendations and conclusion of the paper are presented as a final discussion in sections 6 and 7, respectively.

2. RF RANGE-BASED LOCALIZATION PARAMETERS

There are several methods that can be used indoors and outdoors to pinpoint the precise location of moving or stationary objects. When these methods depend on multiple technologies or a merging of different technologies, they are able to improve localization precision by a larger margin [36]. Numerous measurements are used in these methods to identify the precise location of unknown targets. The most important tools for localizing wireless signals are the received signal strength indicator (RSSI), the time of arrival (TOA), and the angle of arrival (AOA/DOA). The Time Difference of Arrival (TDOA), Round Trip Time (RTT), Angle Difference of Arrival (ADOA), Phase Difference of Arrival (PDOA), Phase of Arrival (POA), Channel State Information (CSI), and Received Signal Quality (RSQ) are also used for positioning and tracking in indoors. The aforementioned techniques could be used to estimate the error distance bias by determining whether the propagation channel is line-of-sight or non-line-of-sight. Also, to obtain an accurate or enhanced distance utilized for precise positioning methods and tracking techniques.

In the following subsections, the most frequently used radio frequency range-based localization parameters will be discussed.

2.1 RSSI-Based Techniques

The RSSI, or received signal strength indicator, is a standardized method that is commonly described by a single chip vendor [37]. In order to estimate the distance between an object and the node without resorting to complex calculations, RSSI is a commonly used metric. The signal strength deficit between two nodes is used to calculate the distance between them. For this technique to accurately estimate a distance, as few as two nodes are needed. The RSSI-based algorithm can outperform competing approaches because it relies solely on the strength of the received signal and does not call for any additional hardware or time synchronization.

Both range-based and range-free methodologies can incorporate the RSSI technique in some capacity. The first method is a path loss model-based RSSI, which is the most common form. Second, constructing a map in accordance with the physical regulations governing the wireless signal is an integral part of the propagation model. The range-based method may identify the object's exact location by employing trilateration, min-max, and maximum likelihood algorithms. However, the clarity and adaptability of the surroundings are reduced while using this method. The latter strategy involves making use of a fingerprinting database, also known as a radio map, to accomplish localization [38]. The fingerprinting method has a greater rate of accuracy and can be utilized in a variety of different indoor settings. RSSI measurement can result in an error due to indoor environmental impacts. The actual conditions found inside buildings include a number of obstructions that interfere with the propagation of radio signals [39]. Noise and multipath effects can significantly reduce RSSI's accuracy for localization [40]. This is because RSSI is susceptible to both of these effects. In addition to this, there is a line-of-sight (LOS) issue between the two nodes, which can have a massive effect on errors. However, the accuracy of the RSSI computation can be improved by radio signal propagation analyzing and calibrating. Radio signal strength indicator (RSSI) techniques are shown in Figure 1.

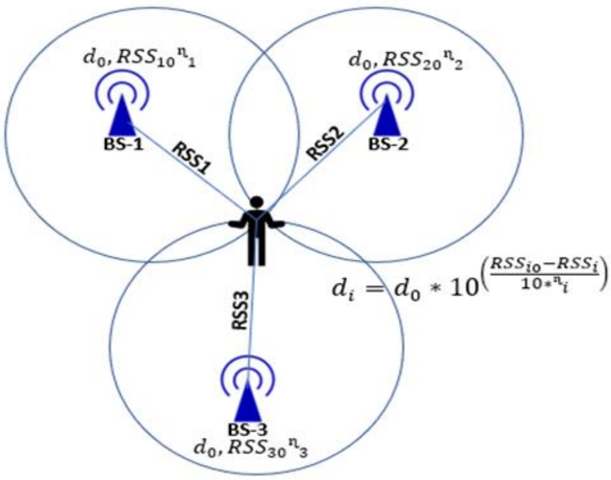

Figure 1. RSSI radio propagation technique

2.1.1. Fingerprinting-Based Technique

Any rise in the total number of BSs will result in higher costs associated with localization [41]. Here, to arrive at an estimate of the current position, the system utilizes the measurements of the current signal strength taken during the online stage and then compares those measurements with the dataset obtained during the offline phase. The idea behind RSSI is to establish a connection that is one-to-one between the signal strength of the BSs and the device that is being targeted. The Received Signal Strength Indicator (RSSI) levels will rise to a higher value whenever there is a shorter distance between the transmitter and the receiver. Due to multipath, however, the RSSI distance margin is not constantly linear, especially in enclosed environments [42]. For RSSI detection and measurement, only a WLAN [39], UWB [43], Zigbee [44], Bluetooth [45], or Infrared [46] detector is needed. Wireless LAN positioning is helpful because it's cheap and always available without human intervention. Diffraction, reflection, and scattering may impact signal strength in indoor propagation, a challenge for fingerprinting-based IPS. This simple positioning method requires a large dataset and can be affected by environmental changes. Due to these changes, the dataset must be updated periodically, which takes time, effort, and money [47]. Interference from other devices, like microwave ovens and Bluetooth devices, may affect positioning accuracy. Since RSSI systems don't require timings, it's possible to create a highly reliable system. Further, synchronization between devices is unnecessary. So, their superiority at shorter ranges means they sacrifice precision at longer distances. However, training and complex matching algorithms are required for localization. Shadowing, low Signal to Noise Ratio (SNR), and NLOS propagation are also threats to RSSI [48]. Utilizing algorithmic machine learning is time-consuming [49], complex [50], and requires storage and computing power [51]. Many machine learning algorithms have been proposed to predict a real-time indoor location with acceptable accuracy. Some need a lot of training data. This increases training time and memory complexity.

2.1.2. RSSI Radio Propagation Technique

The range between a mobile device and a set of base stations (BSs) or wireless access points (WAPs) is determined using received signal strength indicator (RSSI) measurements in conjunction with a modelling technique to calculate the distance. As shown in Figure 3, the trilateration method could be used to calculate the estimated target device's position in relation to the known position of fixed stations. It is one of the cheapest and easiest to manage implementations, and it has the drawback of not providing very excellent precision, around 2–4 meters of location error, because RSSI observations fluctuate due to variations in the testbed vicinity or multipath fading [52].

In the RSSI-based signal propagation method, all that's required is a prior understanding of the relevant environment (which may be established offline) in order to estimate the path loss factor. In spite of this, most researchers ran into difficulties when trying to measure the distance between BSs/WAPs and the target device by calculating the path of loss exponent, signal propagation parameters, and deployment area conditions. To estimate how far away a target device is from base stations and wireless access points (WAPs), Equation (1) could be used [53]:

$$d_{\mathrm{i}} = d_0 * 10^{\left(\frac{RSS_{\mathrm{i}0} - RSS_{\mathrm{i}}}{10 * ^{\eta}{}_{\mathrm{i}}}\right)} \tag{1}$$

where $\mathrm{d_i}$ is the distance between the target objects and the base station. The predicted calibrated distance, at zero distance, is illustrated with d0. The RSSI value for the d0 is present with RSSi0. RSSI is the measured signal power for the received BSs/WAPs signals, and the calculated/calibrated path loss exponent for the received base station signals is denoted by η_i.

2.2 Channel State Information (CSI)

Channel state information utilization represents a more advanced strategy than the path attenuate method, which is also frequently employed in the work that is currently being done in research (CSI). In addition to this, one of the consequences of the constraints imposed by the RSS-based technique is the utilization of (CSI). The status per each channel as it is affected by power decay, scattering, fading, delay distortion, and the multi-path impact with distance can be reflected by CSI [54]. CSI is responsible for collecting channel measures that indicate amplitudes and phases at the subcarrier level [55]. Even in the case when there is no line of sight between the Base stations and the targets, the CSI can produce a more accurate calculation of the distance that separates the two. However, in order to deliver CSI, specialized sets of hardware equipment known as network interface cards are required.

2.3 Vision-Based Technique (VBT)

By extracting scene attributes from images and videos without taking electromagnetic signals into account, the vision-based localization method can be considered as one scene analysis type. After that, through the comparison of online measurements or the features with the closest extracted features, estimate the target device's position [56]. Vision-based localization approaches make use of 3D cameras, omnidirectional cameras, or built-in smartphone cameras to extract data from indoor environments. In Vision-Based methodology, image processing algorithms should be applied in the process of feature extraction. Matching and clustering algorithms have been utilized as well in the vision-based positioning and navigation systems in addition to feature extraction techniques. Even though DL technologies have recently been added to classical ones in computer vision-based navigation systems [57]. On the other hand, in addition to using matching methods to estimate indoor positions, computer vision-based systems of navigation utilize Ego-Motion-based location estimation algorithms as well [58]. The Ego-Motion approach determines where the camera is in location to its surroundings.

2.4 Angle-Based Method (Angulation)

In the context of Angle of Arrival (AoA), angulation is a directing method for identifying the desired object by evaluating the angles of stationary stations relative to the geographic North Pole [59]. As shown in Figure 4, AOA is one type of triangulation method that uses angles obtained from transmitters at known locations to figure out the position of targets. The angulation method makes use of antennas with directional features [60]. The AOA calculates the target device's and fixed stations' directions. AOA measurements indicate the angle at which a target gets signals from multiple base stations at a known location [61]. AOA requires two stationary stations to predict a 2D position. Three or more stationary stations are needed to improve position estimates. Direction-finding requires highly directional antennas or antennas array [62]. Figure 4. illustrates the Angulation-based localization measuring setup. Equation (2) calculates the target location from two or more fixed station directions. To locate the object, two angles between the fixed stations' direction to the target and the North Pole are needed, together with a range measurement when measuring the distance between two displays [63–65].

$$\mathrm{y} = \frac{\mathrm{y}.\tan(\mathrm{A}_2) - \mathrm{X}_2}{\tan(\mathrm{A}_2) - \tan(\mathrm{A}_1)}, \mathrm{x} = \mathrm{y}.\tan(\mathrm{A}_1) \tag{2}$$

where (x1, y1) and (x1, y2) are coordinate values of the Base station1 and Base station positions respectively. θ_1 and θ_2 are the AOAs for the received base station signals, and (x, y) is the coordinate values of the position of the unknown device. AOA-based strategies have a number of limitations, including (1) Employing more antennae to measure angles to improve system accuracy, which raises implementation costs. (2) Multipath and NLOS signal propagation difficulties plague AOA-based techniques. (3) Reflections from objects and walls complicate AOA measurements, especially inside [66]. These factors can modify the direction of signal arrival, reducing the accuracy of AOA-based indoor localization systems.

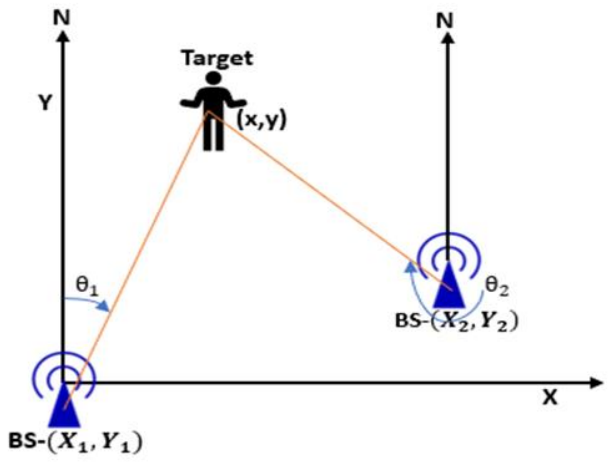

Figure 2. Angulation-based localization measuring setup.

2.5 Time-Based Technique

The time of arrival (TOA) of a Radio signal, and perhaps the time of transmission (TOT), is monitored in order to calculate the range between nodes in a network using a technique known as time-based methods. These strategies have the potential for high-precision locating without the requirement for mapping, and they could either substitute or enhance the existing RSSI methods. Even though they are challenging due to the fast speed at which the signals are propagated, they have the potential for great accuracy positioning. There is a lot of potential in using time-based techniques. Despite this, there are still a lot of unsolved scientific problems. A concise explanation of the most often employed methods and approaches in time-based localization is provided in the following subsections.

2.5.1 Arrival Time (ToA)/Flight Time (ToF)

The ToA approach takes into account the amount of time it takes for radio waves to travel between the transmitting and receiving nodes [67]. Calculating the distance between two points can be done by calculating the amount of time it takes for a signal to travel between them, presuming that the speed at which a signal travels is both constant and known. ToA relies on a one-way measurement of propagation time, which necessitates a precisely synchronized clock at both the sending and receiving nodes. Specifically, this method is employed in GPS-based positioning. ToA-based computations are given in Equation (3) [68]. While $T_{received}$ and $T_{transmitted}$ represent the times at which the signal was received and sent,d_{ToA} represents the distance between the transmitter and receiver nodes. Figure 5 depicts the simplest position measuring system based on the ToA. GPS satellites use atomic clocks for synchronization and transmit a radio signal about their position and time [69].

$$d_{TOA}=\left(T_{received}-T_{transmitted}\right)*C \tag{3}$$

Theoretically, in 2-dimensional, three reference nodes are sufficient for node position prediction, whereas, in 3-dimensional space, four reference nodes are required. Distance measurements (d_a, d_b, d_c) in two-dimensional are related to a receiver (x, y) and sender $(x_a, y_a, x_b, y_b, x_c, y_c)$ coordinates by Equation (4) [70].

$$d_i = \sqrt{(x_i - x)^2 + (y_i - y)^2} \quad i = a, b, c \tag{4}$$

Figure 5 depicts a three-point ToA-based location estimate. The x symbol (bright green) in the figure's centre indicates the receiver node. The red dashed circles illustrate the ideal scenario, with correct distance calculations and a single junction site. Due to measurement inaccuracies, these three circles with estimated distances rarely cross. Blue dashed circles illustrate. In this scenario, the object's location is estimated utilizing the dark green x-shaped intersection.

Synchronization of transmitter and receiver devices is crucial for accurate placement when using ToA techniques. Because radio frequency (RF) signals travel at such a high rate of speed, even a microsecond's delay in synchronization can result in a 300-meter error in location estimation, and other considerations, such as the variability of time spent processing received signals, could further amplify the prediction error.

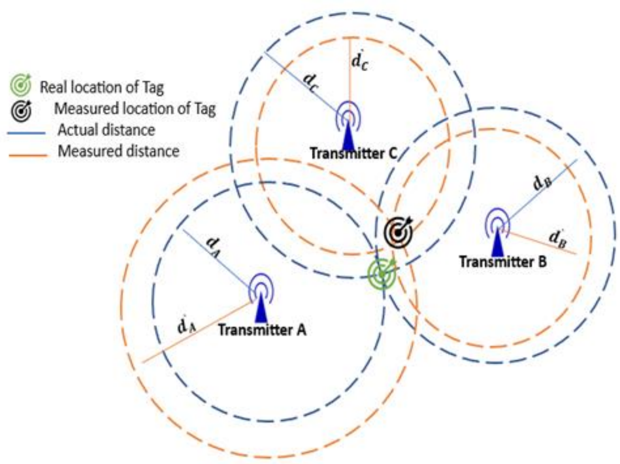

Figure 3. ToA-based location measurement.

2.5.2 Round-Trip ToF (RTT/RTToF) and Two-Way ToA (TW-ToA)

For the purpose of range prediction, many systems also make utilization of the RTT of flight method. RTT is the amount of time, measured in milliseconds, that is needed for a data packet to be transferred from an access point (AP) to a target, in addition to the amount of time that is required for an AP to obtain a response packet from the target [71]. ToA techniques necessitate the exact synchronization of nodes. Round-trip delay between the receiver and transmitter nodes is used by TW-ToA or RTToF techniques to do away with the need for a synchronized clock. TW-ToA-based positioning has the drawback of requiring bidirectional communication between devices and consuming more power. The data request is sent from the sending node to the receiving node, which is then tasked with responding. The period of the transmission in its entirety is captured here. Additionally, the processing time (T_p) is recorded by the receiver node (time between package receive and send). One-way arrival time is calculated by subtracting time consumption from the full-time utilizing Equation (5) [72]. The stages involved in TW-ToA are outlined in Figure 6.

$$d_{TW-TOA} = \left(\frac{T_{total} - T_P}{2}\right) * C \quad (5)$$

where (d) is the true separation of the base station from the target device and (c) is the velocity of light. Obstacles like walls, roofs, and doors can lead to multipath fading and imprecise RTT measurements in an indoor setting. In recent years, scientists have found a way to remedy this by stabilizing the gap between the transmitter and receiver by either signal path analysis or statistical correction. Nonetheless, there are a number of confounding factors that affect RTT during transmission/reception [73]. This consists of (1) noise as a result of the LOS/NLOS circumstance, (2) measurement inaccuracies as a result of non-reception, and (3) distortions as a result of signal latency. Moreover, processing, queuing, and codec delays all play a role in elevating or decreasing the RTT measurement. It is common practice to assume that these variables remain constant between any two communicating nodes (access point and target objects). The latency in TOA is calculated using both the target and the BS clocks, while in RTT, just the target's clock is utilized to compile the transmitted and arrival times. The necessity for the target device and BSs to keep their clocks synchronized is diminished as a result of this benefit to RTT [74]. This strategy has the issue of requiring distance computations from many Base stations, which might cause latencies in Location-Based Services (LBS) systems in which the targeted devices move quickly. The latency in TOA is calculated using both the target and the BS clocks, while in RTT, just the target's clock is utilized to compile the transmitted and arrival times [75].

2.5.3 Difference in Flight Time (TDoF) / Difference in Arrival Time (TDoF)

The TDoA/TDoF approach relies on a combination of two distinct types of measurements. The first technique involves determining the delay in the transmission of a signal from a single node to three or more receivers. The transmitter and receiver are not required to be in sync with one another, like in TW-ToA, but synchronisation is needed for the nodes on the periphery, as shown in [76]. The timing difference between two synchronised signals is what the receiver node uses to calculate the distances. Compared to the ToA method, this approach is a little bit more sophisticated; however, it has the potential to yield more reliable predictions. In Figure 7, an example of the first kind of TDoA approach. The messages or data are being synchronously sent by the middle nodes, and the destination node doesn't have any idea how long the transmission will last. By evaluating the timing differences between each signal, the destination node is able to make estimates regarding their respective distances. Calculating the position of the receiver node requires the utilization of two nonlinear equations, each of which has two variables. This method requires additional processing in comparison to ToA. Equations (6) and (7) display the TDoA calculations for three base stations and one unidentified node.

$$\begin{aligned}\triangle d_{BA} &= \sqrt{(x_b - x)^2 + (y_b - y)^2} \\ &\quad - \sqrt{(x_a - x)^2 + (y_a - y)^2} \\ &= C * \triangle t_{BA}\end{aligned} \quad (6)$$

$$\begin{aligned}\triangle d_{CA} &= \sqrt{(x_c - x)^2 + (y_c - y)^2} \\ &\quad - \sqrt{(x_a - x)^2 + (y_a - y)^2} \\ &= C * \triangle t_{CA}\end{aligned} \quad (7)$$

The latter of TDoA makes use of a variety of communication methods that have varying speeds of propagation, such as radio waves and sound waves. In such a circumstance, because radio waves travel at the speed of light and sound waves travel considerably more slowly, there is a certain disparity between the amounts of time it takes for the messages to travel the same distances. This is due to the fact that radio waves travel at the speed of light. Figure 9 depicts this plan in its entirety. It's important to keep in mind that this strategy places unique constraints on the range of each signal and that different types of waves demand specialized equipment. [77]. consequently, the TDOA methodology's drawbacks in the first TDoA method are comparable to those in the TOA approach. For TDOA to work, the time at all fixed stations must be synchronized. As opposed to this, clock synchronization between the target and fixed stations is necessary for the TOA strategy [78]. Both TDOA and TOA depend on the precision of the clocks used by the nodes to determine the exact position. Multipath, noise, and interference all have an effect on both TDOA and TOA. Additionally, they are challenging to execute in a low-bandwidth setting. Furthermore, they are favoured only in locations with a straight line of sight (LOS), such as open spaces or a big one. The second approach raises the possibility of transmission mistakes due to the unique properties of the individual waves involved.

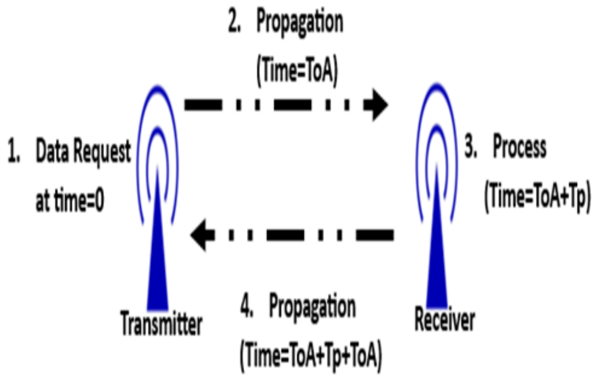

Figure 4. Two-way ranging-ToA

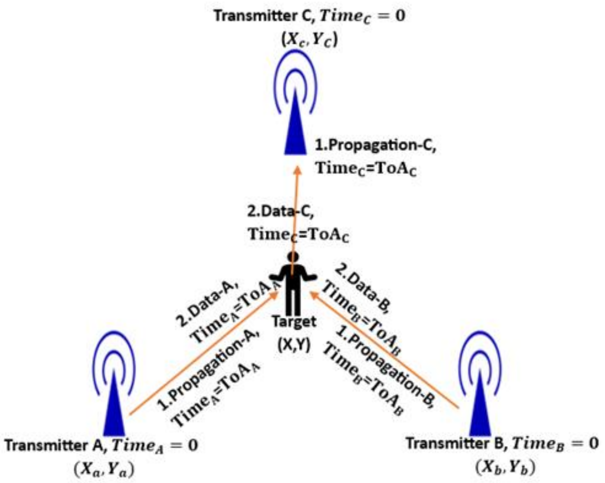

Figure 5. First type of TDoA scheme.

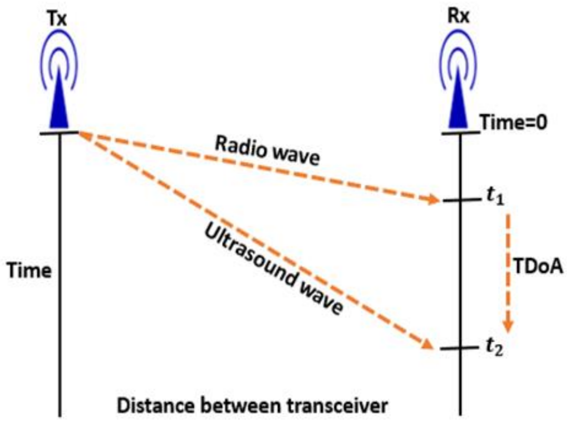

Figure 6. The second type of TDoA scheme.

3. POSITIONING ALGORITHMS

The localization procedure could be broken down into three distinct phases: (i) distance estimation using the chosen strategy, (ii) calculating where the target is, and (iii) pinpointing its location using that information. The initial steps involve making distance or angle estimates between unknown and known nodes. In the second stage, utilization of the collected information is to identify the precise position of each node. A localization system's major component is the last one, which uses position data to locate an exact location [79].

Proximity and triangulation are the two classic location algorithms. The location of an object in IPS could be estimated using a number of techniques, including fingerprinting, PDR, and hybrid methods. Multiple localization techniques can be broken down into four categories: multilateration, signal strength, multiangulation, and hybrid [80]. These geometrical methods are the simplest and most straightforward techniques. Their purpose is to estimate the location of network nodes based on their geometry (as the geometry of triangles). Trilateration, Multilateration, Triangulation, and Min-max are the most popular and significant range-based localization, among these strategies [81-85].

4. METHODOLOGY

In this review paper, Google Scholar and IEEE Xplore have been utilized to conduct a scoping review. The search method in these bibliometric databases has been done according to the title of the article, and keywords, utilized technology, methodology, and outcome. Thereafter, the studies related to range-based indoor positioning systems focusing on the most promising high-accuracy technologies (UWB and Li-Fi) are identified.

5. THE STATE OF ART ON POSITIONING ALGORITHMS AND TECHNIQUES

In this section, a literature survey of the recent IPS is introduced by investigating the most promising technologies by focusing on the UWB and Li-Fi indoor positioning technologies range-based. Also, this literature is based on considering the distinct positioning technology metrics such as accuracy, complexity, scalability, cost, latency, deployment, and usability. Furthermore, the strengths and weaknesses, as well as methodologies and problem statements of each work, are determined. In this context, a brief summary of the aforementioned illustration of the related survey works is shown in Table 1, which illustrates the objective of each article and a brief analysis.

Table 1. The objective with a brief analysis of each article through the literature.

Ref.	Technology	Time	Cost	Energy	Complexity	Accuracy	Channel	Research Critique
[86]	Li-Fi	----	√	-----	-----	-----	LOS	This system is implemented in simulation and real experiments with low-cost commodity components. The obtained positioning error of less than 30cm of 95% from the tested volume. The experiment coverage area is (4m×4m×1m).
[87]	Li-Fi	-----	-----	-----	-----	√	LOS	The created system is implemented in simulation and real experiments. The acquired positioning accuracy is about 8 cm at the edges. This technique requires strict synchronization between the Li-Fi infrastructure. Also, this system can best be realized using a distributed multiple-input multiple-output (D-MIMO) architecture with clock frequency up to 1 GHz zed. The experiment Coverage Area for Simulations is (6m×5m×10m) and in the lab experiment is (1mx1mx2m).
[88]	Li-Fi	-----	-----	-----	√	-----	LOS	This approach is implemented in real experiments on experiment coverage area over a path length of 32 cm at a total duration of approximately 52 s with a handoff at an average speed of 0.6 cm/s to the target receiver. This system is applicable for approximate positioning applications. Also, this approach lacks the accuracy percentage positioning. Furthermore, it is affected by the increase in background light intensity.
[89]	Li-Fi	-----	-----	-----	-----	√	LOS	This system is implemented in simulation only along with a test area over (5 m×5m× 6m). The obtained 3D positioning errors of about 18.62 cm in 95% of test points.
[90]	Li-Fi	-----	-----	-----	-----	√	LOS	The created system is implemented in real experiments in a test area over (8m×3.8m×2.6m). The positioning error variance is above 50cm with trilateration (only three transmitters) and 27cm with multilateration (more than three transmitters).
[91]	Li-Fi	-----	-----	-----	-----	√	LOS and NLOS	Only simulation is implemented in this system in an experiment coverage area over (5m×5m×3m). The localization error ranged from 40cm to 133 (according to FOV=65 deg and FOV >70 deg, respectively. In the typical situation with high-power transmitters (P=1w) and a large FOV receiver (FOV=65 deg) in a low-reflectivity (0.01) room can achieve about 6cm localization accuracy.
[92]	UWB	-----	-----	-----	-----	√	LOS	In simulation and real experiments, this system is implemented. The experiment coverage area for simulation is (10m×10m, 50m×50m, and 100m×100m) and for a real experiment is (9m×9m). The acquired positioning accuracy is roughly 5 cm.
[93]	UWB	-----	-----	-----	-----	√	LOS and NLOS	This system is implemented in real experiments. It requires a high offline lab cost, even if the surveying area is tiny. Also, it needed more computation or execution time. The experiment coverage area is over 80 $m2$ residential apartments with four rooms, a hallway, and a 10-cm-thick wall. This approach is better than the traditional fingerprinting-based approach (C-KNN) in localization with an error margin from 3 to 25cm relative to using five fingerprint database densities.
[94]	UWB	-----	-----	-----	-----	√	LOS and NLOS	This approach is implemented in real experiments with a test area over a corridor less than 5m. The LDA with SVM algorithms takes more computation and execution time than a traditional method. At 500 and 700 measured data, the average identification accuracy of 92% for the case using SVM in the anechoic chamber and almost 100% for Fisher’s discriminant combined with SVM for the corridor scenario, compared with conventional approaches.
[95]	UWB	-----	√	-----	-----	-----	LOS	This system is implemented in simulation, and real experiments consider LOS only. The experiment coverage area is over (7mx7m), which is a significantly small area compared with the present UWB works. The positioning accuracy of less than 40 cm with a 9-cm standard deviation under various static mobile node deployments, with Simulation positioning errors of fewer than 10 cm. This acquired result is far from typical, especially with UWB technology.
[96]	UWB	-----	-----	-----	-----	√	LOS	Only simulation is implemented in this approach in a test area over (15m×15m). The issue with this approach is that it is a complex metric in terms of matrix operation and needs a significant time to install. The acquired positioning error of around 25 cm2 of MSE.

6. AN ANALYTICAL CRITIQUE

Based on the aforementioned literature survey and Table 1, we can clearly claim that the UWB technology is good for LOS and NLOS propagation channels. While the UWB is a promising option for long-range indoor situations, it suffers in NLOS channels and will require NLOS identification and mitigation, which are hard challenges. The Li-Fi technology could be implemented in a LOS environment for only a short range. In turn, to have long-range Li-Fi, a handover process should be implanted to connect the target and the anchor nodes from one group to another based on the received signal. However, the handover process in Li-Fi makes the use of an NLOS propagation channel a complex challenge. For this, the NLOS propagation channel is rarely implemented in an indoor positioning system, so it could be considered that Li-Fi is more complicated than UWB. The positioning accuracy of both UWB and Li-Fi are very close to each other in the LOS propagation channel. Conversely, it isn't easy to compare Li-Fi and UWB in the NLOS propagation channel. Consequently, we claim that each technology has its own indoor applications.

7. RECOMMENDATIONS

After this study, we can recommend to the reader and researcher the following

1) The range based is reliable for to be implemented in an indoor environment.
2) Increasing the number of anchor nodes does not mean an increment in accuracy.
3) Having a limited number of very accurate anchor nodes is preferable to a large number of anchor nodes with a large range error.
4) UWB is more reliable than Li-Fi in indoor environments, especially for long-range and different types of obstacles.
5) Li-Fi could be implemented in small rooms in a LOS environment.
6) The handover process of the Li-Fi received signal should be taken into account significantly to allow a long range of positioning.
7) Both technology Li-Fi and UWB are not costly and could be used for real applications.

8. CONCLUSION

This work offers a systematic review of different positioning technologies, approaches, algorithms, and strategies that have been suggested, with a focus on indoor positioning ranged-based localization. Also, the demonstration of several evaluation metrics and criteria, in addition to comparisons between all of IPS aspects in terms of performance and strong and weak points. Furthermore, a literature survey of the recent IPS technologies range-based with focuses on UWB and Li-Fi is presented. Moreover, the IPS challenges and difficulties that researchers in this field encounter are highlighted in an effort to shorten their journey, along with the advantages and disadvantages of each positioning technology, strategy, and approach.

This paper has profound implications for future studies and prospects determination related to the indoor positioning system ranged-based and presented significant recommendations that the reader and researchers can benefit from them. Also, this work makes it easy for academics and researchers to realize the most common challenges, strengths, and weaknesses as well as methodologies and problems statement of recent promising technologies

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