

A Range Based Localization Error Minimization Technique for Wireless Sensor Network

Sudha H Thimmaiah^{*1}, Mahadevan G²

¹Dept. of Telecommunication & Engg, Dr. AIT, VTU, Bangalore, India

²Annai College of Engg, Kumbakonam, India

Corresponding author, e-mail: sudhacseait@rediffmail.com^{*1}, g_mahadevan@yahoo.com²

Abstract

Wireless sensor network (WSN) is composed of low cost, tiny sensor that communicates with each other and transmit sensory data to its base station/sink. The sensor network has been adopted by various industries and organization for their ease of use and is considered to be the most sorted future paradigm. The sensor devices are remotely deployed and powered by batteries. Preserving the energy of sensor devices is most desired. To preserve the battery efficient routing technique is needed. Most routing technique required prior knowledge of sensor nodes location in order to provide energy efficiency. Many existing technique have been proposed in recent time to determine the position of sensor nodes. The existing technique proposed so far suffers in estimating the likelihood of localization error. Reducing the error in localization is most desired. This work present a TOA (Time-of-Arrival) based localization technique and also present adaptive information estimation model to reduce/approximate the localization error in wireless sensor network. The author compares our proposed localization model with existing protocol and analyses its efficiency.

Keywords: Wsn, localization, radio channel measurement, TOA

Copyright © 2017 Institute of Advanced Engineering and Science. All rights reserved.

1. Introduction

A WSN is composed of large collection of sensor device that collects and sends sensory information to its nearby sink/base station [1]. The sensor devices are composed of low cost and tiny sensor that is used for various sensory application needs. The rapid growth and availability of low cost sensor device has led to the adoption of sensor network by various organization and industries. The sensor network is used for various application services such as disaster management, environmental monitoring, surveillance and so on. The WSN application is self-composed and self-organized which requires prior information of sensor locations, for instance in tracking forest fire the movement of fire pattern can be tracked only if the accurate location information of sensors is obtained. The sensor device are powered by batteries and are deployed in non-rechargeable remote location and recharging of batteries induce high cost as a result pose challenge in developing an efficient localization algorithm [2, 3].

Recent studies show, the localization are broadly classified into two categories as follows the range based and range free based. In range based methodologies the sensor node position is computed based on inter devices angles or device to device distances [4-9]. In range free the location of sensor devices are identified by radio connectivity [10-13]. Range algorithm such as centroid, Amorphous and DV-Hop algorithm, and so on [14]. Among this the DV-Hop algorithm is widely adopted used technique by various researchers, the working of range free model is that it estimates the distance among reference device (Beacon) and the unknown devices. it is represented by mean distance of relays in network among the product and number of relays [15]. The range free strategies are chosen due to low cost of implementation [16]. However, if all of the dives in a network have capable of define their positions, a huge quantum of static anchors are essential. To address several mechanism have been proposed by using GPS in order to reduce anchor deployment cost [17, 18]. However finding optimal number of anchor in the sensing area is an issue that needs to be addressed [19] and [20]. These techniques suffer from energy efficiency issues and the computational cost is also high and it is very expensive to localize the node due topology dynamic as follows (large number of nodes, equipping the sensor with GPS, etc...). An alternative approach based on distance

measurement of reference and unknown node is performed by the following technique. RSS (Received signal strength), AOA (Angle of Arrival), TDoA (Time difference on arrival) and ToA (time on arrival). The RSS based is affected by fading [21] and other environmental condition as a result accuracy of localization of sensor node is not efficient which is experimentally proved [22], AOA improves the accuracy but it is not suitable for large and dense network.

This work adopts TOA based localization estimation model due to the wide adoption of TOA based Localization in adhoc and sensor network [23] and other network architecture [24]. To improve the accuracy of localization using TOA, many strategy have been developed by existing researchers [25-27]. TOA localization methodologies presented in [23] does not support enough mathematical proof to guarantee for these placement strategies, and some key issues are still need to be identify and addressed (e.g. whether a placement strategy is good, what causes the differences among placement strategies). Below is some of the challenges in wireless sensor network that need to be consider in designing localization model. There exist issues and challenges faced in localizing sensor node in wireless sensor network [28-31] which are as follows

Real time: sensor network deals with environment which requires real time delivery of data. In many scenario the information collected by sensors need to be transmitted within time bound in order to take appropriate steps/actions. Very few methodologies attain result in delivering in real time need of sensor network till date. Most of the existing technique either ignore real-time or simply tries to transmit information as fast as possible and hope that this speed is sufficient to meet end requirements. **Power managements:** The availability of low cost sensor device and deployment in one benefit of sensor network. The sensor network is embedded with small memory and has limited processing capability and bandwidth but can be addressed in near future with development of fabrication techniques. Thought the energy efficiency issue is unlikely to be solved due to slow progress battery capacity development. The sensor networks are deployed remotely and replacing of battery is not feasible. **Network Scale and Time:** Varying Features of sensor network under energy constraint, Sensor devices operate with limited capabilities of communication, storage and computing. **Management at a Distance:** Sensor devices are deployed either indoor or outdoor area such as agriculture field, industries etc... It is practically difficult in directly managing huge quantum of sensor device. Thus the protocol/strategies should provide indirect remote management architecture. There are wide localization model for the localization of WSN and each model is intended to achieve certain goals such that they vary interm of cost, size, accuracy, configurability, reliability and security. The localization of sensor node have attained wide attention in order to improve the accuracy without affecting sensor characteristics (power consumption, monetary cost, and form factor). Despite these developments there is still need of robust model required for practical (indoor/outdoor) environment. The main challenges are that how accurately it can identify the sensor node with least cost. There are many issues pertaining to localization of sensor node but cost and accuracy is most concerned. **Cost:** In sensor network reducing cost in localizing sensor node is a challenging task, very few strategies have been developed to reduce cost but they lack in accuracy which will result unnecessary overhead cost. **Accuracy:** In sensor network improving accuracy in localizing is most desired. The high accuracy models are most preferred by military operation which requires in identifying intruders. However for other application use high accuracy is not desired such in advertisement of information from one store to another. **Time Synchronization:** Many existing localization model consider that devices are synchronized. Time synchronization is problematic due to variable sound speed and long propagation delay. **Variation in Sound Speed:** Localization model considers constant sound speed but in actual environment it depends on pressure and temperature. Deviations in in these factors affect the sound speed parameter as result induces error in estimation of distance which affects the accuracy of localization model.

To overcome all these issues and challenges of existing methodologies, this work proposes a TOA (Time of Arrival) based localization technique and also proposes an adaptive information estimation to reduce/approximate the localization error in wireless sensor network. The paper organization is as follows: The literature survey is presented in section two. The proposed TOA based AIES localization models are presented in Section three. The simulation study is presented in penultimate section and last section the research is concluded.

2. Literature Survey

There are several approaches have been proposed to approximate localization error for WSN based application service in recent times in order to reduce localization error and cost of computation which are surveyed below.

In [32] presented a range based localization model by adopting distributed and cooperative strategy. The main goal of this strategy is to preserve the energy of sensor network. To preserve energy the considered a MAC layer adaptation to localize sensor devices. The MAC layer preserves the battery by reducing packet collision and retransmission. To further improve the energy efficiency the clustering technique and cooperative (hop) transmission is adopted and they considered a RSS based localization approach. The outcome shows that the cluster model reduces the localization error when compared to non-cluster network.

In [33] presented trust based localization protocol for wireless sensor network were the messages are transmitted by anchor or localized node to its neighbor nodes. They adopted a distributed and asynchronous based protocol which aid in improving the energy efficiency of sensor network since it does not require prior information of topology. The communicational and computational complexity of their methodology is $O(2E + V)$ and $O(E)$ respectively, where V is the number of sensor device and E is the number of links. Their model improved the performance interm of communication and computational overhead over existing strategies. The issues with this strategy are they did not consider any optimization technique and since they are distributed in nature it is prone to network attack which can bring negative impact interm of performance.

In [34] they reduced the cost in WSN by avoiding the use of GPS for that they presented two algorithm named as bio-inspired optimization algorithm in WSN which is helpful in node localization, and other is frog leaping algorithm. This algorithm is easy to be used in multidimensional search in WSN. Received signal strength indicator (RSSI) proposed in [35] which is based on that constraint particle swarm optimization, here they used similar method to calculate the coordinate value, in this method distance of anchor point is measured and difference is calculated based on actual value and measured value and then after obtained the coordinate value of unknown nodes.

In [36] presented a three localization model (BeSpoon, DecaWave and OpenRTLS) and evaluated their model using various ranging technique such as TDOA and TOA for indoor environment. Experiments are conducted using different chip sets and evaluated the localization accuracy of both TDOA and TOA. They further evaluated their model for IR-UWB (Impulse Radio Ultra-Wide Band) for achieving fast and high precision localization. These localization models are highly applicable for automation industries application. They evaluated the pros and cons of TOA and TDOA for varied chipsets for 2-D space indoor environment. The issues with these strategies they did not consider large density of node, dense and harsh environment which is prone to noise and fading and lastly their model is not scalable since it is not applicable for 3-d space sensor network.

In [37] they evaluated the performance of various range based strategies such as TDOA, ToA and RSSI (Radio signal strength indicator) considering real-time environment. They evaluated there performance interm of computation cost and power consumed for localization. The outcome of SRP-PHAT (Steered Response Power with Phase Transformation) achieves better performance than LLS (linear least squares) interm of computation cost for searching.

In [38] presented a RF (Radio Frequency) based localization technique in order to overcome the deficiency of GPS (global Positioning System) in indoor environment. To evaluate the performance of localization for industrial environment they considered TOA. It is used to predict the static position of robot. Here the TOA approach uses the radio wave propagation time measurement among transmitter and receiver to compute distance among them. They evaluated their model with various existing approach and outcome shows their model improves the accuracy for large scale industrial application environment. The localization performance depends on the environment it is deployed such as fading and shadowing to address this here they considered different topology deployment environment. They evaluated the performance for two localization algorithms such as maximum likelihood and min-max by using TOA approach and outcome achieved shows that min-max perform better. Their model significantly improved accuracy and it is applicable for wide industrial application but still it is not applicable for all environment and they did not considered evaluation for 3-d space network which affects the scalability and robustness of their model.

The research survey shows that there is need to develop a localization algorithm to improve the accuracy and provide scalability and robustness for wide variety of application especially for indoor environment. To address this work proposed an adaptive localization strategy by using Range based TOA approach for 2-d space wireless sensor network which is presented in next section.

3. Proposed Model

For our proposed model we are adopting a base model from [39]. It represented the RSS based modeling which work on nodes received signal strength. Adaptive approach of RSS technique make it flexible for reducing the localization error.

This work presents a model for node location estimation using TOA measurements among sensor nodes in a wireless network. Let consider a system of q blindfolded p and reference nodes. The nodes factors $\alpha = K_1, \dots, K_{p+q}$ where, for a two dimensional sensor architecture, $K_x = [i_x + j_x]^B$ the absolute error relative to the computation of blindfolded nodes axis coordinate $\varphi = [\varphi_1, \varphi_1]$

$$\varphi = [i_1, \dots, i_q], \quad \varphi = [j_1, \dots, j_q] \tag{1}$$

Considering identified reference coordinates $i_{q+1}, \dots, i_q + p, j_{q+1}, \dots, j_{q+p}$

In TOA $I_{xy} = B_{xy}$ is the computed TOA among nodes x and y (seconds). Thi work considers only subset of M(n) of nodes that compute pair-wise evaluation with nodes n, $((B_{xy}))_{xy}$ and $((T_{xy}))_{xy}$ and is considered to be competitively independent due to upper triangular matrices. Let consider that B_{xy} is Gaussian distributed with variance σ_B^2 and mean d_{xy}/s , which is represented as follows

$$B_{xy} \sim H \left(I_{xy} / s, \sigma_b^2 \right), I_{xy} = I(k_x, k_y) = \|k_x - k_y\|^{1/2} \tag{2}$$

where σ_B^2 is not a function of I_{xy} and s is the propagation speed. The arbitrary parameter $T_{xy}(\text{dBm}) = 10\log_{10}T_{xy}$ is Gaussian considering it is logarithmic normal is

$$T_{xy}(\text{dBm}) \sim H(T_{xy}(\text{dBm}), \sigma_{dB}^2) \tag{3}$$

$$T_{xy}(\text{dBm}) \sim T_0(\text{dBm}) - 10h_t \log_{10} \left(\frac{I_{xy}}{I_0} \right)$$

Where σ_{dB}^2 is the shadowing variance, $B_{xy}(\text{dBm})$ is the average power, and $T_0(\text{dBm})$ is the power received in decibel milliwatts at a reference distance I_0 , T_0 is computed by using free space path loss formula and h_t is the path loss exponent of surrounding. Here we formulate the Adaptive information estimation strategy assuming h_t is known and given (3), the density of T_{xy} is

$$f_{T_{ja}}(T_{xy} | \alpha) = \frac{10 / \log_{10}}{\sqrt{2\pi\sigma_{dB}^2} T_{ij}} e \left[-\frac{g}{8} \left(\log \frac{I_{xy}^2}{I_{xy}^2} \right) \right]$$

$$g = \left(10^n / \sigma_{dB} \log_{10} \right)$$

$$I_{xy} = I_0 \left(\frac{T_0}{T_{xy}} \right)^{1/n} \tag{4}$$

Where I_{xy} is the AIES of range I_{xy} specified obtained power T_{xy} Either P_{IJ} or T_{IJ} are presumed to be stochastic process in fact does not change with respect to time. If networks with the similar

relative node coordinates are implemented in many different areas, the variance of any unbiased coordinate estimator will be lower bounded by the proposed AIES which is presented in subsection below.

3.1. Adaptive Information Estimation Strategy (AIES)

In deployed sensor network nodes self-calibration problem occur due to require all parameters details of the sensor nodes. Information collected between node pair and other network node. A device is used for estimating the nodes parameters details known as infrastructure estimator. Synchronization of clock in distributed network can make node preserving pair-wise and offset when density of synchronized device is less.

Precisely a vector of node bounds be $\alpha = \alpha_1 \dots \alpha_{q+p}$. Every nodes has one bound. Nodes $q+1 \dots q+p$ are reference nodes and $1 \dots q$ are blindfolded nodes. The unknown bound vector is $\varphi = [\varphi_1 \dots \varphi_q]$, where $\varphi_1 = a_x$ for $x=1 \dots q$. Note that $\{\alpha_{xy} \mid x = q + 1 \dots q + p\}$ are known. Nodes x and y make pair-wise evaluations I_{xy} with load $f_{|a}(I_{xy} \mid \alpha_x, \alpha_y)$. Let consider scenario were sensor nodes create imperfect assessment as two nodes may have restricted capacity of link/out of range. Let $M(x) = \{y: \text{nodes } y \text{ makes pair-wise assessments with node } x\}$. The likelihood density function of log of the combined conditional is defined as

$$v(I|\alpha) = \sum_{x=1}^{p+q} \sum_{y \in M(x)} v_{xy}$$

$$v_{xy} = \log w_{|a}(I_{xy} \mid \alpha_x, \alpha_y) \tag{5}$$

The adaptive information matrix is estimated as

$$F_\varphi = -E \nabla_\varphi (\nabla_\varphi v(I|\gamma))^B = \begin{bmatrix} w_{1,1} & \dots & w_{1,q} \\ \vdots & \ddots & \vdots \\ w_{q,1} & \dots & w_{q,q} \end{bmatrix} \tag{6}$$

The diagonal elements $V_{n,n}$ of F_φ reduce to solitary sum over $M(n)$ since $\{M(n)\}$ term in (5) that depend on $\varphi_n = \alpha_n$. The off-diagonal elements when $n = v$ as

$$w_{n,v} = \{-\sum_{\gamma \in m(n)} R \left[\frac{\partial^2}{\partial \varphi_n^2} I_{k,l} \right]\} \tag{7}$$

The off-diagonal elements when $n \neq l$ as

$$w_{n,y} = \{-X_{M(n)} R \left[\frac{\partial^2}{\partial \varphi_n^2} v_{n,y} \right]\} \tag{8}$$

where the indicator functions of $X_{M(n)}(W)$, is 1 when $w = \in M(n)$ or else it is 0. Where is an indicator function $I_{H(k)}(l)$, where $l = \in h(k)$ or else it is 0. Let consider that there are p reference sensor node and q blind folded nodes with $\alpha = [i_1, \dots, i_{q+p}]$. The unidentified coordinate $\varphi = [i_1, \dots, i_q]$. Let consider the pair-wise computation among sensor nodes $M(n) = \{1, \dots, n-1, n+1, \dots, p+q\}$. The Eq. (2) obtains distribution of $I_{x,y} = [i_y - i_x]$. The second

partial of $v_{x,y}$ are $\left(\frac{\partial^2}{\partial i_{y^2}} \right) v_{x,y} = - \left(\frac{\partial^2}{\partial i_y \partial i_y} \right) v_{x,y} = -1/\sigma_{Bc}^2 \forall x \neq y$, which is a persistent

with respect to arbitrary parameter B_{xy} . Therefore AIES is computed using Eq. (7) and (8), is $F_B = \frac{[(q+p)X_q - 11^B]}{(\sigma_B^2 c)^2}$ where 1 is an q by 1 vector of ones, X_q is $q \times q$ matrix.

Let consider for $p \geq 1$, it represent an invertible matrix i.e.

$$F_B^{-1} = \sigma_B^2 C^2 / p(q+p) [p(E_q + 11^B)] \tag{8}$$

The unbiased variance for i_x is obtained as follows:

$$\sigma_b^2 \geq \sigma_B^2 c^2 p + 1/p(q + p) \quad (9)$$

The Eq. (9) shows that by adding more reference sensor nodes than blindfolded sensor nodes the value of σ_b^2 can be reduced. Nevertheless the difference among increasing reference devices and blindfolded devices are trivial. Similarly the localization of sensor device for 2-dimensional network in (1) is computed. Let F_B be the TOA adaptive parameter. Each nodes has two value which are partitioned into blocks as in (6)

$$W_B = \begin{bmatrix} W_{B1} & W_{B1I} \\ W_{B1I}^B & W_{B1J} \end{bmatrix} \quad (10)$$

Where W_{B1} is obtained in (6) when $\varphi = \varphi_1$, W_{B1I} is obtained in (6) when i vector $\varphi = \varphi_1$ and similarly the off-diagonal element W_{B1J} are computed. The element of $[W_{B1I}]_{nv}$ when $n = v$ are given as follows

$$[W_{B1I}]_{nv} = 1/S^2 \sigma_B^2 \sum_{x \in M^n} (i_n - i_x)^2 / |k_n - k_x|^2 \quad (11)$$

Similarly the element of $[W_{B1I}]_{nv}$ when $n \neq v$ are given as follows

$$[W_{B1I}]_{nv} = 1/S^2 \sigma_B^2 X_{M(n)}(v) (i_n - i_x)^2 / |k_n - k_x|^2 \quad (12)$$

The element of $[W_{B1I}]_{nv}$ when $n = v$ are given as follows

$$[W_{B1I}]_{nv} = 1/S^2 \sigma_B^2 \sum_{x \in M^n} (i_n - i_x)(j_n - j_x) / |k_n - k_x|^2 \quad (13)$$

Similarly the element of $[W_{B1I}]_{nv}$ when $n \neq v$ are given as follows

$$[W_{B1I}]_{nv} = 1/S^2 \sigma_B^2 X_{M(n)}(v) (i_n - i_v)(j_n - j_v) / |k_n - k_v|^2 \quad (14)$$

The element of $[W_{B1I}]_{nv}$ when $n = v$ are given as follows

$$[W_{B1I}]_{nv} = 1/S^2 \sigma_B^2 \sum_{x \in M^n} (j_n - j_x)^2 / |k_n - k_x|^2 \quad (15)$$

Similarly the element of $[W_{B1I}]_{nv}$ when $n \neq v$ are given as follows

$$[W_{B1I}]_{nv} = 1/S^2 \sigma_B^2 X_{M(n)}(v) (j_n - j_v)^2 / |k_n - k_v|^2 \quad (16)$$

The $W_B \propto 1/(S^2 \sigma_B^2)$ therefore it is adaptable for large, sparse and high density network.

The maximum likelihood of φ for a particular q and p is computed as follows

$$\varphi_B = \arg_{(k_x)}^1 \sum_{x=1}^{p+q} \sum_{y < x} \sum_{y \in B(x)} (s_{B_{xy}} - 1(k_x, k_y))^2 \quad (17)$$

The evaluations of the proposed localization model are presented in next section:

4. Simulation Result and Annalysis

The Simulation environment considered is windows 8.1 home single language operating system, Intel Pentium I-5 class 2.7 GHz, 64-bit processor, with 4GB of RAM and 2GB dedicated Nvidia CUDA graphic card. We have used MATLAB 2013b tool. We have conducted simulation study on following parameter for localization error, Error tolerance and localization distance error and compared our proposed AIES-TOA with standard localization algorithm and We have considered 10m*10m network area, 4 reference device, grid size of 10m, total number of sensor devices is equal to square of grid size, blind folded devices is equal to total devices minus reference devices and we have varied tolerance, localization iteration & distance and conducted simulation study.

The localization error is computed in terms of RMSE as:

$$RMSE = \sqrt{\frac{\sum_{i=1}^n (LOC_{real}^1 - LOC_{est}^1)^2}{n}} \quad (18)$$

In Figure 1 we can see that the proposed AIES-TOA algorithm performs better than the existing standard algorithm in term localization error. The number of iteration is varied from 10 to 50 and average localization error of proposed AIES-TOA is reduced by 12.64% over existing standard algorithm.

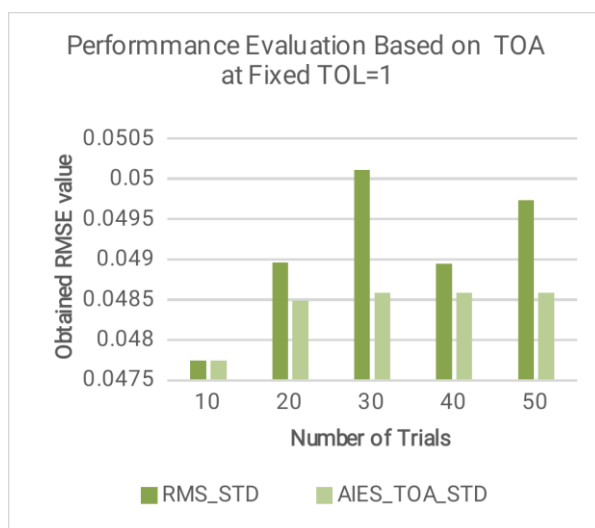


Figure 1. Localization error performance

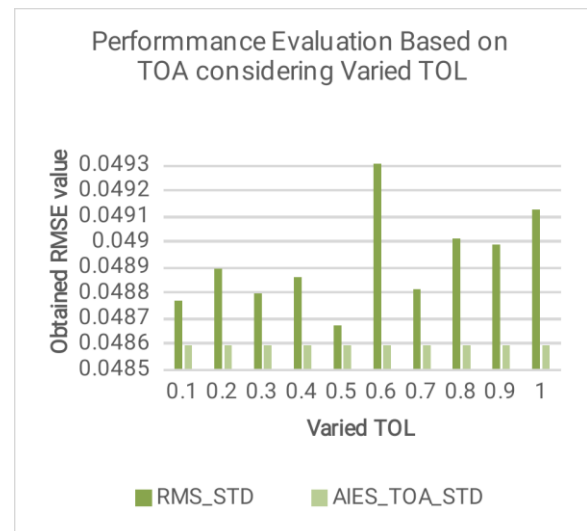


Figure 2. Error tolerance Performance

In Figure 2 we can see that the proposed AIES-TOA algorithm performs better than the existing standard algorithm in term error tolerance performance. The number of tolerance is varied from 0.1 to 1 and average error tolerance of proposed AIES-TOA is reduced by 10.62% over existing standard algorithm.

In Figure 3 we can see that the proposed AIES-TOA algorithm performs better than the existing standard algorithm in term distance error. The number of localization distance is varied from 10 to 100 and average distance error of proposed AIES-TOA is reduced by 86.62% over existing standard algorithm.

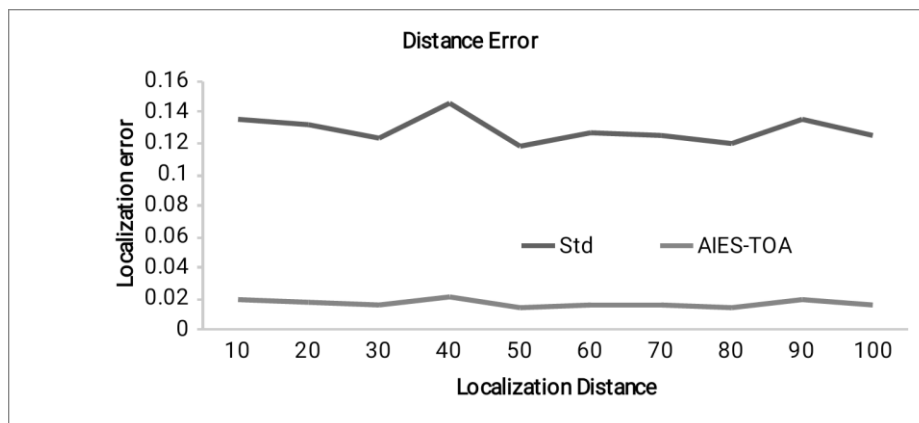


Figure 3. Distance error performance

5. Conclusion

Wireless sensor network is a network that enables correspondence between various devices associated through an infrastructure protocol. Finding the position/location of sensor node (Localization) is an important factor in sensor network for proving efficient service to end user. The existing localization is not efficient interm of accuracy and induces localization optimization overhead. To address this work the presented a TOA based localization technique and also proposes an adaptive information estimation to reduce/approximate the localization error in wireless sensor network. The simulation results show the proposed model reduces 12.64% interm of localization error performance, reduces 10.62% interm of error tolerance performance and reduces 86.62% interm of distance error performance over existing standard algorithm respectively. The overall outcome achieved show the effectiveness of our proposed localization model over existing protocol.

References

- [1] IF Akyildiz, W Su, Y Sankarasubramaniam and E Cayirci. "A survey on sensor networks". *IEEE Commun. Mag.* 2002; 40(8): 102–114.
- [2] AIF, W Su, SY and CE. "A Survey on Sensor Networks". In Proc. IEEE Communications Magazine. 2002; 40: 102-113.
- [3] D Niculescu, B Nath. "Ad Hoc Positioning System (APS)". Proc. of the IEEE GLOBECOM 2001, San Antonio. 2001: 2926-2931.
- [4] P Bergamo and G Mazzini. "Localization in sensor networks with fading and mobility". In Proc. IEEE Int. Symp. Personal, Indoor Mobile Radio Conf. 2002: 750–754.
- [5] A Nasipuri and K Li. "A directionality based location discovery scheme for wireless sensor networks". In Proc. ACM Int. Workshop Wireless Sensor Netw. Appl. 2002: 105–111.
- [6] P Bahl and VN Padmanabhan. "RADAR: An in-building RF-based user location and tracking system". In Proc. IEEE Joint Conf. IEEE Comput. Commun. Soc. 2000: 775–784.
- [7] D Niculescu and B Nath. "Ad hoc positioning system (APS) using AoA". In Proc. IEEE Joint Conf. IEEE Comput. Commun. Soc. 2003: 1734–1743.
- [8] A Savvides, H Park and M Srivastava. "The bits and flops of the Nhop multilateration primitive for node localization problems". In Proc. ACM Int. Workshop Wireless Sensor Netw. Appl. 2002: 112–121.
- [9] A Savvides, CC Han and MB Srivastava. "Dynamic fine-grained localization in ad-hoc networks of sensors". In Proc. ACM Int. Conf. Mobile Comput. Netw. 2001: 166–179.
- [10] D Niculescu and B Nath. "DV based positioning in ad hoc networks". *Telecommun. Syst.* 2003; 22(1): 267–280.
- [11] N Bulusu, J Heidemann and D Estrin. "GPS-less low-cost outdoor localization for very small devices". *IEEE Personal Commun.* 2000; 7(5): 28–34.
- [12] T He, C Huang, BM Blum, JA Stankovic and T Abdelzaher. "Range-free localization schemes for large scale sensor networks". In Proc. ACM Int. Conf. Mobile Comput. Netw. 2003: 81–95.
- [13] C Savarese, J Rabaey and K Langendoen, "Robust positioning algorithms for distributed ad-hoc wireless sensor networks". In Proc. USENIX Tech. Annu. Conf. 2002: 317–327.

- [14] XIAO Liping and LIU Xiaohong. "DV-Hop Localization Algorithm Based on Hop Amendment". *Chinese Journal of sensors and actuators*. 2012; 25(12): 1726-1731.
- [15] Ji Weiwei, Liu Zhong. "Study on application of DV-HOP localization algorithms to random sensor networks". *Journal of Electronics Information Technology*. 2008; 30(4): 970-974.
- [16] Vivekanandan V, Wong VWS. "Ordinal MDS-based Localization for Wireless Sensor Networks". *Journal of Sensor Networks*. 2006; 32(1): 169-178.
- [17] KF Ssu, CH Ou and HC Jiau. "Localization with mobile anchor points in wireless sensor networks". *IEEE Trans. Veh. Technol.* 2005; 54(3): 1187-1197.
- [18] ML Sichitiu and V Ramadurai. "Localization of wireless sensor networks with a mobile beacon". In Proc. IEEE Int. Conf. Mobile Ad-Hoc Sensor Syst. 2004: 174-183.
- [19] X Li, N Mitton, I Simplot-Ryl and D Simplot-Ryl. "Dynamic beacon mobility scheduling for sensor localization". *IEEE Trans. Parallel Distrib. Syst.* 2012; 23(8): 1439-1452.
- [20] CT Chang, CY Chang and CY Lin. "Anchor-guiding mechanism for beacon-assisted localization in wireless sensor networks". *IEEE Sensors J.* 2012; 12(5): 1098-1111.
- [21] PK Sahu, EHK Wu and J Sahoo. "DuRT: Dual RSSI trend based localization for wireless sensor networks". *IEEE Sensors J.* 2013; 13(8): 3115-3123.
- [22] T Van Haute, E De Poorter, I Moerman, F Lemic, V Handziski, A Wolisz, N Wirstrom and T Voigt. "Comparability of RF-based Indoor Localization Solutions in Heterogeneous Environments: An Experimental Study". *Inderscience Publishers*. 2015.
- [23] D Niculescu and B Nath. "Ad hoc positioning system (APS)". In Proc. of IEEE Global Telecommunications Conf. (GLOBECOM01). 2001; 5: 2926-2931.
- [24] Kegen Yu, Hedley M, Sharp I and Guo YJ. "Node Positioning in AdHoc Wireless Sensor Networks". In Proc. of IEEE International Conference on Industrial Informatics (INDIN'06). 2006: 641-646.
- [25] Wang JS and Shen ZX. "An improved MUSIC TOA estimator for RFID positioning". *RADAR 2002*. 2002: 478-482.
- [26] Qiqian Huang and S Selvakennedy. "A range-free localization algorithm for wireless sensor networks". In Proc. of IEEE 63rd. Vehicular Technology Conference (VTC 2006-Spring). 2006: 349-353.
- [27] Min Yin, Jian Shu, Linlan Liu and Hengfeng Zhang, "The influence of beacon on DV-Hop in wireless sensor networks". In Proc. of Fifth International Conference on Grid and Cooperative Computing Workshops (GCCW '06). 2006: 459-462.
- [28] Mohammed Farrag, Mohammed Abo-Zahhad, MM Doss and Joseph V Fayed. "Different Aspects of Localization Problem for Wireless Sensor Networks: A Review". *International Journal of Computer Networks and Communications Security*. 2016; 4(5): 130-140.
- [29] Javed Iqbal Bangash, Abdul Hanan Abdullah, Abdul Waheed Khan. "Issue and challenges in localization of wireless sensor networks". *Sci. Int (Lahore)*. 2014; 26(2): 595-603.
- [30] Mukesh Beniwal, Rishipal Singh. "Localization Techniques and Their Challenges in Underwater Wireless Sensor Networks". *International Journal of Computer Science and Information Technologies*. 2014; 5(3): 4706-4710.
- [31] Indu, Sunita Dixit. "Wireless Sensor Networks: Issues & Challenges". *IJCSMC*. 2014; 3(6): 681 - 685.
- [32] Suman Pandey, Shirshu Varma. "A Range Based Localization System in Multihop Wireless Sensor Networks: A Distributed Cooperative Approach". Springer Science+Business Media New York. 2015.
- [33] AM Abbas. "TrustLP: A trust-based localization protocol for wireless sensor networks". Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt), 2015 13th International Symposium on, Mumbai. 2015: 529-536.
- [34] Chandrasekaran D*, T Jayabarathi. "Wireless Sensor Networks Node Localization-A Performance Comparison of Shuffled Frog Leaping and Firefly Algorithm in LabVIEW". *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2015; 14(3): 516 ~ 524.
- [35] Songhao Jia*, Cai Yang. "Received Signal Strength Indicator Node Localization Algorithm Based on Constraint Particle Swarm Optimization". *TELKOMNIKA*. 2015; 13(1): 221-229.
- [36] J Wang, AK Raja and Z Pang. "Prototyping and Experimental Comparison of IR-UWB Based High Precision Localization Technologies". IEEE 12th Intl Conf on UIC-ATC-ScalCom, Beijing. 2015: 1187-1192.
- [37] A Maddumabandara, H Leung and M Liu. "Experimental Evaluation of Indoor Localization Using Wireless Sensor Networks". In *IEEE Sensors Journal*. 2015; 15(9): 5228-5237.
- [38] T Van Haute; B Verbeke; E De Poorter; I Moerman. "Optimizing Time of Arrival localization solutions for challenging industrial environments". In *IEEE Transactions on Industrial Informatics*. 99: 1-1.
- [39] SH Thimmaiah and G Mahadevan. "An adaptive localization error minimization approach for wireless sensor network". *2016 3rd International Conference on Devices, Circuits and Systems (ICDCS)*, Coimbatore. 2016: 170-173.