A Survey on Various Indoor Localization Techniques in Wireless Sensor Networks

Nisha Singh[#1], Nitika Sharma[*2]

[#]Assitant Professor & Department of Computer Application & Department of Computer Science

Sri Sai University

Palampur, India

***Abstract*—** Wireless Sensor Networks (WSN) deals with variety of numerous applications such as monitoring, target tracking, battlefield surveillance for civilian as well as military purposes. Many such application demands the location information of Sensor Nodes. Thus, localization is really becoming an important challenge over recent years. Since many techniques have been developed to solve the problem of localization, but all of them suffer from certain limitations. This paper provides an overview of the various existing indoor localization techniques with their applications in Wireless Sensor Network.

***Keywords*—** Localization, Sensor Nodes, Wireless Sensor Networks (WSN).

I. INTRODUCTION

Wireless Sensor Network plays a vital role in research area over recent years. These networks have an extremely crucial role in many pervasive technologies. Wireless Senor Network (WSN) deals with various aspects such as security, mobility, routing, energy efficiency and localization. These networks are used to perform various monitoring tasks such as battlefield surveillance, target tracking, search, rescue and perimeter security etc. Many such tasks require location information of the Sensor Nodes (SN). Thus, node localization has become inherently one of the major challenges over recent years.

Localization is a technique used to determine the exact physical location of the object in a geographic map. Localization has primarily several advantages; location awareness facilitates numerous application services, such as location directory services that provide doctors the information of nearby medical equipment and personnel in smart hospitals. Moreover in many military applications, where continuous surveillance is difficult to perform that makes the network suffers from various attacks, localization can help to develop various defence and detection algorithms which protect the networks from various malicious attacks. Since localization can be achieved for both indoor as well as outdoor applications as different application demands different granularity of location information. This paper provides survey of various indoor localization techniques in Wireless Sensor Networks.

II. VARIOUS INDOOR LOCALIZATION TECHNIQUE IN WIRELESS SENSOR NETWORK

A. *Received Signal Strength Indicator(RSSI)*

RSSI indoor localization technique found in the wireless sensor network is very useful in dense traffic scenario where interference is a major concern. This technique measures the power of signals at the receiver and based on the known transmit power; the effective propagation loss can be calculated [6, 1]. It uses the theoretical or empirical model formula to translate the signal strength into distance. RSSI is basically a measurement of the power present in a received radio signal. The attenuation of emitted signal strength is function of the distance between the emitter and the receiver.

The target can thus be localized with at least three reference points and the corresponding signal path losses due to propagation as shown in Fig.1 [6] where A, B and C are the reference points and LS_1, LS_2 and LS_3 denotes the measured path loss.

This method is commonly used by the RADAR or RF signals to provide software access to the amplitude of the received signal therefore this method does not involve any hardware modifications. Thus the method is low cost and can be easily configured without any extra device.

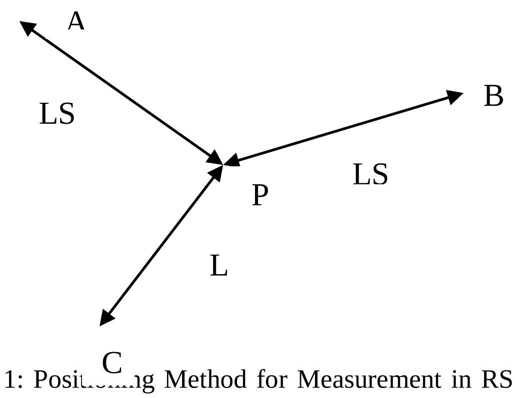

Fig. 1: Positioning Method for Measurement in RSSI [6]

B. *Triangulation [10, 2]*

Triangulation [10, 2]: This method uses the lateration or angulation for the determination of location of a sensor node. Lateration is the calculation of position information of an object by measuring its distance from multiple reference points which is given by:

$$d = l \sin\alpha \ \sin\beta / \sin(\alpha + \beta) \qquad (1)$$

Angulation approach uses the Angle-of-Arrival (AOA) which estimates the angle at which signals are received to find the relative location of the sensor node. Triangulation serves as a basis for many geometry based routing, localization, segmentation and data storage and processing algorithms in wireless sensor networks.

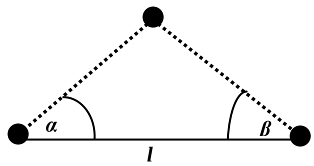

Fig. 2: Positioning Method for Measurement in Triangulation Technique

C. Time of arrival (TOA)

TOA [11, 3] makes use of signal propagation time to obtain range information. A system needs to be synchronous to use TOA for range estimation .It demands high clock resolution to measure the accurate position. TOA can be measured using different signaling techniques such as Direct Sequence Spread Spectrum or Ultra wide Band measurements. Fig.3 [11] shows the measurement method in TOA which requires signals from at least three reference points; here in the figure X, Y, Z are three reference points; R1, R2, and R3 are their respective signal radius and C is the common point of signal intersection of X, Y and Z. GPS uses the TOA technique to calculate the range information. There are other algorithms for TOA such as closest neighbor that estimates the location of the received signal over a time period T, one commonly used among them is TDOA .Many WSN applications including monitoring and tracking users TOA to calculate the node positions thus, solves the problem of both indoor localization.

The distance from the mobile target to the measuring unit is directly proportional to the propagation time. In order to enable 2-D positioning, TOA measurements must be made with respect to signals from at least three reference points. In general, TOA causes two problems mainly. Firstly, all receivers and transmitters in the system have to be precisely synchronized. Secondly, a timestamp should be labeled for transmitting signal in order for the measuring unit to discern the distance the signal has traveled.

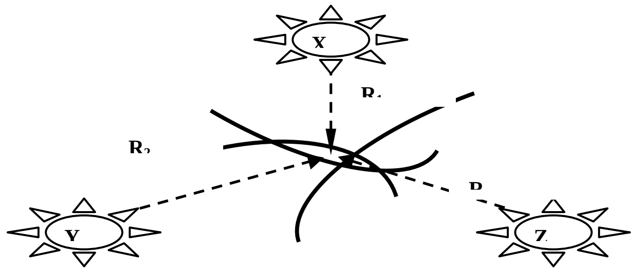

Fig. 3: Positioning Method for Measurement in Time of Arrival [11]

D. Time Difference Of Arrival(TDOA)

TDOA [2] method provides more accuracy under line of sight conditions. TDOA transmits the Ultrasound and Radio signals at the same time to obtain the range information through which distance between node and source is calculated. This method can be applied to many different signals such as RF, ultrasound, acoustic etc. This technique requires special hardware i.e. ultrasonic channel which makes it expensive for wireless sensor networks.The traditional methods to compute TDOA uses correlation techniques and can be estimated from the cross correlation between the received signals at a pair of measuring units. Let, s(t) be the transmitted signal, the received signal at measuring unit n is rn(t).

If rn(t) is corrupted by the noise non(t) and delayed by dn, then rn(t) = s(t−dn) non(t). Similarly, the signal rm(t) = s(t−dm)+ nom(t), which arrives at measuring unit m, is delayed by dm and corrupted by the noise nom(t).Then the cross-correlation function of these signals is given by integrating the lag product of two received signals over a time period T.

$$R_{rn,rm}(\tau) = 1/T \quad (t) \quad (t-\prod \ )dt \qquad (2)$$

A 2-D target location can be estimated from the intersection of the two or more TDOA measurements, as shown in Fig.4 [2]. Two hyperbolas are formed from TDOA measurements at three fixed measuring units A, B and C to provide an intersection point where R1, R2 and R3 are the respective radius signals.

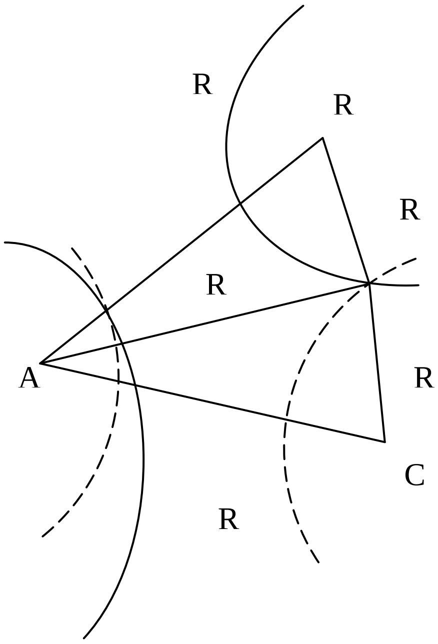

Fig. 4: Positioning Method for Measurement in Time Difference of Arrival [2]

E. Hyperbolic Trilateration[9]

It locates a node by calculating the intersection of three circles. Trilateration [9] involves gathering a number of tuples of the form (a, b, d) to calculate the object location where d represents the estimated distance providing the location reference form (a, b) and the sensor node. Fig. 5 [9] shows the positioning method for calculating the distance p, q and r corresponding to the node pairs (P, S), (Q, S) and (R, S) respectively. This is the most basic method used in wireless sensor network to calculate the node position. Trilateration can also be used for various indoor applications including navigation and surveying to calculate the node position.

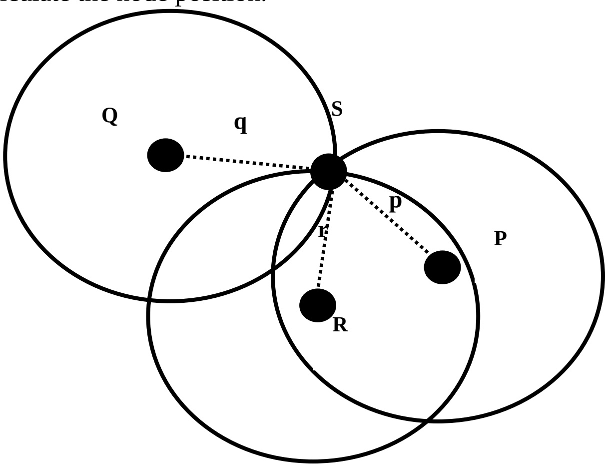

Fig. 5: Positioning Method for Measurement in Trilateration Technique [9]

F. Radio Frequency Technique

RFID enables tracking of people and objects. Data can be retrieved and stored on RFID tags enabling real time identification of users and devices. RFID provides coarse-grain location information. RFID are widely used for automatic identification and tracking. RFID systems are classified into two categories: monitoring and authorizing. In RFID monitoring systems, tags are permanently attached to the entities. Such networks provide the capability to check, monitor and authenticate which tags are present in the interrogation zone. In RFID authorizing systems tags are not permanently attached to the entities and hence the identity of the entity in possession of the RFID tag cannot be verified.

RFID is a means of storing and retrieving data through electromagnetic transmission to an RF compatible integrated circuit and is now being seen as a means of enhancing data handling processes. An RFID system consists of RFID readers and RFID tags as shown in Fig. 6. The RFID reader is able to read the data emitted from RFID tags. RFID readers and tags use a defined RF and protocol to transmit and receive information. RFID tags can be either passive or active. Passive tags can operate without a battery system. They are mainly used to replace the traditional barcode technology and are much smaller, and less expensive than active tags. They reflect the RF signal transmitted to them from a reader and add information by modulating the reflected signal.

RFID can be used in many applications like access management, tracking of goods and persons, toll collection and contactless payment to solve localization for various indoor applications.

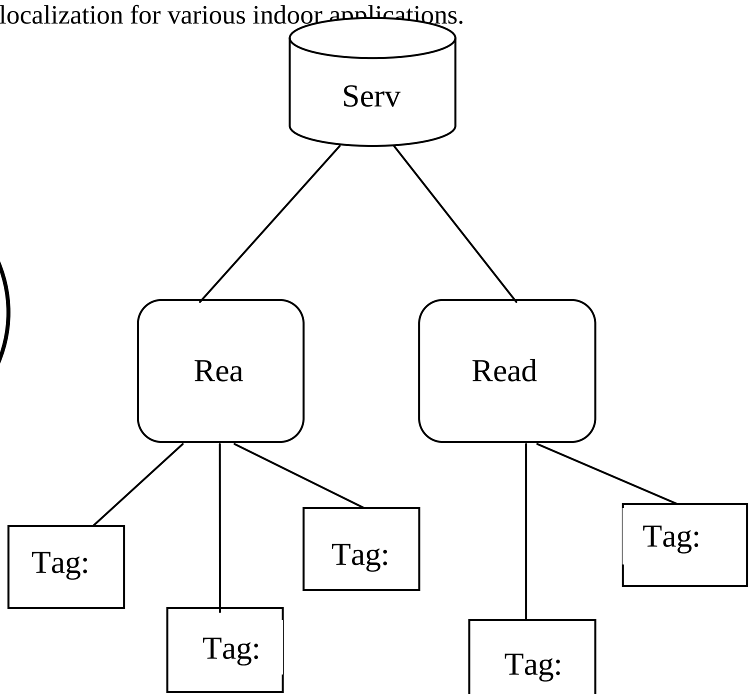

Fig. 6: Architecture of RFID System

G. Angle –Of-Arrival(AOA)

Angle-Of-Arrival is defined as the angle between the propagation direction of an incident wave and some reference directions known as orientation [5] as shown in Fig. 7 [5] where X and Y are the respective angles formed by the propagation of waves. AOA estimates the angle at which the signals are received and use geometric relationships to find the relative positions of sensor nodes. AOA measurements can be obtained using an antenna array on each sensor node or by detecting the angles between nodes. This technique is used in various wireless sensor applications such as controlling traffic in streets, tracking patients in hospitals and monitoring enemy forces in battlefield to know the positions of sensor nodes and solves the problem of indoor localization.

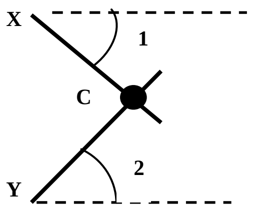

Fig. 7: Positioning Method for Measurement in Angle of Arrival [5]

The advantages of AOA are that a position estimate may be determined with as few as three measuring units for 3-D positioning or two measuring units for 2-D positioning, and that no time synchronization between measuring units is needed. AOA disadvantages includes large and complex hardware requirement and location estimate degradation as the mobile target moves farther from the measuring units. To calculate accurate position the measurement angle need to be accurate.

Table I: Comparison Chart of All Techniques

Techniques	Advantages	Disadvantages
RSSI	Low cost, Easily configured without any extra device.	Signal path losses due to propagation.
TOA	Applicable for both indoor as well as outdoor applications.	Demands high clock resolution to measure the accurate position
TDOA	Provides localization in various military as well as civil applications.	Signal path losses due to propagation.
Triangulation	Provides geometry based algorithms for indoor as well as outdoors applications	Extra hardware Requirement.
Trilateration	Provides navigation and surveying to calculate the node distance.	Require particular network topology.
RFID	Provides management, tracking of goods and persons for indoor as well as outdoor environment.	Require high frequency bands.
AOA	Synchronization	Large and Complex

III. Conclusions

Localization in wireless sensor networks has become a challenging factor for various military as well as commercial applications. Different applications demands different granularity of information. Localization has many important metrics as security, energy efficiency, robustness, accuracy and scalability etc. This paper presents a survey on various localization techniques in wireless sensor network. In this paper we have presented a comprehensive overview of need of localization in wireless sensor network and various techniques used for localization based on different granularity of information. We have also discussed the various requirements of localization needed in wireless sensor network.

There are several direction for future work in wireless sensor network. There is still need to be focused on techniques with more efficiency and inexpensive in terms of hardware and cost. In addition, there is much interest in localization in indoor, outdoor and urban areas where obstacles cause multipath propagation and loss of line of sight. Thus additional work is needed to develop indoor, outdoor localization algorithms with more efficiency and accuracy.

REFERENCES

[1] A.J. Weiss, "On the accuracy of a cellular location system based on RSS measurements," IEEE Trans. Veh. Technol., vol. 52, no. 6, pp. 1508–1518, Nov. 2003.

[2] Nitika Sharma, Manik Gupta, "Localization of Nodes 'A New Challenge for Wireless Sensor Networks', IJCA. Vol-72, June 2013.

[3] K.W. Cheung, H.C. So, W.K. Ma, and Y.T. Chan, "Least squares algorithms for time-of-arrival-based mobile location," IEEE Trans. Signal Processing, vol. 52, no. 4, pp. 1121–1130, Apr. 2004.

[4] C. Wang, H. Wu, and N.-F. Tzeng. RFID-based 3-D positioning schemes. In Proc. of INFOCOM, pages 1235–1243, 2007.

[5] Dragos Niculescu and Badri Nath. Ad Hoc Positioning System (APS) Using AoA. *IEEE InfoCom*

[6] Eiman Elnahrawy, Xiaoyan Li and Richard P. Martin, " The Limits of Localization Using Signal Strength: A Comparative Study, *in Proceedings of IEEE SECON*, pp. 406-414, Santa Clara,California, USA, October 2004.

[7] N. Vaidya and S.R. Das. Rfid-based networks: exploiting diversity and redundancy. SIGMOBILE Mob. Comput. Commun. Rev., 12(1):2–14, 2008.

[8] R. Want. An introduction to RFID technology. *IEEE Pervasive Computing*, 5(1):25–33, Jan.-March 2006.

[9] Manolakis, D.: Efficient solution and performance analysis of 3-D position estimation by trilateration. IEEE Transactions on Aerospace and Electronic Systems 32(4), 1239–1248 (1996).

[10] Esteves, J., Carvalho, A., Couto, C.: Generalized geometric triangulation algorithm for mobile robot absolute self-localization (2003).

[11] Wang, X., Wang, Z., O'Dea, B.: A toa-based location algorithm reducing the errors due to non-line-of-sight (nlos) propagation. IEEE Transactions on Vehicular Technology 52(1), 112–116 (2003).