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Connectivity Based Secure Cooperative Localization Scheme for Wireless Sensor Network

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Abstract:

Localization is one of the important areas of concern in wireless sensor networks. Effectiveness of any localization approach is based on the accuracy in determining the position of the nodes that are unaware about their position in the area of their deployment. One of the prime factors that play its part is the security of the localization approach so that it reduces or diminishes the effect of various attacks on the localization process. So this paper conveys a new approach for secure localization based on the authentication of the nodes that assists in location determination along with the consideration of mobility of nodes as one of the prime factor.

Keywords **—AOA, Elgamal, GPS, RSSI, TOA, TDOA, Trilateration.**

I. INTRODUCTION

WSN sensor nodes sense the target area and transmit the information to base station, now the information received by the sensor nodes is not useful if the location of sensor node is not known in case of ad-hoc deployment. So after deployment of the sensor nodes, nodes have to find out its location in the network is known as localization [1]. Localization means determine the exact position of an event or activity where it is occurring. In WSNs the sensor nodes who know there position are known as anchor node (Beacon nodes or Landmarks) and the nodes who have to find out its position are known as unknown nodes (Free or Dumb nodes) . To solve the problem of localization one method is to place all the sensor nodes manually, but this method will not work in case of large areas, dense forest, volcanoes areas. The another way is to connect all sensor with GPS (Global Positioning System) this method is very costly when huge number of sensing nodes are there in the network [2]. Because of size, power and cost limits of sensor nodes, accurate and efficient algorithm has become a hot research field. Moreover security is the prime factor in case of localization process on account of various adversaries that may be present in the network and cause to false determination of the node position and thus compromised the whole localization process. This paper depicts the process of localization and also suggested a new signature based secure localization algorithm for position determination.

II. LOCALIZATION PROCESS

The exact position of the sensor nodes is determined with three steps as mention here:

Distance or Angle Estimation:-In this nodes determine the distance or angle with the anchor nodes.

Position Computation:-From above step with the help of the distance or angle calculate position.

Localization Algorithm:-This will help to find out the position of other sensor nodes by using available information.

Moreover there are three categories of location measurement techniques like Triangulation, Trilateration and Multilateration.

III. LOCALIZATION SCHEMES

Localization Algorithms [3] are categorised into four parts:

GPS Basis /GPS free:-In GPS basis scheme every sensor node is connected with GPS, this scheme provide the accurate position of every node. But to connect every node with GPS is not possible, reason is GPS communicate in line of sight so due to the obstacles in the path if take the density of plants the GPS will not work and the another reason is GPS increase the cost of the network. In GPS free unknown nodes who have to find out there position will use the anchor nodes to determine there position in the network [1].

Anchor Basis /Anchor free:-In anchor based scheme few of the nodes already knows its position because these nodes are placed by hand or connected with GPS [3]. Anchor nodes start the localization process to find out the location of other unknown nodes. Accuracy in anchor based scheme depends on the amount of anchor nodes. On the another hand anchor free scheme use neighbour distance information to find out the position of the unknown nodes when there is no any anchor node [3].

Centralized /Distributed :- In centralized scheme all the nodes depends on the sink node, another nodes no need to perform any calculations because all the communications are performed via sink node that perform all the calculations for the nodes. The advantage is it provides the more accuracy [3]. In distributed scheme all the nodes perform the calculations all the nodes perform localization algorithm and error increases [3].

Range Based/Range free:-Different types of method are available to find out estimate of distance/angle between the nodes to calculate the position of the nodes. These estimates should be accurate because this information is used to calculate the position of the nodes and in localization algorithm. The various methods to find out the estimate of distance/angle are:- (i) RSSI (Received Signal Strength Indication) (ii) TOA (Time of Arrival) (iii) TDOA (Time difference of Arrival) (iv) AOA (Angle of Arrival). Range free method uses some anchor nodes to find the location of the node [4]. Although the range free method yield less accurate result as compare to range based even then range free methods are used due to the less cost and these are appropriate for large network . Much work has been done in the field related to various localization schemes and algorithms [5,6,7,8].

IV. PROPOSED SECURE LOCALIZATION APPROACH

Network Deployment: First step is to deploy 100 sensor nodes in a area of 100*100m in mat lab environment. Let {A} denotes the set of anchor nodes and {U} denotes the set of unknown sensor nodes.

n (A) = number of anchor nodes

n (U) = number of unknown nodes

Initially, n (A) =10 and n(U) = 90

initially the anchor percentage is 10%. The algorithm can be repeated for different ratio of anchors to study the comparison of results obtained

{ A} = { A_1, A_2,A_3……A_{10}}

{ U} = { U_1, U_2, U_3……U_{90}}

Radio range R = 8.94 m

Sensor nodes will be deployed using **Gaussian distribution** as mention below

$$f(x;\mu,\sigma)=\frac{1}{\sqrt{2\pi}\sigma}\exp\{-\frac{(x-\mu)^2}{2\sigma^2}\}$$

The distribution is denoted by $N(\mu,\sigma)$, It can be shown σ^2 is the variance of x (σ is the standard deviation of x) and μ is the **median or mean .**

Mobility Model: Once the nodes are deployed the mobility can be model as Gauss Markov model or Random Wave point model where $\sigma = 1$.

Velocity and direction at any instant can be fixed based on the model choose for the implementation. So mobility of nodes is the new thing which is introduced in this algorithm which is not taken care much in most of the previous implementations.

Security Integration: Anchors Aj Є {A} broadcast beacon periodically and U_i will receive the beacon if $A_{ij} \leq$ 8.94m. Beacon will contain the location of anchor A_j along with other details such as ID_s.

Introducing Authentication using the ElGamal Digital Signature Scheme

Key generation Routine:-

p = large prime number of field Zp^*

e_1 = generator of Z < p,*>

1. Each anchor Aj € {A} selects a private key 'd' using following subroutines:-

   Select random d

   If (d< p-1)

   Proceed to 2

   Else

   Choose d < p-1.
2. Compute $e_2 = e_1^d \bmod p$

Anchor public key triad is (e_1, e_2, p)

Signature Routine:-

1. Aj € {A} choose a secret random number 'r'(Each time for a new algorithm)
2. Compute $S_1=e_1^r \bmod p$ // **First signature**
3. Compute $S_2=(M - d * S_1) * r^{-1} \bmod(p-1)$ // **2nd signature**

// Here the 'M' can either be ID of the anchor node or it can be concatenated bit string representing X and Y coordinate of Anchor A_j , separated by the delimiter 10101010

Example if A_j is (3, 5)

M = …… 011 10101010…….101

4. A_j sends M_1, S_1,S_2 to each U_i € {U}in its radio range R = 8.94m

Verification Routine:-

1. U_i checks if $0<S_1<p$
2. U_i checks if $0< S_2< p-1$ using following subroutine

   If (S2 < p-1)

   Proceed to step 3

   Else

   Discard

   Exit
3. U_i computes

   $V_1= e_1^M \bmod p$

   $V_2= e_2^{S1} * S_1^{S2} \bmod p$
4. If (V_1== V_2)

   Accept M

   Else

   Discard

Position Estimation:

U_i € {U} selects 3anchors from which it had heard. The selection of anchors will be based on Euclidean distance. The three anchors having the least Euclidean distance will be selected. Other considerations such as energy dissipation can also be taken in to account. However since we are already modelling the mobility, authentication, energy computation might increase the time complexity.

Illustration for Position Estimation:-

Suppose Ui selects three anchors naming A_k, A_l, A_m with positions (x_k, y_k) , (x_l, y_l) and (x_m, y_m) . The position of unknown node can be computed using trilateration.

Assume the coordinates of unknown node 'N' is (x', y'). Then based on the working of the trilateration approach for the location determination following steps is to be executed:

$(x'-x_k)^2 + (y'-y_k)^2 = d^2_{k,N}$

$(x'-x_l)^2 + (y'-y_l)^2 = d^2_{l,N}$

$(x'-x_m)^2 + (y'-y_m)^2 = d^2_{m,N}$

$$N_{<k,l,m>} = \begin{bmatrix} x_{k,l,m} \\ y_{k,l,m} \end{bmatrix} = C^{-1}B$$

$$C^{-1} = -2 * \begin{bmatrix} x_k - x_m & y_k - y_m \\ x_l - x_m & y_l - y_m \end{bmatrix}$$

$$B = \begin{bmatrix} d^2_{k,N} - d^2_{m,N} - x^2_k - y^2_k + x^2_m + y^2_m \\ d^2_{l,N} - d^2_{m,N} - x^2_l - y^2_l + x^2_m + y^2_m \end{bmatrix}$$

Cooperative Localization:-

Once the U_i € {U} gets localized, for next iteration or subsequent localization, it will act as a anchor node and undergoes operations mention below

n(A) = n(A) + C

n(U) = n(U) – C , C is the number of unknown sensors that are localized in the iteration 'i'.

For i = 1 to C

Add U_i ($1 \le i \le C$) to {A}

Remove U_i ($1 \le i \le C$) from {U}

End loop

Update {A}

Update {U}

Repeat the steps 1 to 5 till {U} =1

n (U) = 0.

V. CONCLUSION

Localization in WSN is very challenging task in form of estimating the accurate position of node. The new proposed algorithm will reduce the distance error, because localization of sensor node is depended on the distance between the nodes, distance error have huge impact in the localization of the node. Proposed algorithm has the capabilities of authentication of the nodes prior to their usage in the location determination and thus may leads to more accurate values of position coordinates for location determination of unknown nodes even in the presence of malicious nodes.

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