Wireless Indoor Positioning Techniques Based on Ultra Wideband (UWB) Technology

B. Venkata Krishnaveni, K. Suresh Reddy, P. Ramana Reddy

Abstract--- ***Indoor positioning is a challenging research area, and numerous varieties of indoor positioning systems have been advanced based on specific technologies.Now a day, localization in indoor has appear as a tough characteristic in lots of end person utilizations; which includes civilian, navy, catastrophe remedy. In evaluation to outdoorarea, information of location in indoor needs a better accuracy and it is a tough assignment in element due to numerous items return and scatterwave forms. Ultra Wideband (UWB) is acome upgeneration of indoor localization and proven superior overall precisionin comparison to alternatives.***

This paper affords an outline of indoor positioning solution primarily based on UWB technology. First, the theory, standardization, and benefits of UWB had been added, followed by means of an in depth relativesurvey of UWB localization techniques. For put down the degree for the effort, we offer an analysis of the modern technology in indoor positioning, followed through an in depth comparative evaluation of UWB positioning technology. Dissimilar to prior work, this paper provides new classifications, evaluating main recent advances, and disputes for more investigation through the studies.

Keywords: Indoor positioning, Ultra-wideband, UWB, Measuring techniques

1. INTRODUCTION

Positioning is the method of calculating location of person, system, and different items. It has lately been a lively study vicinity where many studies makes a specialty of using prevail techniques to deal with the trouble of location calculation. Indoor and outdoor positioning are the two classifications of positioning, depending on the surroundings wherein the site is conducted. Outdoor positioning is implemented exterior construction, indoor positioning is implemented interior construction (e.g., homes, health centers, and department shops). Global Positioning System (GPS) is an era this is appropriate and effective to exterior areas instead of indoor spaces due to the fact satellite signals cannot get through stable obstacles and barriers [1, 2].

Indoor positioning systems (IPSs) decide the placement of an item in area constantly and in actual-time, see Figure1.Indoor positioning has its very unique necessities that separate outside positioning. Accuracy, resolution, delay in getting area upgrades, infrastructure effect; and impact of random errors at the device which includes mistakes because of signal interference and reflection are different quality metrics. [4].

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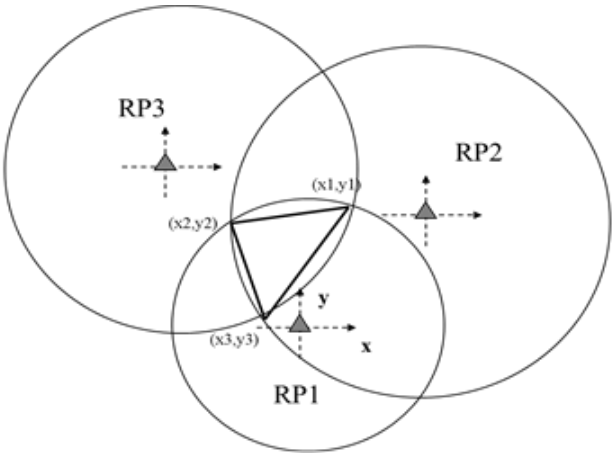

Figure1. Positioning using reference points.

Accurate location calculation is acrucial requirement for the techniques of indoor positioning. In indoor positioning, UWB is a lead approach which has confirmed powerful. It is necessary to perform a comparative analysis of the today's UWB indoor positioning systems.

Civilian applications using UWB were studied intensively and explored globally, due to the recent allowance for using unlicensed UWB communications by U.S. Federal Communications Commission (FCC). Also, the improvement of worldwide Wi-Fi conversation rules that recommended research and improvement efforts on UWB. Accordingly, growing experimental calculations to enhance UWB localization accuracy is rising as avigorous studies vicinity.

In latest years, ultra wideband (UWB) communications has acquired awesome interest from both the research community and enterprise. The potential energy of the UWB radio approach lies in its use of extremely extensive transmission bandwidths, which results in suited skills together with correct position place and ranging.

2. INDOOR POSITIONING SYSTEMS

An indoor positioning system (IPS) has various applications [5] in which a system that constantlycalculates the location of a human or an itemin real-time in an interior infrastructure [3]. Different kinds of domestic needs like sensing and tracing of items uses IPSs andapplications for old and differently abled personsby offering assistance in their everydayworks. Common infrastructures (e.g., shopping centers and museums) may be chosen for different beneficial programs of IPSs for blind and visually impaired human ssuch as offering

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indoor navigation systems, traveler's assistance system in museums, and kids monitoring system in busyareas. Treatment concern in hospitals is anothera critical software region of IPSs, as they may be used for monitoring sufferers, monitoring high priced device to save you thefts, and accomplishing specific positioning for robotic help all through surgical procedures. Furthermore, IPSs may be utilized by police for rescue operations. Used by fire fighters as monitoring fire fighters in a house is vital to dealing with the action and making instant effort to save if wanted. Also, IPSs may be utilizedto assist the police for sensing the location of skilled police dogs while finding the bombs in the buildings, to findany thieve merchandise, or to locate a closer crisisdoor faster in a smoky surroundings. Some industries with the operations like industrial robots, robotic intelligence operations and also robot coordination with the implementation of automation and control systems are depending highly on IPS's.

2.1. Need of Indoor Positioning Systems

In contrast with outside, indoor surroundings seem extracomplicateddue to couple of items(consisting of pieces of gadget, partitions, and persons) that scatter wave formsandresult in fading problems. The presence of different items, indoor surroundingsusually depend upon non-line-of-sight (NLOS) directionwhere wave formsdid not propagate in directwaybetweengenerator and reception that reasons uneven time delays at the reception. Additionally, the presence of items results in excessivereduction and signal diffuse. Interior localization trouble due to signal balance, as signal amplitude varywithout difficulty becauseof the life of many interference resources around us along with cell gadgets, Bluetooth, Zigbee, WiMAX and wireless gadgets.

Relative to outsidesurroundings, indoor surroundings are situation to structural actions in which structures including reference nodes may easilymove from one area to other. This could tune and calibrate the positioning system to address latest adjustments within the structure. Normally, interior localization apps needbetter precision and exactness compared to outside localization applications to address highly small regions and existing limitations.

2.2. Indoor Positioning Technologies

The suitable indoor positioning technology ought to be chosen precisely so as to make the correct harmony balance between the complexity and the overall performance of IPSs [3].

Inappraisal to the past classifications [6], we recorded another classification for indoor positioning technologies as indicated by the foundation of the framework that utilizations them, see Figure 2. We categorize indoor localization techniquesas two principle classes; building biasedand building unbiased. Infrastructure dependent indoor positioning technology seek advice from technologies that rely upon the building that they may perform in. They rely either on acurrent technology in the building or on the map and shape of the constructing. Building based indoor positioning technologies can be in addition divided into two predominant classes: indoor positioning technologies that require dedicated building and indoor localization techniques that make use of the constructing infrastructure. The need for devoted infrastructure is decided in line with the general structure of maximum modern buildings; e.g., most buildings contain WIFI even as nearly none includes radio frequency identification. Indoor positioning technologies that require dedicated infrastructures are (i) radio frequency that is either RFID or UWB; (ii) ultrasonic; (iii) infrared; (iv) Zigbee; and (v) laser. Indoor positioning technologies that make use of the constructing infrastructure are (1) WIFI; (2) mobile based; and (3) Bluetooth.

Then again, the building unbiased technologies do not require any extraordinary equipment in a building, for example, dead retribution and picture based advances. In dead retribution, an item can decide its present position through understanding its past location, its velocity and the path it is moving. Picture based techniquese specially rely upon animage. Picture based techniques may be infrastructure biased or infrastructure unbiased. Picture based infrastructure biased techniqueshang on exceptional signals inside or a map of the infrastructure. Picture based building unbiased techniques do not need data about the infrastructure map or other exceptional signals. Figure 2 indicates our classification of indoor localization techniques based on the infrastructure of the system that makes use of them. Further assessment among indoor positioning technologies is given in Table 1.

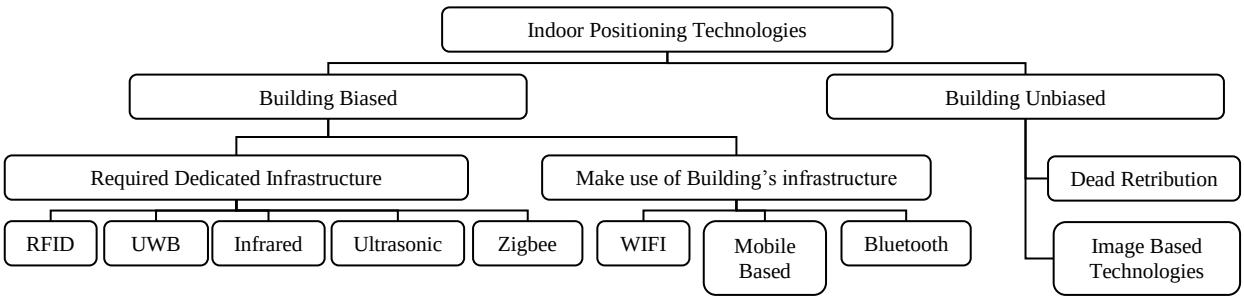

Figure2. Classification of indoor positioning technologies.

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Table 1. Different indoor localization techniques.

Technology	Estimating methods	Positives	Negatives
RFID	Proximity, RSS	Passes through stable, non-metallic items; no longer need line of sight between RF generators and recipients.	The antenna impactsits waveform, the localization range is less. Cannot be incorporated smoothly with other systems, It is not secure and consumes greater energy than its gadgets.
UWB	TOA,TDOA	Large precision localization in the existents of excessive scattering also, correctly penetrates via partitions, device, and another barriers; It will now not interfere with current RF frameworks if designed correctly.	High price of its device; even though UWB is much less liable to disturbances with respective to different techniques, it is still undergone to interference resulting from metal substances.
Infrared	Proximity, AOA	Since its waveform can't passes via partitions, it is acceptable for sensitive transmissions. It will not be reachable exterior to a room or an infrastructure.	Does not penetrate partitions, therefore it is typically used in small areas which include one room; IR communication is blocked by obstacles that block light which includes almost everything solid requires LOS among sender and receiver with the use of direct IR.
Ultrasonic	TOA,TDOA	No need of line of sight; does not interfere with electromagnetic signals.	Does not penetrate solid walls; there may be loss of signal because of obstruction; false signals because of reflections; and interference caused by high frequency sounds (e.g., keys jangling).
Zigbee	RSS, Phase shift dimensions	Its sensors needs less energy, and price.	ZigBee that function in unlicensed IS bands seem vulnerable to interference resulting from an extensive variety of waveforms (the usage of the equal frequency). This may interrupt radio transmission; it's far appropriate for systems wherein interaction among devices requires few milliseconds which lets in the transceiver to interchange to rest mode speedy.
WLAN	RSS	Utilizing current transmission topologies which could enclose multiple infrastructure; the maximum of gadgets accessible in recent times are prepared with WLAN connectivity; WLANs exist about in most people of infrastructure; No need of LOS requirement.	An essential downside of WLAN finger printing frameworks is the re-measurement of the pre defined waveform power map if modifications at the surroundings (e.g., closed/opened doorways and the shifting of furnishings in companies).
Cellular based	RSS	No disturbance with gadgets which perform at the equal frequency; the equipment of normal cell telephones also can be utilized.	Low reliability because of varying signal propagation conditions.
Bluetooth	Proximity, RSS	Does not need LOS among communicating gadgets; a lighter standard and highly ubiquitous; it is also built into almost smartphones, personal digital assistants, etc.	The extra the sectors, the lesser the scale of every sector and consequently good precision, but large sectors will increases the price; need for few enormously steeply priced recipient sectors; needs a host device to discover the Bluetooth radio.
Dead Retribution	Monitoring	No need of other separate equipment like sensors	It measures arelevant location only.
picture based techniques	Pattern identification	They are fairly cheap in comparison with different technologies.	Line of sight is required, less coverage area.

3. UWB POSITIONING

In recent years UWB is the accurate and promising technology. UWB is defined as impulse, base-band, and carrier-free technology.UWB is a technology that transmits extremely very low duration pulses, uses strategies that reason a widening of the radio strength (through an extensive frequency range) with a small power spectral density. This excessive band width giveslarge information rate for conversation[7].

Thelarge information amount of UWB may achieve hundred Mbps that results it an incredible answer to small areas for information exchange. Likewise, the excessive data transfer capacity and extraordinary low duration wave forms benefit for bringing down the impact of scattering obstruction and encourage calculation of TOA to large conveyance from generator to recipient that results UWB as note worthy suited answer to localization in indoor environment compared to various innovations. Furthermore, the low recurrence of UWB wave forms empowers to adequately pass barriers together with dividers and items which enhance precision. In truth, UWB gives an excessive exactnesss to reduce failure rate. So, UWB is thought as a stand out amongst various appropriate alternatives to applications of crucial localization which needs exceptionally correct outcomes [8, 9]. Besides, the price of its device is less and it devours low energy compared to various focused arrangements.

One famous positioning frame work that utilizes this is the 'Ubisense'. In this a person incorporates badges which generate signs of UWB to fixed reference points that utilize the signals to decide the client's positions the use of time of arrival (TOA) technique [10].

As indicated by a report distributed by TechNavio statistical surveying organization, the marketplace of localization interior services is predicted for development and could be utilize for diverse programs in department shops, air terminals, museums, and others. Because of the boom in call for, corporations begin to investigate new possibilities for utilizing the benefits of this era for offering large modern answers.

'Alere on' is ultra wideband military project that utilized to protect contractors and authorities' organizations for allowing wireless reconciliation to locate gadgets, items. This localization affords facts of gadgets, guns, phones, and encourage trooper discovery.

Deca wave is another agency that makes use of UWB innovation with TOA calculations for deciding gap between gadgets and stable reference points for assisting one of a kind package including stock administration, manufacturing flow tracking, retail income screen and consumer behavior. Incorporating UWB chips interior phones are verified by way of another up-coming agency named 'Be Spoon' not inflicting any obstruction how manner the phones work. This combination gives a massive scope for beneficial programs consisting of finding a person's belonging, fending off leaving smartphones at the back of, and customizing smartphones based on modern indoor place.

3.1 UWB Positioning Algorithms

So as to utilize this innovation, diverse positioning calculations had produced where location data is separated from wave forms going to mobile hub from reference hubs not with standing the location data of the reference hubs. Positioning algorithms divided into four important classifications explained underneath.

AOA Based Algorithms

The Angle of arrival is to apply exceptional statistics of signals for localization. As indicated by the AOA, we will draw the perspective route line between an estimating unit and the versatile target. The position of the versatile target is the crossing point of those course lines. For a portable target, it requires two estimating units to frame two angels for localization. Figure 3 is a representation for AOA. The angel is given by

$$\mathrm{Tan}(\theta i) = \frac{x-xi}{y-yi}, i=1,2$$

We may use antenna array or directional antenna for calculation of AOA.

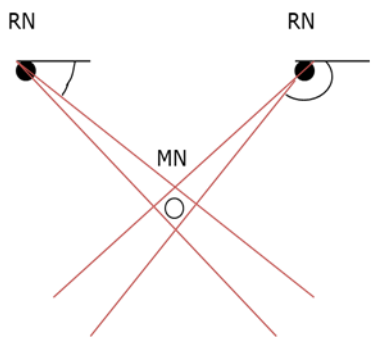

Figure3. Calculation for position of object using AOA

Angle of arrival calculations had utilized in an enormous measure of history. Xu et al., offered another agreeable localization technique that depend on AOA which uses pairwise AOA data between all sensor nodes instead of depending most effective on mobile nodes [11]. Lee demonstrated the utilization of a sign version and weighted-normal for calculating AOA specifications to less information rate. A Kalman filter using AOA calculation set of rules become delivered with the aid of Subramanian that is predicated on another quadratic frequency domain covariant beam forming approach [12].

Mok et al., contemplated the plausibility and execution this in the 'Ubisense Real-Time Location System (RTLS)' when coordinated to GPS for encouraging asset administration in buried railway building destinations. The influence of UWB directional antennas on the performance of AOA estimation was analyzed in detail by Gerok et al. [13] who presented a corrected AOA estimation algorithm that mitigates the error resulting from the UWB directional antenna.

TOA-Based Algorithms

The gap between the reference nodes and mobile node is precisely related to the time of propagation. For 2-D localization, TOA values ought to be calculated for signals

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from minimum of 3 reference nodes, as given in Fig. 1. To this system, the single-manner time of transmission is calculated, after that gap of mobile device and waveform generator is measured.

A trustworthy technique utilizes a geometric approach to calculate the point of intersection of the rounds of Time of arrival. By considering the required terminal, placed at (p_0,q_0), and t_0 is the time at which signal generate, the N reference nodes positioned at (p_1,q_1), (p_2,q_2),..., (p_N,q_N) get hold of the waveform at $t_1,t_2,...,t_N$. To calculate exact accuracy, the value characteristics may be shaped by means of

$$F(p) = \sum_{j=1}^{N} \propto_j^2 f_j^2(p)$$

In which α_i may be select to scatter the depend ability of the wave form got at $f_j(p)$ and estimating unit j is defined below.

$$f_j(p) = c(t_j - t) - \sqrt{(p_j - q)^2 + (p_j - q)^2}$$

In which c is speed of light, and p = (p,q,t)T. The characteristic has been generated to every estimating unit, j=1,...,N, and $f_j(p)$ will be reduced to zero using best preference of t, p, and q. By minimizing F(p) function, we can decide position estimate.

A detailed study of various localization algorithms for UWB and resources causing TOA error was given by Dardari et al., and also provided essential TO Alimits to be stand multi path surroundings [14]. Choliz et al., given a practical indoor state of affairs stipulate through format of barriers and arcades, using a particular UWB method to estimate exclusive styles of Time of arrival calculations like least square with distance contraction (LS-DC),weighted least square with multidimensional scaling (WLS-MDS), trilateration, extended kalman filter (EKF), particle filter (PF)[6].

Segura et al., given a singular UWB route device to interior surroundings which utilizes time of arrival based evaluation set of rules to correctly discover the versatile robot[9]. Kok et al., composed an interior localization technique in view of a sensor combination approach which mixes inertial reference nodes and TOA calculations. This method relies upon UWB generator which inflexibly connected to inertial estimations node and various UWB reception set inside. UWB estimations were demonstrated the usage of a substantial followed asymmetric conveyance and control errors of estimations because of multi path and NLOS. Keeping in mind to gain statistics of a location using ultra wideband estimations, synchronization of clocks is needed. Their analysis indicates that their UWB estimations method gives exact location measurements [15].

TDOA-Based Algorithms

Unlike the TOA approach that makes use of the time of propagation, the TDOA use the time of difference to calculate the location of the target node. The time difference refers back to the time distinction for reaching at various estimating nodes. It can remedy the trouble created by estimation errors of TOA. Utilizing estimating devices, we will achieve few hyperbolas. The target node need to be on the crossing point of a hyperbola fashioned through TDOA estimations, as represented in Fig.4. The condition of the hyperbola is written with the aid of

$$R_{i,j} = \sqrt{(p_i - p)^2 + (q_i - q)^2 + (r_i - r)^2} - \sqrt{(p_j - p)^2 + (q_j - q)^2 + (r_j - r)^2}$$

Where (p_i,q_i,r_i), and (p_j,q_j,r_j) are the permanent reference nodes and (p,q,r) is the target position. 2-D target position may be calculated from the point of inter section at which 2 or further time difference of arrival estimations, given as Figure 4. Two hyperbolas have been created by TDOA values at 3 stable reference nodes to get place of crossing, that position the required user.

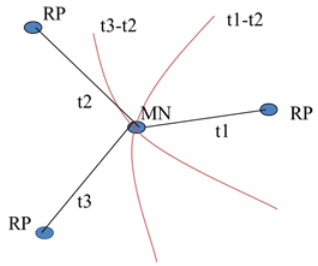

Figure 4. Calculation for position of object using TDOA

Krishnan et al., utilized TDOA to UWB localization method here area is split as slots where every slot contains4 UWB receivers placed at peak curves for direct path with target. The observers can get the waveforms from the mobile node then transfer TOA to a main observation system for calculation of TDOA to calculate target position [10]. Rowe et al., developed a frame work using two reference nodes and one user node utilizing TDOA measurements for calculation of target position [16]. On-off keying (OOK) modulation utilized to conquer the impact initiated due to synchronous node communication, increment the execution, and diminishing the expense and power in the meantime. Leitinger et al., used earlier learning of room design for enhancement of localization in scattering environment utilizing theory of equivalent Fisher information [17].

Ruiqing Ye exhibited a point by point learn regarding UWB positioning frame work with distinctive precision necessities and complication. Author built up a three dimensional position frame work with a centimeter exactness utilizing UWB innovation to monitor smaller than normal mechanical elements of a plane wheel. The framework utilizes a TDOA calculation and four recipients keeping in mind the end goal to monitor these elements. Two technical demanding situations are located after trying

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out the system in surroundings rich with metal gadgets: one is angle-based signal scattering, the other is path overlap. The author recommended a distance measurement technique for diminishing the flaw due to path overlap. Hedebated the impact of the recipient structure for TDOA exactness as well. Furthermore, the writer recommended a positioning framework with centimeter exactness [18].

Garcia et al., presented a robust UWB indoor localization for exceptionally critical interior structure where non line of sight is largely predicted [19]. The framework detects NLOS condition using response of impulse keeping in mind the goal to adequately use the EKF which enhances the exactness.

RSS-Based Algorithms

In RSS-based algorithms, the tracked target computes the wave form power of wave forms got through various generators for utilizing waveform power as an estimator of the range from the generator to the recipients. Then the beneficiary will have the capacity to calculate the location in respect to generator points. In spite of the fact that received signal strength is sensitive to multipath interference and a small-scale channel impact that reasons an arbitrary scatter from mean waveform power, it is utilized normally with unlikely suppositions. As indicated by Pittet et al., the exactness of RSS for NLOS and fading condition is less. Which demonstrates plainly that RSS isn't the correct measurement technique for interior localization frameworks [20]. Gigl et al., explained the accuracy of this algorithms for localization with UWB technique [21]. They also explained how the small scale fading effects the system performance; a test system based UWB channel model 802.15.4a was utilized for calculating the measurements instead of depending on genuine situations to interior conditions, Leitinger et al., utilized most extreme probability measurement to enhance localization within the presence of diffuse multi path for the non-line of sight condition[22].

RSS-based calculations may be sorted as two primary kinds: fingerprinting and trilateration. Trilateration calculations utilize RSS estimations to assess the separations to three distinctive reference hubs and consequently measure the present position. Finger printing needs gathering a database of RSS of an area that is used afterwards to suit online estimations with the nearest fingerprint inside the database with the intention to evaluate the position.

Hybrid Algorithms

Where numerous localization strategies are utilized, they may supplement one another. Altogether exactness will increment and additionally complication and price. Jiang et al., introduced a framework for tracking sufferers, staff, and machines of the hospital. They utilized UWB and GPS simultaneously for indoor, outdoor monitoring. Besides, the area was partitioned as sectors, everyone had four UWB recipients and a GPS receiver. They utilized a PDA which has in built GPS receiver and is associated with a UWB tag keeping in mind the end goal to use GPS and UWB in meantime. UWB utilizes both TDOA and AOA achieved through UWB recipients to measure the client location. Kuhn et al., planned an approach for a UWB positioning framework with more number of nodes, where minimum-shift keying (MSK) modulation was utilized in the range of 1–100 m [11].

Wymeersch et al., designed a best level perspective of helpful limitation procedures for UWB wireless systems [23]. They additionally exhibited a new helpful positioning approach which maps the geometrical method of interference onto the cutting edge technique. In spite the set of rules is absolutely disseminated, it increases excessive positioning exactness with less transmission high up. A pedestrian monitoring answer was added by Pittet et al., which mixes a UWB positioning framework and micro electro mechanical sensors (MEMS) to enhance the accuracy of pedestrian localization [20].

UWB interior tracking framework was designed by Segura et al., incorporate positioning system and mobile robot (MR) control system [9]. They recognized the signal that arrives firstly through outlining a dynamic threshold crossing calculations and utilizing TOA/TDOA. Time division multiple access (TDMA) was utilized to overcome interference from multiple users. Some more attempts was done to enhance localization in UWB utilizing hybrid algorithms.

3.2 Comparison of Positioning Techniques

Following the analysis of the four normal localization techniques, we gave a broad differentiate in Table 2. Hybrid calculations were the best efficient answers for UWB localization framework as they add the advantages of algorithms.

Table2. UWB Algorithms

Method	Angle of arrival (AOA)	Time of arrival (TOA)	Time difference of arrival (TDOA)	Received signal strength (RSS)
Location measurement	The crossing point of lines drawn using angles.	Time of waveform to reach user point from reference points. The separation is straight forwardly relative to the time of propagation.	The differenceof time among the signal reaching the different reference points. The time contrasts were transformed o numerous converged hyperbolas.	The received signal's strength from few reference points at the objectivepoint. The separation is related inversely by signal power.

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2D	Minimum of 2 reference points.	Minimum of 3 reference points.	Minimum of 3 reference points.	Minimum of 3 reference points.
3D	Minimum of 3 reference points.	Minimum of 4 reference points.	Minimum of 4 reference points.	Minimum of 4 reference points.
Synchronization	Clock precision and synchronization is not required.	All generators and recipients in the framework need to be synchronized. Difficult and costly.	Only the reference points required to be synchronized.	No need.
Issues	Less faults in angle calculation may effect exactness. Need expensive and high dimensions of antenna arrays.	Relative clock drift among transmitter and recipient.	The exactness is lower compare to TOA having the equal geometry of framework.	Sensitive to channel irregularity Need expensive and huge dimensions of antenna arrays Need low separations among points.

CONCLUSION

Localization is a standout amongst the most significant and intense stages in monitoring systems where particular innovation have been progressed to upgrade overall precision. In this paper, we gave a systematic examination of UWB localization, where a point by point and refreshed assessment of UWB localization method was demonstrated. UWB offers a high exactness localization notwithstanding numerous different features. In evaluation to various innovations, UWB framework have risen as best fundamental improvements to interior localization and utilizing in various bigger number of uses than already.

So many factors can add to the upgrade of positioning accuracy. For instance, from the earlier learning of the surroundings may enhance the localization accuracy while coordination of the nodes can improve the accuracy if deliberately abused. Hybrid strategies appear to be encouraging because they were more unbiased to outer side impact of fading.

REFERENCES

1. Hightower, J.; Borriello, G. Location systems for ubiquitous computing. IEEE Comput. 2001, 34, 57–66.
2. Liu, H.; Darabi, H.; Banerjee, P.; Liu, J. Survey of wireless indoor positioning techniques and systems. IEEE Trans. Syst. Man Cybern. Part C Appl. Rev. 2007, 37, 1067–1080.
3. Gu, Y.; Lo, A.; Niemegeers, I. A survey of indoor positioning systems for wireless personal networks. Tutor. IEEE Commun. Surv. 2009, 11, 13–32.
4. Al-Ammar, M.; Alhadhrami, S.; Al-Salman, A.; Alarifi, A. Comparative Survey of Indoor Positioning Technologies, Techniques, and Algorithms. In Proceedings of the 2014 International Conference on Cyber worlds (CW), Santander, Spain, 6–8 October 2014; pp. 1–8.
5. Al Nuaimi, K.; Kamel, H. A survey of indoor positioning systems and algorithms. In Proceedings of the 2011 International Conference on Innovations in Information Technology (IIT), IEEE Society, Abu Dhabi, United Arab Emirates, 25–27 April 2011; pp. 185–190.
6. Chóliz, J.; Eguizabal, M.; Hernandez-Solana, A.; Valdovinos, A. Comparison of Algorithms for UWB Indoor Location and Tracking Systems. In Proceedings of the 2011 IEEE 73rd Conference on Vehicular Technology Conference (VTC Spring), Budapest, Hungary, 15–18 May 2011; pp. 1–5.
7. Siwiak, K.; McKeown, D. Ultra-Wideband Radio Technology; John Wiley & Sons, Ltd: Newark, NJ, USA, 2005.
8. Arias-de Reyna, E.; Mengali, U. A maximum likelihood UWB localization algorithm exploiting knowledge of the service area layout. Wirel. Pers. Commun. 2013, 69, 1413–1426.
9. Segura, M.; Mut, V.; Sisterna, C. Ultra wideband indoor navigation system. IET Radar Sonar Navig. 2012, 6, 402–411.
10. Krishnan, S.; Sharma, P.; Guoping, Z.; Woon, O. A UWB based localization system for indoor robot navigation. In Proceedings of the IEEE International Conference on Ultra-Wideband, ICUWB 2007, Singapore, 24–26 September 2007; pp. 77–82.
11. Kuhn, M.; Mahfouz, M.; Turnmire, J.; Wang, Y.; Fathy, A. A multi-tag access scheme for indoor UWB localization systems used in medical environments. In Proceedings of the 2011 IEEE Topical Conference on Biomedical Wireless Technologies, Networks, and Sensing Systems (Bio Wire leSS), Phoenix, AZ, USA, 16–19 January 2011; pp. 75–78.
12. Subramanian, A. UWB Linear Quadratic Frequency Domain Frequency Invariant Beam forming and Angle of Arrival Estimation. In Proceedings of the IEEE 65th Vehicular Technology Conference, VTC2007-Spring, Dublin, Ireland, 22–25 April 2007; pp. 614–618.
13. Gerok, W.; El-Hadidy, M.; El Din, S.; Kaiser, T. Influence of the real UWB antennas on the AoA estimation based on the TDoA localization technique. In Proceedings of the 2010 IEEE Middle East Conference on Antennas and Propagation (MECAP), Cairo, Egypt, 20–22 October 2010; pp. 1–6.
14. Dardari, D.; Conti, A.; Ferner, U.; Giorgetti, A.; Win, M.Z. Ranging with ultra wide band width signals in multi path environments. IEEE Proc. 2009, 97, 404–426.
15. Kok, M.; Hol, J.D.; Schon, T.B. Indoor positioning using ultra wide band and inertial measurements. IEEE Trans. Veh. Technol. 2015, 64, 1293–1303.

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16. Rowe, N.; Fathy, A.; Kuhn, M.; Mahfouz, M. A UWB transmit-only based scheme for multi-tag support in a millimeter accuracy localization system. In Proceedings of the 2013 IEEE Topical Conference on Wireless Sensors and Sensor Networks (WiSNet), Austin,TX, USA, 20–23 January 2013; pp.7–9.
17. Leitinger, E.; Meissner, P.; Rudisser, C.; Dumphart, G.; Witrisal, K. Evaluation of Position-Related Information in Multipath Components for Indoor Positioning. IEEE J. Sel. Areas Commun. 2015, 33, 2313–2328.
18. Porcino, D.; Hirt, W. Ultra-wideband radio technology: potential and challenges ahead. IEEE Commun. Mag. 2003, 41, 66–74.
19. Garcia, E.; Poudereux, P.; Hernandez, A.; Urena, J.; Gualda, D. A robust UWB indoor positioning system for highly complex environments. In Proceedings of the 2015 IEEE International Conference on Industrial Technology (ICIT), Seville, Spain, 17–19 March 2015; pp. 3386–3391.
20. Pittet, S.; Renaudin, V.; Merminod, B.; Kasser, M. UWB and MEMS based indoor navigation. J. Navig. 2008, 61, 369–384.
21. Gigl, T.; Janssen, G.; Dizdarevic, V.; Witrisal, K.; Irahhauten, Z. Analysis of a UWB Indoor Positioning System Based on Received Signal Strength. In Proceedings of the 4th Workshop on Positioning, Navigation and Communication, WPNC '07, Hannover, Germany, 22 March 2007; pp. 97–101.
22. Leitinger, E.; Fröhle, M.; Meissner, P.; Witrisal, K. Multipath-assisted maximum-likelihood indoor positioning using UWB signals. In Proceedings of the 2014 IEEE International Conference on Communications Workshops (ICC), Sydney, Australia, 10–14 June 2014; pp. 170–175.
23. Wymeersch, H.; Lien, J.; Win, M.Z. Cooperative localization in wireless networks. IEEE Proc. 2009, 97, 427–450.

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