Scientific Journal of Impact Factor (SJIF): 5.71
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406
International Journal of Advance Engineering and Research Development
International Conference of Trends in Information, Management, Engineering and Sciences (ICTIMES)
Volume 5, Special Issue 02, Feb.-2018 (UGC Approved)

Time-of-Arrival (TOA), Angle-of-Arrival (AOA) and Hybrid - TOA &AO Abased Localization in Wireless Sensor Networks

Dr.V.Bhoopathy[1], *M Aharonu*[2]

[1]*Professor, Department of Computer Science and Engineering, Malla Reddy College of Engineering*
[2]*Assistant Professor, Department of Computer Science and Engineering, Malla Reddy College of Engineering*

Abstract - *This paper mainly focuses to reduce the localization error of a sensor node which is deployed in a Wireless SensorNetwork (WSN). Here, time-of-arrival (TOA) and angle-of-arrival (AOA) based random transmission directed localization (RTDL) technique is considered. This technique can be applied in wireless sensor networks, especially suitable for network with low frequency range in the wireless sensor network. In this work, localization Error could be improved via TOA–AOA during node communicating with each other.Ad hoc On-Demand Distance Vector* (AODV) *routing protocol to be implemented in this work.The nodecategories in two ways: those nodes equipped with known vector position of the Omni-direction antenna (Source-nodes) and those nodes equipped with unknown vector position of the Omni-direction antenna (Sink-nodes). All nodes are capable of communicating with other nodes. Source-nodes are capable of positioning (TOA–AOA estimation) the other nodes located in their coverage area. The system estimates the error rate of distance between the nodes, by measuring TOA–AOA based RTDL at an appropriate number of nodes. This paper shows the proficiency of the proposed method to reduce the localization error and determine the attacker's nearest location in the network.*

Keywords*- Wireless Sensor Networks (WSN),Time-of-Arrival (TOA), Angle-of-Arrival (AOA), Ad-hoc On-Demand Distance Vector* (AODV*)*

I. INTRODUCTION

1.1 Wireless Sensor Networks

Wireless sensor networks comprises of the upcoming technology that has attained noteworthy consideration from the research community. Sensor networks comprise of many small, low cost devices and are naturally self-organizing ad hoc systems. The function of the sensor network is monitoring the physical environment, collect and transmit the information to other sink nodes. In general the range of the radio transmission for the sensor networks are in the orders of the magnitude which is smaller than the geographical extent of the intact network [1].

Wireless sensor network comprises of a great number of minute electromechanical sensor devices which possess the sensing, computing and communication abilities. These devices can be utilized for gathering sensory information, like measurement of temperature from an extended geographical area [2].

Many of the features of the wireless sensor networks give rise to challenging problems [3-7]. The most important three characteristics are:

- Sensor nodes are the ones which are prone to maximum failures.
- Sensor nodes make use of the broadcast communication pattern and have severe bandwidth restraint.
- Sensor nodes have limited amount of resources.

Despite the huge research effort, still a well-accepted approach on how to solve the localization issue is being realized. Since the sensor nodes are inexpensive and are in huge number it is not practical to equip these sensors with a Global Positioning System (GPS) receiver. Various localization approaches have been proposed and can be seen in the literature [8] and there is not a single approach which is simple, distinct and gives decentralized solution for WSNs. The Ultra-Wide Band (UWB) techniques [9] give very decent localization accuracy but the systems are expensive.

The commonly used approaches for measuring position estimate in WSN are Time of Arrival (TOA) [10], Time Difference of Arrival (TDOA)[16], Received Signal STRENGTH (RSS)[17] AND ANGLE OF ARRIVAL (AOA) A.K.A., Direction of Arrival (DOA)[18]. Where, the TOA, TDOA, and RSS measurement gives the distance calculation between the source sensor and the receiver sensors while DOAs provide the information of the angle and the distance measurements from the source and the receiver. Calculating these distance and angle measurements is not simple because of the nonlinear relationships with the source.

Given the TOA, TDOA, RSS and DOA information, the main focus of this paper is based on TOA positioning algorithms. We consider a two dimensional (2D) rectangular area where the sensors are deployed in Line-of-Sight (LOS) transmission, i.e., there is a direct path between the source and each receiver [19]. Also, we conclude that the measurements are well inside the expected range in order to obtain reliable location estimation.

II. RELATED WORK

In the view of localization infrastructure, [11] they utilized infrared strategies, and [12] ultrasound to perform localization. Both of them have to deploy specific framework for localization. Then again, disregarding its few meter-level accuracy [13], utilizing RSS [14, 15], the work in [16] is an alluring methodology, in light of the fact that it can reuse the current wireless infrastructure. Dealing with ranging approach, range based algorithms include distance estimation to milestones by utilizing the estimation of different physical properties [17], for example, RSS [14, 18], time of arrival (TOA) [19], and time difference of arrival (TDOA) [12].

Mobile location with TOA/AOA data at single base station is initially proposed in [20]. The authors in [21] examine the location exactness of TOA/AOA hybrid algorithm with a single base station in the LOS situation. Deng and Fan [22] present TOA/AOA location algorithm with various base stations. Moreover, the velocity of the mobile station is thought to be low and the relative movement between the base station and the mobile station is not recognized [23]. Utilizes an obliged nonlinear optimization technique, when range estimations are accessible from three base stations. Limits on the Non-Line-Of-Sight (NLOS) error and the relationship between the real ranges are obtained from the geometry of the cell design and the measured range circles to serve as demands [24]. Introduces twohybrid TOA/AOA systems, Enhanced Time of Arrivals (E-TOA) and Enhanced Angle of Arrival (E-AOA), so as to advance the estimation of location positioning [25]. Proposes a residual test (RT) that can in turn all the while focus the amount of LOS base stations and recognize them such that localization can move ahead with just those LOS base stations.

Hybrid location approaches by joining time and angle estimations which can minimize the amount of time taken by the receiving base stations and enhance the scope of location based service all the while. Exhaustive overviews of design difficulties and newly proposed hybrid positioning algorithms for wireless networks could be found in [26–28].

Range-free algorithms [29–31] use coarser measurements to place limits on applicant positions. An alternate technique for classification depicts the system for mapping a node to a location. Lateration approaches [31–33] use separations to milestones, which is as much angulation as it uses the angles from points of interest.

In [37], proposed a novel technique for minimizing the localization error in MANET. TOA/AOA based Random Transmission Directed Location (TAR) approach used for locating nodes. And also they used hybrid TOA/AOA which effortlessly segregates the nodes in the same vector with the help of the magnitude.Moreover, Ad hoc On-Demand Multipath Distance Vector has been used for reliable routing and to identify the presence of an attacker. Their simulation results have shown that TOA/AOA based on random transmission directed localization technique reduces the delay, drop rate, location error, estimation error, localization time and increases the throughput and network efficiency.

In [38], presented the problem of position estimation of a sensor node in a Wireless Sensor Network, using TOA measurements in LOS environments. The CRLB for the position estimation problem has been derived first and later four methods namely LLS, SA, WLLS and Two Step WLS methods of linear approach have been derived and presented. Their research work can be extended to the nonlinear approaches also and shall be reported in a future communication. They have not discussed in detail about TOA and combined solution for both TOA and AOA.

In [39], proposed a novel technique for an improved algorithm of the node localization in ad hoc network and decrease in location accuracy due to transmission delay is mitigated. They claimed that the positioning of the node according to current routing table will be incorrect if the nodes are moving fast. They proposed a node localization forecasting algorithm to plot the current position of the node. The proposed method reduces only the error impact of node localization due to transmission delay but no precise location is achieved.

III. MATHEMATICAL MEASUREMENT MODEL

3.1 Time of Arrival (TOA) Ranging Measurements

Time of Arrival (TOA) is used method for positioning and ranging. The vital idea behind TOA is to estimate delay between the source nodes andsink. To attain this, source nodes and sink clock should be synchronized.

Then distance can be estimated from the speed of the signal from source to destination and also from the time taken by the signal from the source to destination.

$$r_i = c.\ t_i = \sqrt{(x - xi)2 + (y - yi)2}$$

wherer_i is the distance, where c represent signal propagation speed between nodes while t_i represents the time taken by the signal to travel from the source to destination.

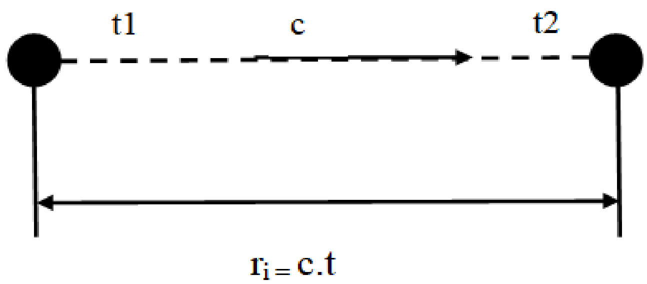

Figure 1: TOA approach for distance estimation

The distance estimation using TOA with two nodes, as shown in Fig. 1. It is shown thatthe distance between the nodes is proportional to the signal propagation time between twonodes.

3.2 Angle of Arrival (AOA) Ranging Measurement

Angle of Arrival (AOA) is another method to estimate the position of the target node based on the angle measured. The AOA technique can be further subdivided into two classes: those that make use of the response phase of receiver antenna and those that make use of amplitude phase of receiver antenna. Beam forming is done using anisotropy in the response pattern of the antenna. The beam of the antenna at the receiver is rotated and the direction in which maximum signal strength is obtained is considered as the direction of the transmitter. But problem arises when there is varying transmitted signal strength.

Because of this, the receiver cannot differentiate variation in signal strength. To address this issue, a non-rotating omnidirectional antenna is used.

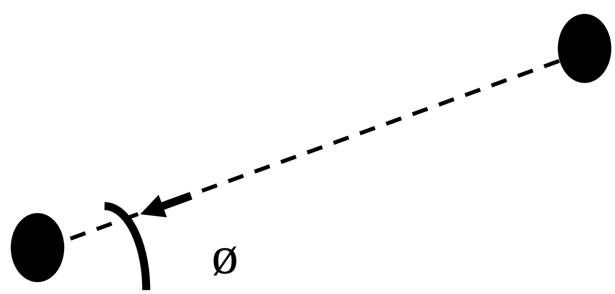

Figure 2: AOA Approach for angle measurement

AOA estimation at the target node provides information about the direction over which the target node has been located as shown in Fig. 2.

3.3 Hybrid TOA/AOA Ranging Measurement

Hybrid approach plays a vital role in providing location estimation. Hybrid techniques are combination of distance or range and AOA measurements to locate unknown nodes which are useful when the network coverage is poor. To locate a node with high accuracy, it is necessary to measure TOA and AOA to obtain the distance and direction estimates. With the estimated distance r_i and direction hi, the position of the unknown node (xi, yi) from the base node (x, y) is computed as

$$xi = x + ri = \begin{vmatrix} cos\theta i \\ sin\theta i \end{vmatrix}$$

$$yi = \mathbf{y} + \mathbf{ri} = \begin{vmatrix} cos\theta i \\ sin\theta i \end{vmatrix}$$

which defines the location of the unknown node (xi, yi) from the TOA and AOA measurementswith respect to the base node.

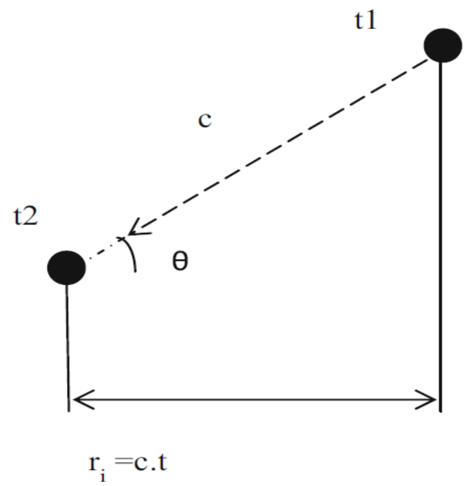

Figure 3: TOA/ AOA approach for distance and angle measurement

The TOA/AOA estimation is used to identify the position of the target node with knowndistance and angle measurements, as shown in Fig. 3.

IV. TAR APPROACH AND AODV PROTOCOL

A novel TOA/AOA based on random transmission directed localization (TAR) technique is proposed to identify the location of the target node. Initially the network consists of random number of nodes. If the number of intermediate nodes between the source node and the destination node increases, the position accuracy decreases where by resulting in the increase of the error rate. To solve this issue, the proposed technique makes accurate identification of the target node by estimating the distance and the direction of the target node. In addition, the system uses an Ad hoc On-Demand Distance Vector Routing protocol (AODV) to determine shortest path between the source and destination that is reliable and secure (Fig. 3).

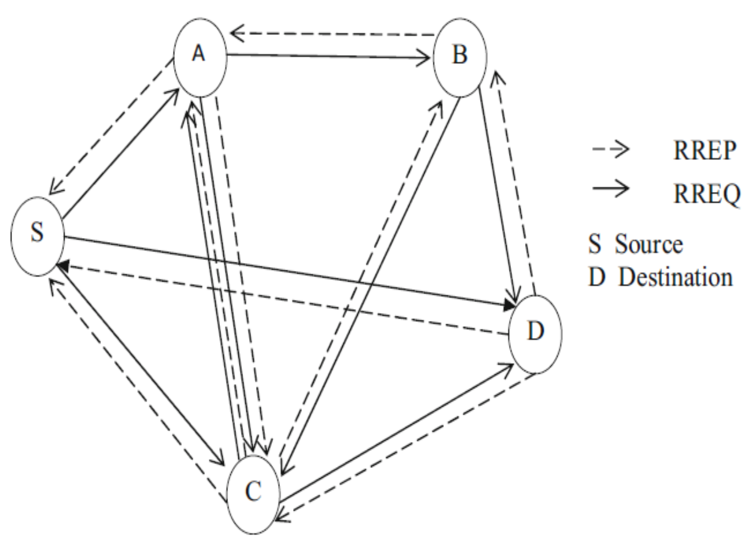

Figure 4: RREQ and RREP propagation in AODV

4.1 TOA/AOA Based on Random Transmission Directed Localization

The initial assumption is that the packet data size and the number of intermediate nodesbetween the source and the destination are obtained. The localization process starts byforwarding the data packet to the destination. The departure time and the arrival time of thedata packets are recorded. Next, packet travelling time is estimated, in addition packetwaiting time or regeneration time if any are added to packet travelling time to obtain TOAfor measuring the distance using Eq. 1. The direction of the node is then obtained by usingAOA measuring technique. The TOA/AOA measurements are then used to obtain theposition of the destination node. In this approach, TOA and AOA are computed for two cases: two nodes with same magnitude and vector and also for two nodes with differentmagnitude and vector. Finally the accuracy and error factor of the TOA is computed usingEq. 4 and 5 respectively.

$$AF = (ATj * ADj) - (STj * ADj)$$

whereATj is the packet arrival time at the jth round, ADj is the angular velocity at thedestination at the jth data transfer cycle, STj is the start time of the packet while AF is theAccuracy Factor.

The error factor is estimated as,

$$E = \sqrt{(ET - ST)} \Big/ \sqrt{(AD - AS) + SC}$$

where ET is the arrival time of the packet at the destination, ST is departure time of thepacket at the source, AD angular velocity at the destination, AS is the angular velocity atthe source, SC is the packet sequence count while E is the error factor.

4.2 Ad hoc On-Demand Distance Vector Routing protocol(AODV)

Ad hoc On-Demand Distance Vector (AODV) is the most widely used ad hocrouting protocol on the on-demand basis. AODV uses a hop-by-hop routing instead ofsource routing. The key idea in AODV is to compute multiple paths during route discovery.

AODV uses the concept of advertised hop count in order to maintain multiplehops with the same destination sequence number. The advertised hop count field contains the total number of paths to the destination, nexthop ip has the list of next hop nodes, hop count field gives the corresponding hop countvalue, while the entry expiration time field provides the expiry time after which a requestreply packet will not be received and in turn discards the entry.

When the source node needs to forward packet to the destination, it initializes routediscovery by broadcasting Route Request Message (RREQ) to the destination. The intermediateupon receiving the RREQ packets, sets up the reverse path to the source using theprevious hop count as the next hop value. If the intermediate node contains valid route tothe destination, a RREP packet is generated and forwards to the source. If the intermediatenode does not contain route to the destination, it rebroadcasts the RREQ packets. Theduplicate RREQ packets received by the node define an alternate path to the destination.

Any two RREQ packets arriving at the intermediate node via unique neighbor of thesource would not have travelled the same node, since node does not forward duplicateRREQ packets. This ensures node disjoint path. When the destination node receives theintermediate node, it generates RREQ packet and forwards it to the source via the reversepath. As the RREP packet traverses to the source, a forward path is established to thedestination node. Here a loop free path is assured by only accepting the alternate pathwhose hop count is less than the advertised hop count of the destination path.

V. SIMULATION RESULTS

5.1. Simulation Setup

The performance of Time of arrival and Angel of arrival is evaluated through NS2 simulation [12]. A random network deployed in an area of 1000 X 1000 m is considered. Initially the nodes are placed randomly in the specified area. The base station is assumed to be situated 100 meters away from the above specified area. The IEEE 802.11b MAC layer is used for a reliable and single hop communication among the devices, providing access to the physical channel for all types of transmissions and appropriate security mechanisms.

Table 1: Simulation Parameters

No. of Nodes	100
Area Size	1000 m X 1000 m
MAC	802.11b
Routing protocol	AODV
Simulation Time	600 sec
Traffic Source	CBR
Packet Size	512 bytes
Transmission Range	250m
No. of events	4
Speed of events	20 m/s

5.2. Simulation Result

The simulation results are presented in below

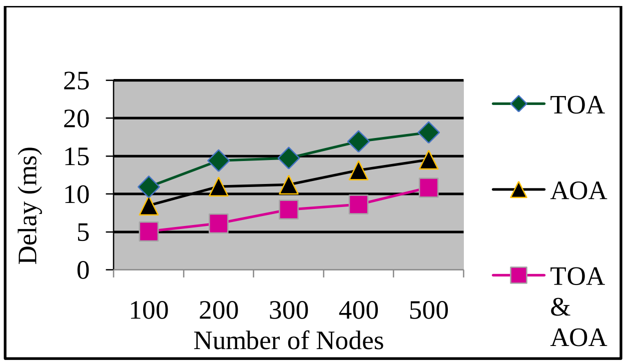

Figure 5: Nodes Vs Delay

Figure 5 gives delay analysis with respect to the number of nodes. The delay for TOA, AOA and HYB-TOA &AOA when the number of nodes is increased. From the figure, it can be seen that the Time of arrival (TOA), Angle of arrival (AOA) has high delay when compared with Hybrid time of arrival and hybrid angle of arrival (HYB-TOA &AOA).

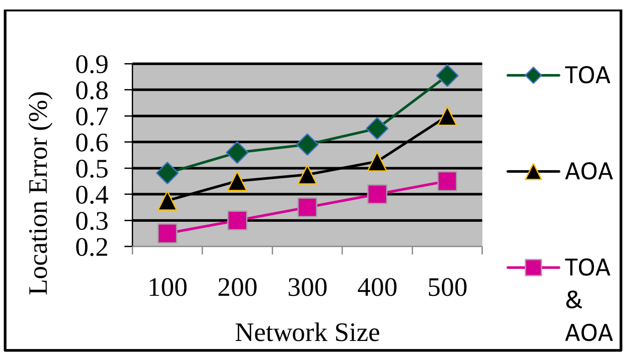

Figure 6: Network Size Vs Location Error

Figure 6 presents the location error of for TOA, AOA and method. The location error and it is defined as the process of estimating the location of mobile nodes in the WSN. The error rate for each transmission is computed in milliseconds (ms) and it is shown that there is reduced number of errors in proposed approach.

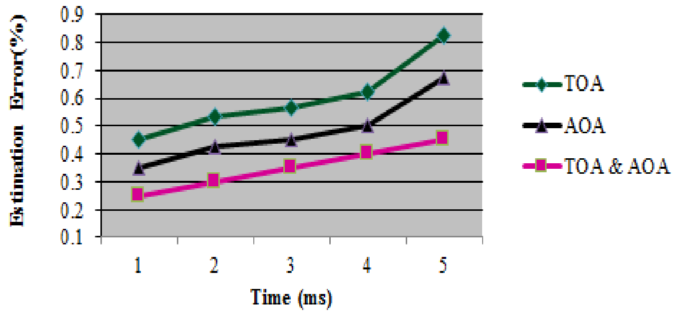

Figure 7: Time Vs Estimation Error

Figure 7 shows the graphical representation of estimation error for a particular time and the estimation error factor of the proposed technique in case of both direct and n-hop neighbors is reduced.The error rate for each transmission is computed in milliseconds (ms) and it is shown that there is reduced number of errors in proposed approach.

VI. CONCLUSION

This paper mainly focused to reduce the localization error of a sensor node which is deployed in a Wireless Sensor Network (WSN). Hence, time-of-arrival (TOA) and angle-of-arrival (AOA) based random transmission directed localization (RTDL) technique was implemented. In this work, Ad hoc On-Demand Distance Vector (*AODV*) routing protocol implemented to improve localization Error via TOA–AOA. The system estimated the error rate of distance between the nodes, by measuring TOA–AOA based RTDL at an appropriate number of nodes. The research workshows the proficiency of the proposed method to reduce the localization error and determine the attacker's nearest location in the network.

References

[1] Dorottya Vass, Attila Vidacs, "Distributed Data Aggregation with Geographical Routing in Wireless Sensor Networks", Pervasive Services, *IEEE International Conference* on July 2007.

[2] JukkaKohonen, "Data Gathering in Sensor Networks", Helsinki Institute for Information Technology, Finland. Nov 2004.

[3] Gregory Hartl, Baochun Li, "Loss Inference in Wireless Sensor Networks Based on Data Aggregation", IPSN 2004.

[4] Bhoopathy, V. and Parvathi, R.M.S. "Energy Efficient Secure Data Aggregation Protocol for Wireless Sensor Networks", European Journal of Scientific Research, Vol. 50, Issue 1, pp.48-58, 2011.

[5] Bhoopathy, V. and Parvathi, R.M.S. "Secure Authentication Technique for Data Aggregation in Wireless Sensor Networks" Journal of Computer Science, Vol. 8, Issue 2, pp 232-238, 2012.

[6] Bhoopathy, V. and Parvathi, R.M.S. "Energy Constrained Secure Hierarchical Data Aggregation in Wireless Sensor Networks" American Journal of Applied Sciences, Vol. 9, Issue 6, pp. 858-864, 2012.

[7] Bhoopathy, V. and Parvathi, R.M.S. "Securing Node Capture Attacks for Hierarchical Data Aggregation in Wireless Sensor Networks" International Journal of Engineering Research and Applications, Vol. 2, Issue 2, pp. 458-466, 2012.

[8] H. Wymeersch, J. Lien and M. Z. Win, (2009), "Cooperative localization in wireless networks," IEEE Signal Processing Mag., vol.97, no.2, pp.427-450.

[9] Gezici S, Tian Z, Giannakis GB, Kobayashi H, Molisch AF, Poor HV, et al. (2005), "Localization via ultra-wideband radios," IEEE Signal Process Mag.; 22:70–84.

[10] A. Jagoe (2003), Mobile Location Service: The Definitive Guide, Upper Saddle River: Prentice- Hall

[11] Want, R., Hopper, A., Falcao, V., & Gibbons, J. (1992). The active-badge location system. ACMTransactions on Information Systems, 10(1), 91–102.

[12] Priyantha, N., Chakraborty, A., &Balakrishnan, H. (2000). The cricket location support system. In Proceedings of ACM MobiCom, pp. 32–43.

[13] Krishnakumar, A., & Krishnan, P. (2005). On the accuracy of signal-strength based location estimation techniques. In Proceedings of IEEE INFOCOM, pp. 642–650.

[14] Bahl, P., &Padmanabhan, V. N. (2000). RADAR: An in-building RF-based user location and tracking system. In Proceedings of IEEE INFOCOM, pp. 775–784.

[15] Chen, Y., Francisco, J., Trappe, W., & Martin, R. P. (2006). A practical approach to landmark deployment for indoor localization. In Proceedings of 3rd IEEE SECON, pp. 365–373.

[16] Yang, J., & Chen, Y. (2008). A theoretical analysis of wireless localization using RF-based fingerprint matching. In Proceedings of 4th SMTPS, pp. 1–6.

[17] Patwari, N., Ash, J. N., Kyperountas, S., Hero, A. O., Moses, R. L., &Correal, N. S. (2005). Locating the nodes. IEEE Signal Processing Magazine, 22(4), 54–69.

[18] Chen, Y., Kleisouris, K., Li, X., Trappe, W., & Martin, R. P. (2006). The robustness of localization algorithms to signal-strength attacks: A comparative study. In Proceedings of DCOSS, pp. 546–563.

[19] Enge, P., &Misra, P. (2001). Global positioning system: Signals, measurements, and performance.Lincoln, MA: Ganga-Jamuna.

[20] Cesbron, R., & Arnott, R. (1998). Locating GSM mobiles using antenna array. Electronics Letters, 34, 1539–1540.

[21] So, H. C., &Shiu, E. M. K. (2003). Performance of TOA–AOA hybrid mobile location. IEICE Transactions on Fundamentals, E86-A, 2136–2138.

[22] Deng, P., & Fan, P. -Z. (2000). An AOA assisted TOA positioning system. In Proceedings of International Conference on Communication Technology; Beijing, China, pp. 1501–1504.

[23] Venkatraman, S., Caffery, J, Jr, & You, H.-R. (2004). A novel TOA location algorithm using LOS range estimation for NLOS environments. IEEE Transactions on Vehicular Technology, 53, 1515–1524.

[24] Deligiannis, N., Louvros, S., &Kotsopoulos, S. (2007). Optimizing location positioning using hybrid TOA-AOA techniques in mobile cellular networks. In Proceedings of Mobimedia'07; Nafpaktos,Greece, pp. 1–7.

[25] Chan, Y.-T., Tsui, W.-Y., So, H.-C., & Ching, P.-C. (2006). Time-of-arrival based localization under nlos conditions. IEEE Transactions on Vehicular Technology, 55, 17–24.

[26] Guvenc, I., & Chong, C.-C. (2009). A survey on TOA based wireless localization and NLOS mitigation techniques. IEEE Communications Surveys & Tutorials, 11, 107–124.

[27] Gustafsson, F., &Gunnarsson, F. (2005). Mobile positioning using wireless networks. IEEE Signal Processing Magazine, 22, 41–53.

[28] Tang, H., Park, Y.-W., &Qiu, T.-S. (2008). A TOA–AOA-based NLOS error mitigation method for location estimation. EURASIP Journal on Advances in Signal Processing, 8, 1–14.

[29] Shang, Y., Ruml, W., Zhang, Y., &Fromherz, M. P. J. (2003). Localization from mere connectivity. In Proceedings 4th ACM MobiHoc, pp. 201–212.

[30] He, T., Huang, C., Blum, B., Stankovic, J. A., &Abdelzaher, T. (2003). Rangefree localization schemes in large-scale sensor networks. In Proceedings of 9th ACM MobiCom, pp. 81–95.

[31] Niculescu, D., &Nath, B. (2001). Ad hoc positioning system (APS). In Proceedings of IEEE GLOBECOM, pp. 2926–2931.

[32] Enge, P., &Misra, P. (2001). Global positioning system: Signals, measurements, and performance. Lincoln, MA: Ganga-Jamuna.

[33] Langendoen, K., &Reijers, N. (2003). Distributed localization in wireless sensor networks: A quantitative comparison. Computer Networks, 43(4), 499–518.

[34] Bahl, P., &Padmanabhan, V. N. (2000). RADAR: An in-building RF-based user location and tracking system. In Proceedings of IEEE INFOCOM, pp. 775–784.

[35] Youssef, M., Agrawal, A., & Shankar, A. U. (2003). WLAN location determination via clustering and probability distributions. In Proceedings 1st IEEE PerCom, pp. 143–150.

[36] Chen, Y., Kleisouris, K., Li, X., Trappe, W., & Martin, R. P. (2006). The robustness of localization algorithms to signal-strength attacks: A comparative study. In Proceedings of DCOSS, pp. 546–563.

[37] Kalpana&Baskar, "TAR: TOA–AOA Based Random Transmission Directed Localization" (2016), Wireless PersCommun.

[38] Ravindra&Jagadeesha, (2015) "Time of Arrival Based Localization in Wireless Sensor Networks: A Non-Linear Approach" Signal & Image Processing: An International Journal (SIPIJ).

[39] Wang Anbao and Zhu Bin,(2014) "An Improved Algorithm of the Node Localizationin Ad Hoc Network", JOURNAL OF NETWORKS, VOL. 9, NO. 3, pp. 549 -557.