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A Survey of Recent Indoor Positioning Systems using Wireless Networks

Basem Amer, Aboelmagd Noureldin

***Abstract* – Global navigation satellite systems (GNSS), which are widely used today by positioning and navigations systems, are becoming increasingly important in daily life. GNSS, however, do not work well in indoor environments due to the satellite signal outages that occur in closed structures. Yet the demand for indoor positioning systems is growing as handheld devices become cheaper. Consequently, position estimation is a problem that has been addressed using a variety of technologies. This study classifies indoor positioning technologies into four types, radio frequency (RF), proximity detection, triangulation, and scene analysis, of which the final two are the most common for wireless sensor networks. RF systems are widely used owing to the properties of radio signals. Recent research shows that radio signal strength (RSS) methods have several advantages over time based methods. Lastly, a review is provided of recent studies on wireless positioning for an indoor environment using a wireless sensor networks.**

***Keywords* – Indoor Positioning, Localization, Wireless Sensor Networks, ZigBee, Location Estimation, Positioning Techniques, RSS.**

I. Introduction

The growth in wireless communication technology has encouraged many researchers to investigate developing models for positioning algorithms. The ongoing decrease in the cost of handheld wireless devices, coupled with the growing demand for these, has increased the demand for localization applications [1]. A positioning system is defined as a procedure used to obtain information on a tracked object with respect to a set of reference points within a predefined space. A system deployed to determine or estimate the location of an entity is called a *position location system* or *positioning system* [2]. Positioning systems are classified based on the target environment, that is, whether the environment is indoor, outdoor, or of mixed type [3]. For localization in an outdoor environment, global navigation satellite systems (GNSS) like GPS are ideal. Unfortunately, GPS functions poorly in indoor and underground environments, due to the presence of urban canyons, walls, and other structures. Indoor positioning, therefore, can be defined as any system that delineates position within a closed structure such as a home, office, hospital, airport, or subway. The development of indoor positioning techniques is particularly challenging because accurate positioning is required in environments that are characterized by the presence of obstacles, like people or walls, and non-line of sight (NLOS). Towards achieving accurate positioning, localization algorithms can be implemented to facilitate either centralized or distributed localization. In centralized localization, a powerful central node or station collects data from all other nodes. On the other hand, in distributed localization, each node in a network is able to localize itself. Localization methods can be categorized further based on whether they rely on position fixing or dead reckoning (DR) [4]. In the position fixing method, the localization system obtains data from external sources with known locations to estimate position. An example of this type of method is the global positioning system (GPS). The DR method, however, computes current location based on the previous one. The inertial navigation system (INS) is a typical DR-based system.

II. Overview of Indoor Positioning Systems

An indoor positioning system (IPS) is a network of devices or nodes used to determine the position of objects or people inside a building. This position can be in 2-dimensions (2D), 3-dimensions (3D), or 2.5 dimensions (2.5D). When the object position is tracked in discrete planes of a 3D space, this is referred to as 2.5D. For example, tracking a person in multiple 2-dimensional floor-plans in a 3-dimensional building can be considered 2.5 dimensional tracking [5]. Currently, there are several types of wireless indoor positioning systems, each of which uses different technologies. Fig. 1 shows the state of the art wireless communications positioning systems.

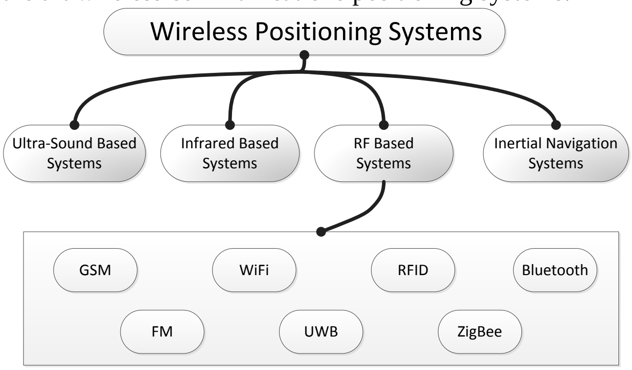

Fig.1. Classification of wireless positioning systems

A. *Inertial Navigation Systems (INS)*

An inertial navigation system is an independent system that provides position, velocity, and attitude based on measurements from inertial sensors and by applying the dead reckoning (DR) method [4]. INS has been widely used in aircrafts, guided missiles, and submarines. Before the introduction of GPS, INS was the most common instrument used to determine position. Moreover, INS systems are self-contained in the sense that all measurements are taken by sensors that are part of the system without having to depend on any external input [4]. The development of micro-electromechanical systems (MEMS) has led to the shrinking of the size of sensors.

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MEMS are used for many applications, one of which is position estimation. Nowadays, most smartphones are equipped with MEMS sensors.The most important MEMS components for determining indoor location are accelerometers and gyroscopes [6]. The inertial measurement unit (IMU), which contains three accelerometers and three gyroscopes mounted in one unit, is used to measure the movement and rotation of an object [4], for example, a vehicle, airplane, or person. Fig.2 illustrates the fundamental module of an inertial navigation system.

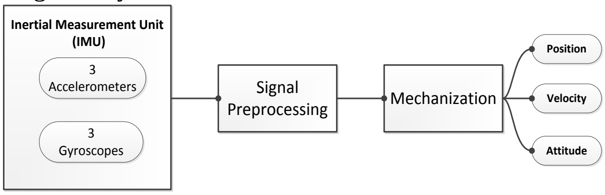

Fig.2. The fundamental module of INS.

i) Accelerometers

Accelerometers comprise a spring and a mass. The force exerted by the acceleration extends the springs. Fig.3 shows the principles of an accelerometer [1]. Force and extension are linearly related while the spring is constant. An accelerometer measures translational acceleration along its sensitive axis, typically by sensing the motion of a proof mass relative to the case [4]. The simplified equation (1) determines the output of an accelerometer. Through calibration, the spring constant $,k,$ can be determined.

$$f = a - g \tag{1}$$

Where f is the specific force.
a is the acceleration with respect to the inertial frame.
g is the gravitational acceleration which is +9.8 m/s2.

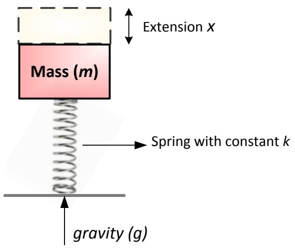

Fig.3. Accelerometer principles

ii) Gyroscope

Gyroscopes measure angular rotational velocity and displacement more accurately than accelerometers [1]. Fig.3 illustrates the fundamentals of gyroscopes. The measurements of a gyroscope can be given as [4]:

$$\omega_{ib}^{b} = \omega_{ie}^{b} + \omega_{en}^{b} + \omega_{nb}^{b} \tag{2}$$

Where
ω_{ib}^{b} is the rotation rate of the body with respect to the i-frame.
ω_{ie}^{b} is the rotation rate of the body with respect to the navigation frame (n-frame).
ω_{en}^{b} is the rotation rate of the navigation frame with respect to e-frame.
ω_{nb}^{b} is the rotation rate of the Earth with respect to the i-frame.

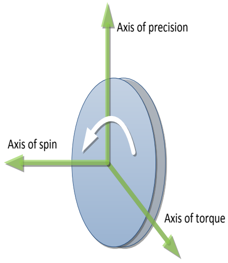

Fig.4. Gyroscope principle

B. Infrared Based Systems

Infrared radiation (IR) positioning systems are one of the most common types of positioning systems that use wireless technology. Infrared signals are electromagnetic signals of a wavelength longer than that of visible light, but shorter than that of radio waves. Many objects, such as people, vehicle engines, and aircraft, generate and retain heat which makes them visible in the infrared wavelengths of light and therefore stand out from objects in the background [3]. Because infrared signals cannot pass through walls or obstacles, most IR-based wireless devices require line-of-sight (LOS) communication between the transmitter and receiver without interference from strong light sources. Additional limitations of these systems include that they have a range of only a few meters (~5m), they require expensive hardware and costly to maintain [7].

C. Radio Frequency Based Systems

Radio frequency (RF) positioning systems are used widely because of the ability of radio signals to penetrate obstacles, (ie. walls, people). They can provide coverage of large areas, and unlike other systems, they require no special hardware. GSM, RFID, Bluetooth, WLAN, ZigBee, and FM all are used in RF based indoor positioning.

i) GSM

Global System for Mobile Communications (GSM) is a technology for digital cellular networks that enables telephony for mobile phones. GSM can also be used to estimate the location of a mobile phone. Accordingly, base stations in the vicinity of a mobile phone measure the strength of the signal that it transmits [8]. The distance between the base station and mobile phone can be estimated using a propagation model of the radio signals that are transmitted by the mobile phone, and RSS measurements. Trilateration or fingerprinting can then be used to estimate the location of the mobile device in the cellular network [9].

ii) Wi-Fi

Wi-Fi is the current standard for small scale fast wireless networks. The name is a trademark for products using the IEEE 802.11 standards family. An advantage of Wi Fi positioning systems is that they are able to locate the position of almost every Wi-Fi compatible device without installing additional hardware. Moreover, localization using Wi-Fi is possible because it uses radio signals in the 2.4 GHz range, which is a standard that allows software to query the signal strength of devices in range [10].

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Consequently, this enables the use of RSS based localization methods [11] to estimate the location of target devices. Furthermore, line of sight is not required by Wi-Fi positioning systems. This advantage has contributed to their widespread use for localization. Fingerprinting is the most common technique Wi-Fi localization technique [10].

iii) RFID

RFID (Radio Frequency Identification) shows promise as a technology for locating objects or people in 2D [12] and 3D [13]. This is the case even though it was originally developed for identifying objects, rather than positioning and tracking them. RFID is able to track objects over a distance of several meters through a network of radio enabled scanning devices. Trilateration and fingerprinting can be implemented in RFID based positioning. RFID positioning technology is used in many applications including those for the automobile assembly industry, warehouse management, and asset management [16]. It does not require line of sight contact.

iv) Bluetooth

Bluetooth, like Wi-Fi, is a wireless networking technology [8], but on a smaller scale. Like Wi-Fi, it transmits radio signals at 2.4 GHz, and it uses many of the localization principles applicable to Wi-Fi [16][16].

v. FM

FM radio systems are widely available and very popular. They consist of low-cost and off-the-shelf components, and have several features which make them distinct from other localization technologies. However, there are only few applications for FM radio based positioning, Nonetheless, a proposed FM positioning system [17] achieved a high-level of performance compared to other positioning technologies such as Wi-Fi.

vi) Ultra-wideband

Ultra-wideband (UWB) is a radio technology for short-range, high-bandwidth communication; its properties include strong multipath resistance. Widespread use of UWB in a variety of localization applications provides greater accuracy, within 20–30 cm, than is achievable using conventional wireless technologies (e.g. RFID, Wi-Fi). One UWB-based indoor localization system [18], consists of a large number of energy scavenging, cost-effective, transmit-only tags, a small number of battery-powered hubs as relay stations, and a few base stations. The localization method is based on the time of arrival (ToA) of the UWB pulses at reference nodes.

vii) ZigBee

ZigBee is a specification for a low-cost and low-power network protocol based on the IEEE 802.15.4 personal area network (PAN) protocol standard. ZigBee-based wireless devices operate in 868 MHz, 915 MHz, and 2.4 GHz frequency bands [19].The maximum data rate is 250 K bits per second. ZigBee's low-cost and low-power features make it a an appropriate protocol for Wireless sensor network applications requiring large coverage and long operating time on sensor devices running on small batteries. In many ZigBee applications, the total time the wireless device is involved in any type of activity is very limited because the device spends most of its time in a power-saving mode, also known as sleep mode. As a result, ZigBee enabled devices are capable of being operational for several years before their batteries need to be replaced [20]. There are two types of devices in an IEEE 802.15.4-ZigBee wireless network: full-function devices (FFDs), and reduced-function devices (RFDs). While an FFD is capable of performing all the tasks described in the IEEE 802.15.4 standard and can accept any role in the network, an RFD has limited capabilities. For example, an FFD can communicate with any other device in a network, but an RFD can talk only with an FFD device. RFD devices are intended for very simple applications such as turning a switch on or off, and they normally have less processing power and memory than FFDs [20]. A ZigBee network consists of one coordinator, several routers and end devices. ZigBee networks always have a single coordinator device. That radio establishes the network, passes addresses, and manages the other functions that define the network. A router, on other hand, is a full-featured ZigBee node. It can join existing networks, send, receive, and route information. End devices are essentially stripped-down versions of a router. They act like routers, join networks, and send and receive information, but they don't have the ability to route information. End devices use less expensive hardware and conserve energy by being set temporarily to sleep mode [21].

D. Hybrid positioning systems

Hybrid positioning systems are defined as systems for determining the location of a mobile node by combining several different positioning technologies [3]. While many location technologies estimate the position of a mobile client, positioning systems sometimes work poorly in areas like indoor environments. For example, GPS-based systems do not work inside buildings due to the outage of GPS signals. Consequently, there is a need for positioning systems that work both indoors and outdoors. Several studies have investigated enhancing positioning performance in a variety of environments [3] through using mixed systems. They have proposed a GPS-GSM solution [22], the integration of RFID, ZigBee, and INS [23], and a GPS/INS combination [4].

III. Position Estimation Techniques

Several position estimation methods can be used in a locating engine to calculate a person or an asset's position. Only the most widely used methods will be described.

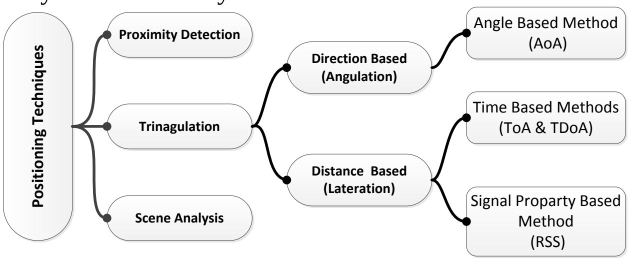

Fig.4. Classification of positioning techniques

The choice of position estimation algorithm depends on the features of the application scenario, including coverage area, cost, and accuracy. Position detection techniques can be divided into three general categories [1]: proximity detection, triangulation, and scene analysis. Fig.5 shows the classification of positioning techniques.

A. Proximity Detection

Proximity detection is one of the simplest positioning methods to implement. The position of the mobile node is estimated by the cell of origin (CoO) method within a limited range [9]. The principle of this method is based on mobile cellular networks. In a cellular network, the position of the mobile phone can be approximately determined by knowing which cell site a device is using at a given time. The main benefit of Cell-ID is that it is already in use today and is supported by all mobile handsets. Proximity detection methods can use a variety of physical media, and they can be implemented using different types of physical media. Several wireless technologies can implement proximity detection methods, for example infrared radiation (IR), radio frequency identification (RFID), GSM (Cell-ID), and Bluetooth [3].

B. Scene analysis

RF-based scene analysis refers to the type of algorithms that collect features (fingerprints) from a scene and then estimate the location of objects by matching online measurements with the closest *a priori* location of fingerprints [24]. There are two stages for positioning using fingerprints: the offline and the online. During the offline stage, or training stage, the system collects site data then stores it in a database. The collected measurements typically include the coordinates of objects and the respective signal strength readings from nearby stations. During the online stage, the system uses the current signal strength measurements and compares them with the measurements collected during the offline stage to estimate the current position.

C. Triangulation

Triangulation depends on the geometric properties of triangles to determine the target's location. It has two derivations: direction-based and distance-based techniques. Techniques based on the measurement of the propagation time method (i.e. ToA and TDoA) and RSS-based methods are called lateration or distance-based techniques [24]. While direction based techniques like AoA estimation technique is called an angulation technique.

i) Angle of Arrival (AoA)

The Angle of Arrival (AoA) method calculates the direction of propagation of an RF signal received from a transmitter node at a receiver node. A mobile node must be equipped with an antenna array to be able to determine the angle of arrival of the received signal. In this way, the location of the mobile node can be estimated using the AoA of the received signal.[25]. Fig.6 shows the basic concept of location estimation using AoA. The anchor nodes, which are located at known locations, propagate RF signals using omnidirectional antennas. The mobile node receives an RF signal from these anchor nodes and determines the angle of arrival of the received signal [20]. If the orientation with respect to the anchor nodes of the mobile node is known, the location of the mobile node can be obtained by using two anchor nodes and applying simple triangulation. For each anchor node, the AoA of the signal received from the nodes is calculated and then an algorithm is used by the location engine to determine the position of the mobile node. If the orientation of the mobile node is unknown, the location can be estimated by calculating the angles between three nodes. Among the drawbacks of this system is that taking measurements requires a complex set of antenna arrays, and the accuracy is proportional to the number of antenna arrays used. These factors make this method costly. Additionally, the resulting angle measurements are sensitive to multipath propagation. Therefore, this method is best suited for direct line of sight (LOS) measurements between mobile and anchor nodes [25].

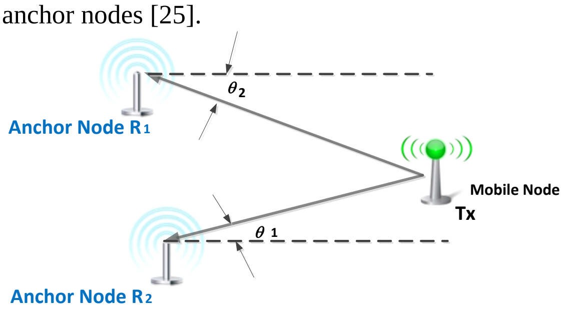

Fig.5. Positioning Estimation using Angle of Arrival (AoA)

ii) Time of Arrival (ToA)

Time of Arrival (ToA) is a method based on the measurement of the propagation delay of the radio signal between a mobile node and one or more anchor nodes. Propagation delay is the difference between the transmission time at the anchor node and reception time at the mobile node. Elapsed time refers to the time it takes for the radio signal to transmit from the anchor node to the mobile node. Mobile node position can be estimated by converting the propagation time to distance by multiplying the propagation time by the speed of the signal. Determining the location of a mobile node in a 2D plane requires at least three anchor nodes; at least four anchors are required to locate the node in a 3D plane [25][6]. The distance of the mobile node from the three anchor nodes, as shown in Fig.7, can be observed as an intersection of the circles centered on the anchors.

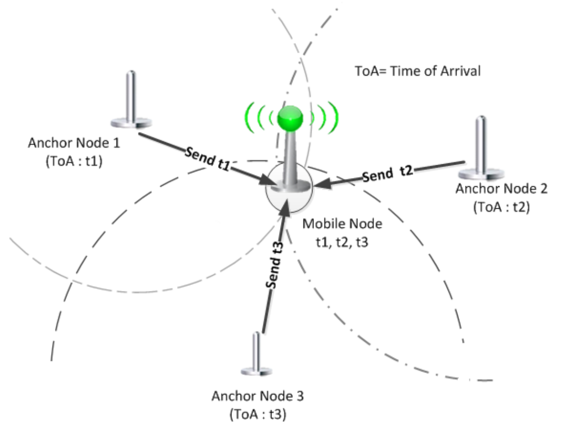

Fig.6. Positioning using Time of Arrival (ToA)

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The accuracy of this method depends on how well the clocks of the mobile and anchor nodes have been synchronized. Also, the node clocks must be precise to the nanosecond to achieve a reasonable level of accuracy. Clock synchronization in ZigBee wireless sensor networks [20] entails additional hardware and costs.

iii) Time Difference of Arrival (TDoA)

In Time Difference of Arrival (TDoA), the mobile node measures the difference in transmission times between signals received from each anchor node. Three or four nodes at known locations are required to estimate the position of a mobile node. The mobile node receives signals synchronously from all anchor nodes and records the time stamp for each signal individually. These records are processed by a localization engine which estimates the difference in the amount of time it takes for each anchor to receive the signal. This difference is processed through an algorithm to provide an estimated position for the mobile node [6][20]. Fig.8 illustrates the determining of mobile node position with TDoA. In a 2D plane, the mobile node is located at the intersection of three hyperbolas, while in a 3D space it is positioned at the intersection of three hyperboloids.

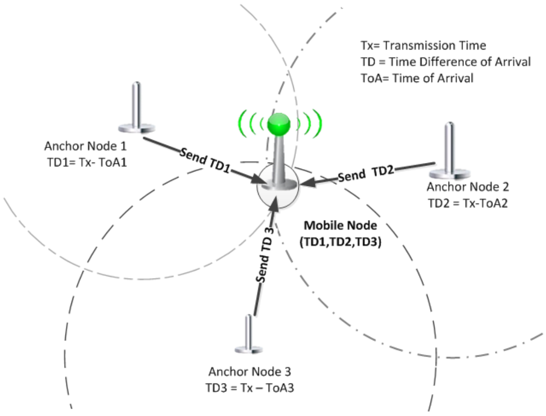

Fig.8. Localization using TDoA.

The drawbacks of the TDoA method are similar to those of the ToA method. TDoA requires the synchronization of anchor node clocks. The accuracy of localization with TDoA is linked to the accuracy of the clocks used in the nodes. Moreover, TDoA is sensitive to multipath propagation, noise, and interference [20][6]. Consequently, TDoA is preferable only where direct LOS is possible, for instance in an open area or in a large open building.

iv) Received Signal Strength Indicator (RSSI)

The Received Signal Strength Indicator (RSSI) method measures the strength of the signal between anchor nodes and the mobile node. RSSI is a well-known location method that uses a known mathematical model that describes signal path loss with distance. RSSI measurement-based location systems are potential candidates to enable indoor location-aware services due to pervasively available wireless local area networks and handheld devices [1]. In this method, the mobile node position is estimated based on the measured RSSI values from at least three anchor nodes. If the function between RSSI and distance is known, theoretically or experimentally, the distance between two nodes can be determined. Then, the distance is used in a trilateration algorithm to determine the correct position between three or more nodes [25]. Fig.9 illustrates localization using the RSSI method.

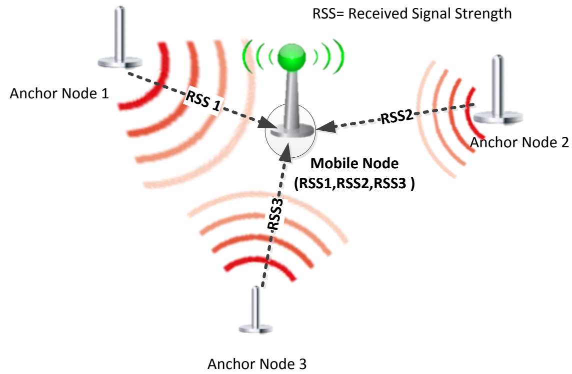

Fig.9. Localization using RSSI method

Mathematically, the models of propagation path loss are the following: free space propagation, log-distance path loss, Hata, log-distance distribution etc. [26]. Free space propagation and log-distance distribution are the models that are most often used for indoor environments. The free space received power is given by the Friss equation propagation model [27]:

$$P_{R}=P_T G_T G_R \left[\frac{4\pi d}{\lambda}\right]^2 \quad (3)$$

Where P_R is the received power, P_T is the transmitted power, G_T is the transmitted antenna gain, G_R is the received antenna gain, λ is the wavelength of the transmitted signal and d is the distance between the transmitter and receiver. The free space path loss in (dB) is given as equation (4) [27]:

$$Loss\ (P_L) = 10\log\frac{P_T}{P_R} = -10\log\left[\frac{G_T\ G_R\ \lambda^2}{(4\pi d)^2}\right] \quad (4)$$

When antenna gains are excluded the antennas are assumed to have unity gain. The equation (4) can be written as

$$Loss = 32.4 + 20\log d(km) + 20\log f(MHz) \quad (5)$$

where $\lambda = \frac{c}{f}$, c is the speed of light and f is the frequency (MHz).

In embedded devices, the received signal strength is converted to the received signal strength indicator, RSSI, which is defined as the ratio of the received power to the reference power P_{ref} [27]. Typically, the reference power represents an absolute value of $P_{ref} = 1mW$.

The RSSI formula is shown in equation (6) below:

$$RSSI = 10\log\left(\frac{P_{rx}}{P_{ref}}\right)\ dBm \quad (6)$$

An increasing received power results in a rising RSSI. Distance (d) is inversely proportional to RSSI. In practice, the ideal distribution of P_{rx} is not applicable, because several influencing effects interfere in the propagation of the radio signal. Fig.10 illustrates the relationship between the transmitted power and the distance as the log-normal model.

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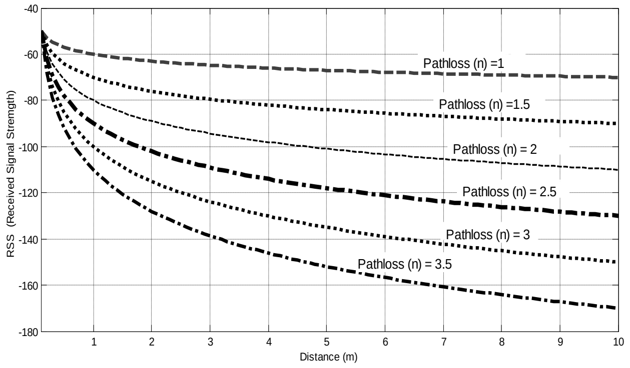

Fig.10. Log-normal model at different values of path loss exponent (n)

Therefore, RSSI can be expressed, according to the log-normal model, as a function of distance d, as shown in equation (7):

$$RSSI = -(10\, n\, \log d) + P_{1m} \quad (7)$$

Where $RSSI$ is the received signal strength, d is the distance between the transmitter and receiver, n is path loss, and P_{1m} is the received power at 1 meter.

The distance (d) between the mobile node and other nodes (anchor nodes) can be calculated by using equation (7). The following equations are written using Euclidian distance [20]:

$$(X_1 - X_m)^2 + (Y_1 - Y_m)^2 = {d_1}^2 \quad (8)$$

$$(X_2 - X_m)^2 + (Y_2 - Y_m)^2 = {d_2}^2 \quad (9)$$

$$(X_3 - X_m)^2 + (Y_3 - Y_m)^2 = {d_3}^2 \quad (10)$$

Where $(X_m, Y_m)(X_1, Y_1), (X_2, Y_2)\ and\ (X_3, Y_3)$ are the locations of the mobile node, node 1, node 2, and node 3 respectively, $d_1, d_2\ and\ d_3$ are the distances between the mobile node and other nodes.

Equations 8, 9, and 10 can be written in matrix form as shown in equation (11):

$$\begin{bmatrix}(X_1 - X_m)^2 & + & (Y_1 - Y_m)^2\\(X_2 - X_m)^2 & + & (Y_2 - Y_m)^2\\(X_3 - X_m)^2 & + & (Y_3 - Y_m)^2\end{bmatrix} - \begin{bmatrix}{d_1}^2\\{d_2}^2\\{d_3}^2\end{bmatrix} = \begin{bmatrix}0\\0\\0\end{bmatrix} \quad (11)$$

Because it is impossible for the right-hand side of equation (11) to equal zero [20], an error vector (E) is introduced instead:

$$abs\left\{\begin{bmatrix}(X_1 - X_m)^2 & + & (Y_1 - Y_m)^2\\(X_2 - X_m)^2 & + & (Y_2 - Y_m)^2\\(X_3 - X_m)^2 & + & (Y_3 - Y_m)^2\end{bmatrix}\right\} - \begin{bmatrix}{d_1}^2\\{d_2}^2\\{d_3}^2\end{bmatrix} = \begin{bmatrix}e_1^2\\e_2^2\\e_3^2\end{bmatrix} \quad (12)$$

$$Square\ Error = e_1^2 + e_2^2 + e_3^2 \quad (13)$$

The main aim of the location estimation algorithm becomes finding (X_m, Y_m) to minimize the square error in equation (13). Recent localization research has introduced several methods including the Kalman filter [28], particle filters [29], and swarm optimization [30] to minimize the value of an error function.

Compared with the ToA and TDoA methods, RSSI has several advantages. It does not require additional hardware [25]. Owing to the simplicity of RSSI, the most recent research on localization using wireless sensor networks uses RSSI-based algorithms. RSSI can be read directly from the last received packet. Moreover, the modulation method, data rate, system timing precision, and synchronization, are irrelevant in RSSI measurement [6].

IV. Recent Related Research in Indoor Positioning using WSN

Recent studies in the field of wireless indoor localization systems are summarized in this section. These systems, as tabulated in Table I, use variety of underlying location estimation algorithms.

A Closer Tracking Algorithm (CTA) was used [31]to locate a mobile user using ZigBee CC2431 modules. CTA combines the improved fingerprint and real time tracking methods to adjust the operational modes according to threshold values. As a result, the proposed algorithm selects suitable adaptive modes to determine location more precisely. Experiment results show that the proposed algorithm accurately determines position with a margin of error of less than one meter.

Artificial intelligence (AI) modules were integrated into localization algorithms [32] by another study. Here, fuzzy distance measuring technology was adopted. This was done using a neuro-fuzzy system, specifically an Adaptive Neural-Fuzzy Inference System (ANFIS), to create a model that maps RSSI into the correct T-R distance. Two of the network inputs were receiving power and theoretical distance. The former was calculated with RSSI, and the latter was determined using a free-space model equation. This experiment shows that fuzzy T-R distance measuring achieves good results when used for pure T-R distance measuring; however, measuring distance this way results in localization errors. Optimal performance is achieved when an unknown node is put at the center of triangle formed by three known position nodes.

Use of a distributed algorithm that can be implemented based on common 8-bit MCU (Microcontroller Unit) has been proposed [33]. The use of a log-normal path loss model was rejected for use in this algorithm in favour of a piecewise linear one. Consequently, when estimating range with RSSI, only linear operations were used. To simplify coordinate calculation, the only min-max method employed was the maximum likelihood estimation method. Furthermore, ZigBee compatible sensor node modules were developed to carry out the control experiments. The results demonstrated that the new method was nearly as precise as, or even more precise than the method using a basic algorithm, but cost less.

An RSSI-based tracking technique that is divided into two phases has been applied to the problem of localization [34]. In the first phase, RSSI coefficients are calibrated (deterministic phase), while in the second, the position is estimated by iterative trilateration (probabilistic phase). A low complexity RSSI smoothing algorithm is used to minimize the dynamic fluctuation of the radio signals received from each reference node while the target node is moving. These measurements analyze the sensitivity of RSSI.

An adaptive filtering (smoother) based location and tracking algorithm for indoor positioning has been studied

[35]. This algorithm was developed by fusing RSSI and link quality indicator (LQI), which is particularly well-suited to support context aware computing. The researchers test a new mathematical method for reducing error in location identification due to interference within the infrastructure-based sensor network. Their method calculates the distance using LQI and RSSI which are predicted based on previously measured values. The calculated distance corrects the error caused by interference.

PSO-RSSI, which is based on Particle Swarm Optimization (PSO), has been explored [26] to optimize the LQI that an unknown node receives from a sink node. Distance was then obtained by switching from LQI to RSSI. Experiment results show that this algorithm enhances localization accuracy. The RSSI self-correcting mechanism is integrated into this algorithm to improve the accuracy of ranging. Meanwhile, the improved PSO algorithm [36] is proposed to optimize the problem of local extreme value. This localization scheme was more stable than others and also achieved better overall performance.

Indoor localization using wireless sensor networks has been proposed through equipping sensor nodes with two RF front-ends operating at 433MHz and 2.4GHz, respectively [37]. A location estimation and tracking algorithm that exploits the different channel propagation characteristics at the two frequencies was proposed. Ranges are estimated based on the received signal strength indicator (RSSI) and path-loss models at both frequencies. Location is calculated using ordinal multi-dimensional scaling (OMDS). Instantaneous estimates are filtered by a Kalman filter (KF), together with a simple motion model. Algorithm performance is tested by using real-world measurement data.

To improve the accuracy of ZigBee positioning and implement an indoor personnel tracking system, researchers have proposed combining two methods, namely, Neighbor Area Majority Vote Priority Correction (NAMVPC), and Environment Parameter Correction (EPC) [38]. The main purpose of the NAMVPC method is to reduce the effect of “drift phenomenon.” This occurs when the unstable estimation of locations of blind nodes causes the positioning program to display blind nodes drifting from place to place. EPC, meanwhile, uses adjustable environment parameters representing the signal dBm (parameter A), and consumption of the path of attenuation (parameter N), respectively.

Equipping a quadrotor UAV with ZigBee and INS sensors has been proposed for indoor localization in a known environment [39]. A ZigBee indoor location system was developed, in which a quadrotor was associated with the Zigbee wireless nodes for self-localization. Additionally, inertial sensors, including an airspeed meter and an accelerometer, were used to increase localization precision, while an extended Kalman filter (EKF) was used to estimate the position using ZigBee and INS sensors separately.

Table I: RecentIndoor positioning using WSN

Ref.	Proposed system	Method	Range
[31]	CTA	FPT	N/A
[32]	Fuzzy distance-ANFIS	RSSI	25m
[33]	Distributed Algorithm	RSSI	30 m
[34]	RSSI-based tracking	RSSI	30~29m
[35]	Adaptive RSSI-LQI filter	RSSI,LQI	10m
[26]	PSO-RSSI	RSSI	10m
[36]	Improved PSO	RSSI	100 m
[37]	OMDS-KF	RSSI	10m
[38]	NAMVPC	RSSI	N/A
[39]	EKF	RSSI,INS	1 room

V. Conclusion

Localization in wireless sensor networks is becoming increasingly important because many applications need to locate the source of received measurements as precisely as possible while keeping costs low. Various indoor positioning methods and technologies for wireless sensor networks are explained in this paper. Triangulating and scene analysis are the most common positioning techniques for wireless sensor networks. RF based systems are appropriate for indoor environments because of the characteristics of radio signals. Time based techniques, such as TOA and TDoA, require additional hardware and incur extra costs for localization applications. RSS techniques, on other hand, are simple and work using any wireless network and do not entail additional costs. Therefore, RSS based techniques are shown to be capable of producing equivalent and accurate localization solutions for indoor environments, which makes these methods suitable for localization applications based on low power and low cost WSN such as ZigBee. Because the demand for localization applications is increasing, demand for the development of position estimation algorithms, is likewise expected to grow.

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AUTHOR'S PROFILE

Basem Amer

received the B.Sc. degrees in computer engineering from Azzawia University, Azzawia, Libya, and Master degree in Electrical/Electronic and Telecommunication engineering from University Technology of Malaysia, Johor, Malaysia, in 2003 and 2007, respectively, and is currently working toward the Ph.D. degree in the Department of Electrical and Computer engineering, Royal Military College of Canada, Kingston, Ontario, Canada. His research interests include wireless and inertial navigation systems, and artificial intelligence.

Aboelmagd Noureldin

received the B.Sc. degree in electrical engineering and the MSc degree in engineering physics from Cairo University, Giza, Egypt, in 1993 and 1997, respectively, and the Ph.D. degree in electrical and computer engineering from the University of Calgary, Alberta, Canada, in 2002. He is across-appointment associate professor in the Department of Electrical and Computer Engineering, Queen's University, Kingston, Ontario, Canada, and the Department of Electrical and Computer Engineering, Royal Military College (RMC) of Canada. He is also the founder of the Nav Inst Research Group, RMC. His research interests include artificial intelligence, digital signal processing, wavelet multi resolution analysis, and adaptive filtering, with applications in mobile multisensor integration for navigation and positioning technologies. He is the chair of the Alternative Integration Methods Research Group, International Association of Geodesy. He is a senior member of the IEEE.