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An Object Tracking Mechanism in Wireless Sensor Networks

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Abstract: The continuously widening variety of Wireless Sensor Networks (WSNs) applications requires node this is certainly precise which needs efficient and error free localization practices. Localization methods created in past times are totally centered on really good computation this is certainly numerical of network variables such as for example transmission range, propagation form, transmitted or received power, delivering or arrival time, connection information etc. These variables are susceptible towards ecological presence and circumstance of hurdles in the environment. As wireless sensor companies tend to be ubiquitous in general, localization is a factor this is certainly essential be fixed. Localization of a node that is unknown be identified through a collection of research nodes. In this work, we provide a novel hybrid localization strategy, which determines the location this is certainly exact of an unknown node through the mixture of both range free and range based practices.

Keywords: Wireless Sensor Network, Sensor Placement, Wireless Sensor Networks, DOA Localization, RSS Localization.

I. WIRELESS SENSOR NETWORK

Wireless sensor networks become apparent for military needs and found its way into civil applications. Today, wireless sensor networks have become a key equipment for different types of “smart environments”, and an intense research effort currently continues to enable the application of wireless sensor networks for a wide range of industrial problems. Wireless networks have importance when a large number of sensor nodes have to be deployed, and/or in an unsafe situation [1].

In an ad-hoc network, each and every node are allowed to communicate with each other without any fixed infrastructure which is actually one of the different feature between ad-hoc and other wireless technology like cellular networks and wireless LAN which actually required infrastructure based communication like through some access point.

“A sensor network is a deployment of massive numbers of small, low-cost, self-powered devices that can sense the event, compute, and communicate with other devices for the purpose of gathering local information to make decisions globally about a physical environment”.

II. LOCALIZATION PROBLEMS IN WSNS

Localization is the ability to determine the position either relative or absolute position of a sensor node, with an acceptable precision. In a WSN, localization is a very important task; however, localization is not the objective of the network. In reality, localization is relevant to numerous applications such as target tracking, intruder detection, environmental monitoring, etc., which depend on knowing the location of nodes [2]. Localization is also used by the network for its main functions: communication, cluster creation, network coverage geographical routing etc. Even collaboration also depends on localization of nodes.

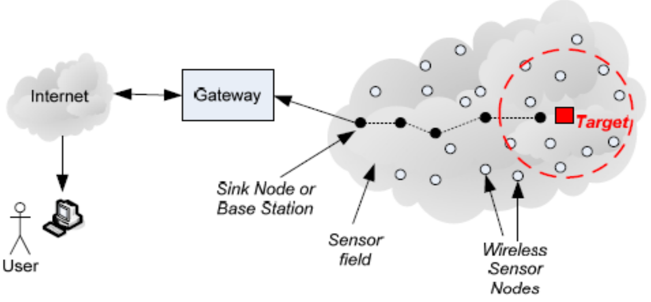

Figure 1: Localization in Wireless Sensor Network [2]

III. TARGET TRACKING

Since sensor networks are generally used to monitor the environment, one fundamental issue is the location-tracking problem, whose goal is to trace the paths of moving objects/individuals in the area in which sensors are deployed [3]. This problem is challenging because:

(1) There is no central control mechanism and no backbone network in such an environment.
(2) The wireless communication is very limited.

At present, location tracking is done using GPS. GPS has its limitations such as it cannot be used in most indoor environments, depends on Line of Sight. GPS does not yield accurate results in non-urban outdoor settings because it depends too much on factors such as terrain, foliage and topographical settings of the place where the object is located. Since, GPS receivers may be too large, too expensive or too power intensive, using wireless sensor networks provides us with a better alternative for location tracking with small, inexpensive and low power devices. They are much more viable considering economic and convenience constraints.

The general tracking's strategies for deciding which nodes are activated for tracking purposes i.e. in terms of energy efficiency are [4]:

1) **Naive Activation (NA):** In such a tracking scheme all nodes are in tracking mode all the time. This strategy offers the worst energy efficiency. Since it offers the best tracking results, it is a useful baseline for comparison.
2) **Randomized Activation (RA):** In this strategy, each node is on with a certain probability p. On an average, a fraction p of all nodes will be on and in the tracking mode. It is a more energy efficient solution than NA.
3) **Selective Activation (SA):** In this activation technique, a few selected nodes in the network are selected at a time depending on their distance from the object. As and when the object moves, the distances also change from those nodes and thus, 'handovers' take place between nodes. It offers a good balance between energy efficiency and tracking precision.
4) **Duty-Cycled Activation (DA):** In this, the entire sensor network periodically turns on and off with a regular duty cycle. The major advantage of this scheme is that it be used in conjunction with the three techniques mentioned above. It is not the smartest of solutions in terms of energy efficiency but fares better than NA.

IV. KEY ASPECTS OF LOCALIZATION ALGORITHMS

There are little aspects that have to be believed after arranging or selecting a localization algorithm, like manipulated resources, the density of nodes, number Network topology, kinds of signals utilized, attendance of obstacles or terrain irregularities, and node mobility (if nodes are stationary or mobile)[2]. Most of the continuing algorithms can accomplish good localization accuracy. But, normally, they can merely change to a little of these key aspects.

Limited resources: Usually, a sensor node comprises four basic components: sensing unit (transmitter and receiver), power (a battery) unit, a processing unit, and a transceiver unit. New advancements allow the sensor nodes of the present generation to become still smaller and cheaper. Therefore, nodes have reduced memory and processing capacity. The battery is limited. Furthermore, due to a short transmission range, nodes can merely communicate with its local neighbors. A fine localization solution must consider all these resource limitations (computational, transmission minimizing energetic and hardware costs).

Number and density of nodes: The accuracy of most localization algorithms are affected by the number of nodes and/or by the density of nodes. On one side, some algorithms cannot process accurately with low-density WSNs because they will give significant localization errors. On the other side, localization can be a costly process when using highly density WSNs.

Network topology adaptability: A number of the localization algorithms calculate the Euclidian distance between a pair of nodes; consider the shortest path between them. This is only valid for such cases where shortest paths are like a straight line. In networks where the deployed area has a concave topology (S or C shape environments etc.), this is usually not valid.

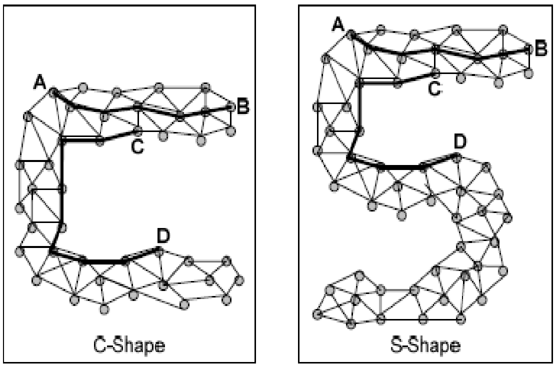

Figure 2: Network topology adaptability in WSN

Obstacles and irregularities: A number of the proposed localization solutions have low accuracy in obstructed environments. This is due to the survival of obstacles, which block the line-of-sight between nodes. Obstacles and terrain irregularities can cause signal reflections, what lead to incorrect distance estimations.

Stationary or mobile nodes*:* In a large amount WSNs, nodes are stationary. Most localization algorithms are designed purposely to this kind of networks. Though, due to the emergence of new applications, algorithms should adjust to the existence of mobile nodes.

Type of signals*:* It is really essential to know which type of signal that is used by an algorithm, owed to its propagation characteristics. Typically, localization algorithms use one type of signal, among three possibilities: acoustic, radio and ultrasounds.

V. TYPES OF LOCALIZATION ALGORITHMS

Localization algorithms can be categorized into two main categories:

a Range-based approaches

Range-based approaches are depended on distance or angle measurements, requiring the installation of hardware (for e.g., directive antennas). [5].

b Range-free approaches

Range-free approaches trust connectivity data amid adjacent nodes. They use exceptional protocols to remove the demand for wireless gesture measurements

These methods do not require extra hardware since they do not depend on any distance measurements hardware. Nevertheless, there are additionally hybrid resolutions, like the use of anchor nodes, established in MDS or mobile-assisted, centralized or distributed [5].

VI. RANGE-BASED

In range-based approach, distance estimation is generally performed using one of the following techniques: TDoA, RSSI, ToA or AoA/DoA. Then, distance estimation is used to establish nodes position. Range based approaches are called one-hop approaches because nodes have to be at a one-hop distance from a minimum of anchor nodes [6].

1) The RSSI (Received Signal Strength Indicator) technique

The RSSI method is based on the attenuation of the radio signal with the amplification of distance (according to 1/r2, where r is the distance between the sender and the receiver). So, the receiver has to measure signal attenuation to estimate the distance to the sender. This method is suitable for outdoor environments. But it is not simple to forecast radio signal behaviour indoors.

2) ToA (Time of Arrival) techniques

This method uses the signal propagation time to measure the distance between nodes. The nodes transmit a signal to their neighbours at a predefined speed and wait for answers. Their neighbours send a signal back to them. Inter-node distance is measured by calculating the difference between sending and receiving times which is called round trip approach.

3) TDoA (Time-Difference of Arrival) techniques

This method also measures the distance between nodes using signal propagation time. In this way, for distance measurements nodes transmit two different signals, which travel at diverse speeds, to their neighbours. Sender and receiver should synchronize their clocks firstly. The sender broadcasts a radio message followed by an acoustic signal (chirp). Then the distance is calculated based on the difference in propagation times of radio and acoustic signals originate at the same point which results in the distance between nodes.

4) AoA (Angle of Arrival) measurement techniques

This method makes use of the amplitude and phase response of receiver's antennas. The correctness of AoA measurements is affected by the direction of the antenna, shadowing effect and multipath reflections.

VII. RANGE-FREE

These algorithms are based on connectivity information, i.e., "who is within the radio range of whom", to estimation the location of nodes. The connectivity can be tested by calculating a number of received packets. These methods do not require extra hardware since they do not depend on any distance measurements hardware. The major advantages of range-free approaches are its ease and low cost. Range-free approaches can be hop-based, where distance is calculated by the number of hops between the nodes and also consider the shortest path [5].

VIII. PROPOSED HYBRID LOCALIZATION

The hybrid technique is one of the main categories of distributed techniques [7]. An example of such category is the use of RSS combined with Triangulation. Combining both RSS and Triangulation in one node provide a significant improvement to the accuracy of localization when compared to RSS on its own. Triangulation is considered a computationally expensive technique, but the use of it can be justified for some applications that need higher localization accuracy. In addition, just a few nodes in the network are going to use Triangulation to localize other nodes.

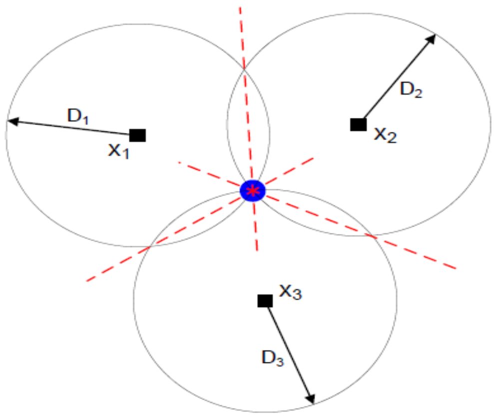

Figure 3: RSS localization Scenario.

I. RSS FORMULATION

RSS is a common technique in localizing sensor nodes; this is due to the fact that almost all nodes have the ability to measure the strength of the received signal. RSS technique benefits from the fact that radio signals diminish with the square of the distance from the signal source. In other words, the node can calculate its distance from the transmitter using the power of the received signal, knowledge of the transmitted power, and the path-loss model. The RSS between nodes *i* and *j* at time *t* can be calculated using:

$$RSS = -\left(10nlog_{10}d_{ij}\right) + P_0$$

Where *n* is the signal propagation constant (environment dependent), d_{ij} is the distance between nodes *i*and *j*, and P_0 is the Received Signal Strength at a distance of 1 meter. Let us consider the simplest scenario where there are only three reference nodes and a single blind node as shown in Figure 3. Each two circles intersect with one another at two points. These two points are used to draw a line which will intersect with another line from other anchor nodes.

The distance between the ith reference node and the blind node is given by [8]:

$$D_i = \left||x_{i-}x_s|\right| = \sqrt{(x_{i-}x_s)^2 + (y_{i-}y_s)^2}$$

Where x_i is the position of the i^{th} sensor, x_s is the position of the source transmitter, and ||x|| denotes the norm of the vector x. The straight dotted lines shown in Figure 3 can be calculated using the following equations:

between x_1 and x_2 :

$$(x_{2-}x_1)x_s + (y_{2-}y_1)y_s = \frac{1}{2}\left(\left||x_2|\right|^2 - \left||x_1|\right|^2 + D_1^2 - D_2^2\right)$$

between x1 and x3 :

$$(x_{3-}x_1)x_s + (y_{3-}y_1)y_s = \frac{1}{2}\left(\left||x_3|\right|^2 - \left||x_1|\right|^2 + D_1^2 - D_3^2\right)$$

between x2 and x3

$$(x_{3-}x_2)x_s + (y_{3-}y_2)y_s = \frac{1}{2}\left(\left||x_3|\right|^2 - \left||x_2|\right|^2 + D_2^2 - D_3^2\right)$$

The location of the blind node can be determined by solving for *xs* and *ys* in equation (3) and (4). In this case, there are only two independent lines, which means that there will be only one intersection. However, as the number of reference nodes increases, the number of independent lines increases, which results in increasing the number of intersections. Those lines are not going to intersect at the same point due to the error in the distance measurements. Therefore, it is required to use an algorithm to estimate the values *xs* and *ys.*

For a system with *N* reference nodes, there will be *N - 1* linear line equations that will intersect at a different position forming a polygon. The blind node position can be estimated by averaging the intersection points or calculating the centroid of the polygon.

The least square method is an alternative approach to estimate the position of the blind node. Each of the *N* - 1 independent lines is represented in the following form:

$$a_{i,1}x_s + a_{i,2}\, y_s = b_i i = 1,2,3, \dots\dots, N-1$$

Where $a_{i,1}$, $a_{i,2}$ and bi are known.

This equation can be rewritten as:

$$\boldsymbol{a_i x_s} = b_i$$

where $\boldsymbol{a_i} = \left[a_{i,1}\ a_{i,2}\right]$ and $x_s = [x_s y_s]^T$

The equations describing all of the lines can also be written in matrix form as:

$$\mathbf{A}\boldsymbol{x_s} = \mathbf{b}$$

$$\text{where } \mathrm{A} = [\mathrm{A}_1\ ,\mathrm{A}_2, \mathrm{A}_3 \dots \mathrm{A}_{\mathrm{N}-1}] \text{ and } \boldsymbol{x}_s = [x_s y_s]^T \text{and } \mathbf{b} = [\mathrm{b}_1 \mathrm{b}_2 \mathrm{b}_3 \dots \mathrm{b}_{\mathrm{N}-1}]^T$$

Since the straight lines do not intersect with each other in a single point, there is no solution for the above equation. However, least square estimation can be used to estimate the values of $x_s$that are as close as possible to the actual blind node coordinates. The estimated location $\widehat{Xs}$ of the blind node is given by [8]:

$$\widehat{Xs} = (A^T A)^{-1} A^T B$$

This algorithm is obviously much less difficult than the geometric one since there is no need to compute intersections of many lines.

IX. POINT IN TRIANGULATION IN WSN

APIT is a non-localized iterative algorithm that uses beacon packets from anchor nodes. It employs an area-based approach for location estimation by isolating the environment into triangular regions between anchors nodes. By using combinations of anchor positions, the estimated area‟s diameter in which a node resides can be reduced for providing accurate location estimates. In this method, a node chooses three anchors from nearby anchors and checks whether it is inside the triangle by relating these three anchors. The trilateration technique used the intersection of three circles (anchor nodes' range circle) to find out the exact spatial coordinates of the object.

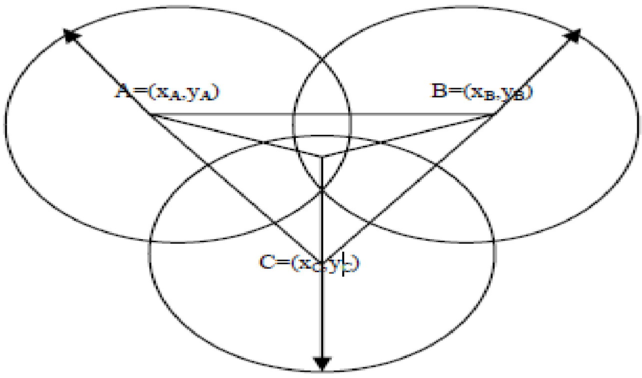

Figure 4: Position Approximation Algorithm

In real world scenario, three circles never intersect at a common point. To minimize the error of estimation, an approximation algorithm has been used the difference function [9]. The difference function, x, y s is calculated as

$$\sigma_{x,y}\left|\sqrt{(x-x_A)^2+\ (y-y_A)^2}-r_A\right|+\left|\sqrt{(x-x_B)^2+\ (7-y_B)^2}x-rb\right|+\left|\sqrt{(x-xc)^2+\ (y-yc)^2}-r_c\right|$$

where A, B and C are the sensor nodes and (xA ,yA), (xB ,yB) and (xC ,yC) are their center coordinates and rA, rB and rC are the distances to A, B and C from any point (x,y) on the plane.

X. RESULTS AND ANALYSIS

In our proposed work Total Average End to End Delay between nodes is around 0.065 seconds which is sufficient for deploying real-wosrld sensor nodes using Hop by Hop location tracking mechanisms. The packet delay is the time of creation of a packet by the source node up to the destination node reception. At this time a packet starts to move across the working network. Time is expressed in seconds. Hence all the delays in the network are called packet end-to-end delay, like buffer queues and transmission time. This delay can be called as latency; it provides a same sense as a delay. There are different kinds of activities because of which network delay is increased. Packet end-to-end delay is a measure of how sound a routing protocol adapts to the various constraints in the network to give reliability in the routing protocol.

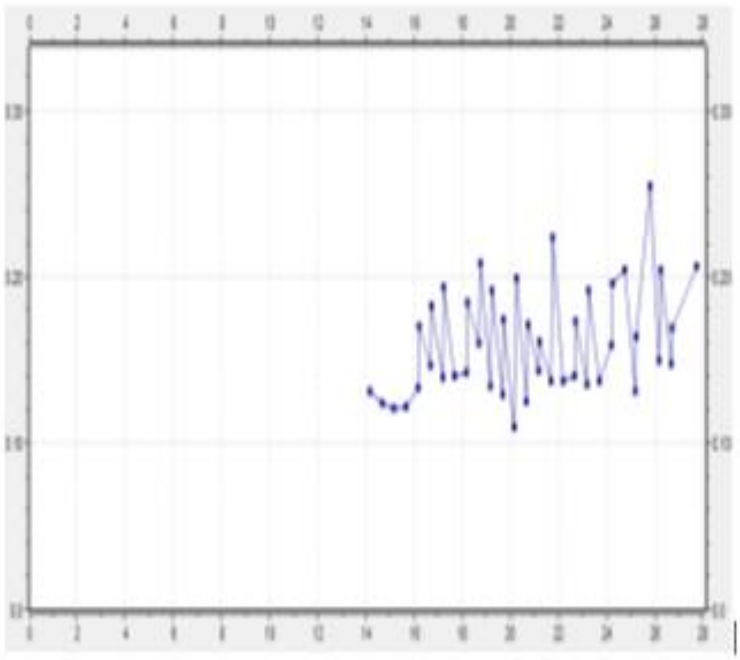

Figure 5: End to End Delay between nodes in seconds

Change in Energy describes the total Energy consumed during simulation of 400 nodes for locating the target; the localization algorithm must provide linearly depreciating energy as shown in the figure. For 400 nodes with 3J of initial energy total of 1200J was available and after 50 rounds the energy drops to 1100 which is quite expected and is improved from previous works.

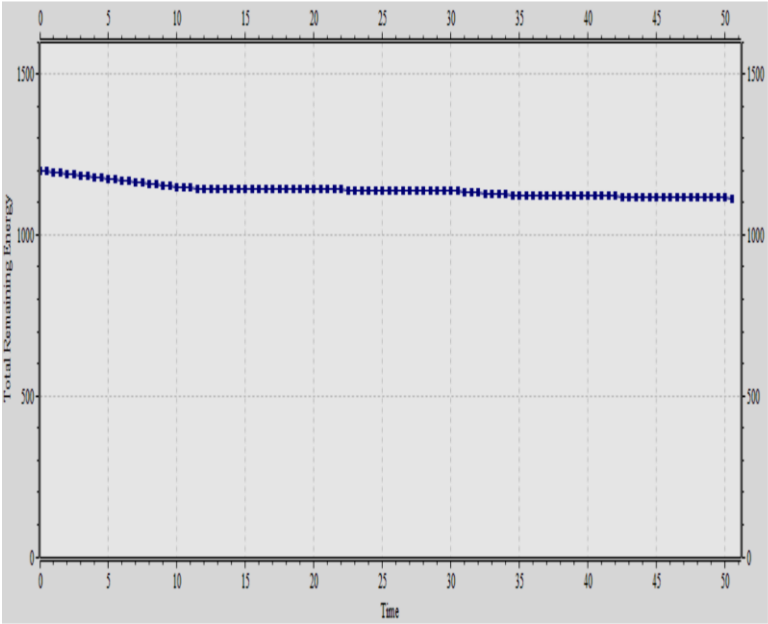

Figure 6: Change in Total Energy of the System during Simulation

The throughput or network throughput is the rate of successful message delivery over a communication channel. This data may be delivered over a physical or logical link, or pass through a certain network node. The throughput is usually measured in bits per second (bit/s or bps), and sometimes in data packets per second or data packets per time slot.

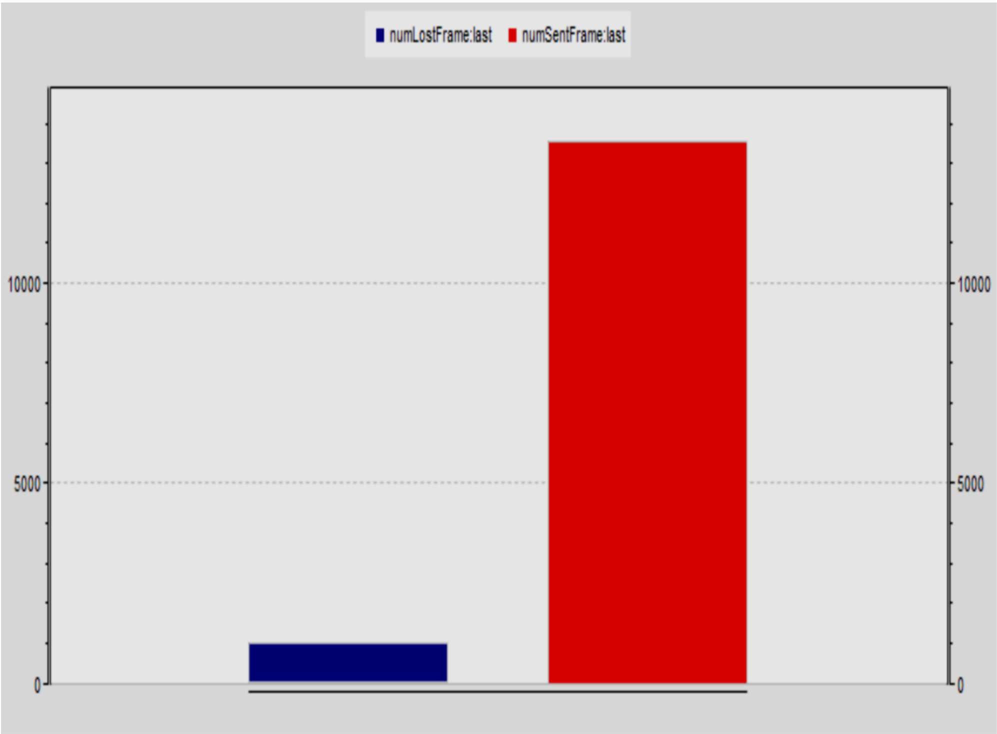

Figure 7: No. of Lost Frames and Total Sent Frames

$$Network\ Throughput\ = \frac{Total\ frames\ sent - Lost\ Frames}{Total\ Frames}$$

$$\text{Network Throughput } = \frac{13566 - 994}{13566}$$

=92.67%

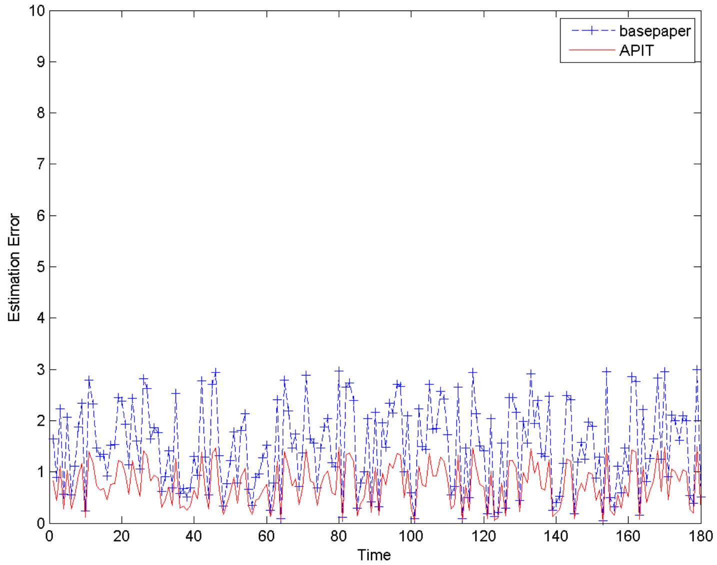

Fig: 8 Estimation Error with Respect to time compared with Base paper (blue) [5] and Proposed work scheme (red).

The authors have developed and proposed the mechanism and procedure to model the location estimation for object tracking in large-scale WSNs which uses range free positioning technology as well as centralized data. The designed modeling was a simple scheme without complex processing. They have uses MATLAB to conduct the simulation and numerical analyses to find the optimal modeling variables.

CONCLUSION AND FUTURE WORK

In the proposed work, we use the alteration based localization by using the least square distance method to reduce the estimation error of the position. It can provide about 92% of throughput with very less energy consumption. This research work was done on ground sensor network using Hop by Hop trace-back mechanisms which consider target's mobility only. In future, work can be done when sensor nodes are also mobile. This method is not suitable for handling underwater mobility due to 3d nature of underground sensor network. We can take on Underwater Acoustic Sensor Networks for more advancement in future.

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