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ANALYSIS OF NODE DENSITY PARAMETER TO DETERMINE RANGE ESTIMATES IN WSNs USING RSSI METHOD

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ABSTRACT

In recent years, Wireless Sensor Networks (WSNs) has predominantly emerged as one of the leading technologies with research interests. In a broad spectrum, WSNs are extensively applicable in monitoring, controlling and surveillance areas. In all these areas of application, the need to determine the range estimates and the number of sensor nodes required is of paramount importance to minimize localization errors computed by RMSE. The parameters that affect localization- Node density (Number of Nodes), Anchor Nodes and Communication Range are considered. In this study, simulation analysis for determination of range estimates using RSSI method is computed using MATLAB.

Key words - WSNs-Wireless Sensor Networks, NN-Number of Nodes, AN-Anchor Nodes, CR-Communication Range, RSSI-Received Signal Strength Indicator, RMSE-Root Mean Square Error.

1. INTRODUCTION:

A WSN can be defined as a network of devices that can communicate the information gathered from a mentioned field through wireless links. Precise location information of sensor nodes is critical for the success of WSN applications and for providing efficient service to the end users. Since in most of the applications, the sensors are deployed randomly, the position of the sensors is unknown and must be estimated by localization techniques. Localization in sensor networks is to identify the location or position of the sensor nodes which are deployed randomly in the area of application (Cheng et al., 2012). Many localization techniques have been proposed to provide location information of the unknown sensor nodes in WSNs. Broadly, localization techniques are divided into two categories: Range based and Range free methods. In range based method, the location of the sensor node can be determined by distance or angle estimates. These methods include Time of Arrival (ToA), Time Difference of Arrival (TDoA), Angle of

Arrival (AoA) and Received Signal Strength Indicator (RSSI). The location information provided by these methods is accurate but requires additional hardware for computation which results in increase of bulkiness and cost of the device. In range-free method, the location of the sensor is estimated on the basis of hop information. APIT, DV-Hop and Centroid are some of the methods. The advantage of these methods is that they do not require any additional hardware and hence are cost effective and consume less energy (Amitangshu Pal, 2010).

1.1. Stages in Localization

In WSN, estimating the exact position of sensor node is an important research problem and its location accuracy impacts the efficiency of localization algorithms. There are three different stages in localization, they are: (i) distance/angle estimation between the nodes, (ii) position computation of a single node, (iii) a localization algorithm - used for localization of whole network (Amitangshu Pal, 2010), Different techniques with varying accuracy and complexity exist at each stage.

(i) Distance/Angle Estimation: This refers to the measurement of distance or angle between the transmitter and receiver node. Distance/Angle estimation is the pre-requisite for remaining two phases of localization. Different techniques for distance/angle estimation include - Time of Arrival (ToA), Time Difference of Arrival (TDoA), Received Signal Strength Indicator (RSSI) and Angle of Arrival (AoA).

(ii) Position Calculation: Due to various constraints, existing localization systems, such as GPS, cannot be used for the localization of wireless sensor nodes. After the initial calculation of a nodes distance or angle estimation, -its own position can be calculated or computed using any one of the methods such as-trilateration, multilateration, triangulation, probabilistic approaches and the central position. The choice of which method is applicable for a particular application depends upon the information available and the processors limitations (Boukerche et al., 2007).

(iii) Localization algorithm: Localization algorithm is the last and most important stage of localization system. It utilizes the information collected in previous two stages. It defines how this information can be transformed to localize sensor nodes cooperatively. Mostly, accuracy of this stage is affected by the ranging method, deployment environment, and the relative geometry of unknown nodes to the anchor nodes. Broadly, localization algorithms in WSNs can be divided into two categories: (*i*) *Centralized*, and (*ii*) *Distributed*.

Centralized localization requires the migration of internode ranging and connectivity data to a sufficiently powerful central base station. Centralization is much more complex than a distributed setting. On the basis of ranging method used, localization algorithms for WSNs can be broadly categorized into two types: (*i*) R*ange based localization*, and (*ii*) R*ange free localization*. Range based localization algorithms use the range – distance or angle information from the beacon node to estimate the location. Several ranging techniques exist to estimate an unknown node distance to three or more beacon nodes. Based on the range information, location of a node is determined. Some of the range based localization algorithm includes: Received signal strength indicator (RSSI), Angle of arrival (AoA), Time of arrival (ToA) (Li et al., 2004), Time difference of arrival (TDoA). Range-free localization algorithms use connectivity information between unknown node and landmarks. A landmark can obtain its location information using GPS or through an artificially deployed information. Some of the range-free localization algorithm includes: Centroid, Appropriate point in triangle (APIT) and DV-HOP (Wang et al., 2009).

In the experiment, simulation of range based method using received signal strength is considered for sensor nodes localization. The measured range in the above mentioned methods are based on the establishment of mathematical models (Patwari et al., 2005). The localization algorithm, adaptive information estimation strategy is proposed in which, the unknown sensors are localized by an estimator that includes pair wise measurements between all the sensors in the network. The determination of range estimates is computed and plotted against the RMSE (Ruz et al., 2019).

2. METHODOLOGY:

AIES-RSSI Algorithm- In the Adaptive Information Estimation Strategy methodology, sensors work together in a peer-to-peer manner and pairwise measurements are made. Also, an estimator estimates all positions of the sensor nodes. Measurements between any pairs of sensors aids the location estimate and enhances the accuracy of the localization system. By means of statistical models based on the pairwise measurements, distances can be estimated. The distance error added to the true pairwise distances can be based on a statistical model for RSSI. The AIES-RSSI methodology is divided into two modules-

2.1. Module 1: WSN Deployment

2.2. Module 2: RSSI statistical model implementation with AIES

2.1. MODULE 1: WSN DEPLOYMENT

Number of anchor nodes and unknown nodes are specified. The coordinates of each node is generated randomly and the communication between one node to other is defined to obtain the set of nodes within the communication range to form subset of WSN.

Step 1: Specify the number of anchor nodes and unknown nodes

Step 2: Randomly generate the coordinates value (x,y) of defined number of nodes

Step 3: Define the communication range

Step 4: Deployment of nodes for WSN

Step 5: Filter the nodes having more than the communication range to form the subset of nodes.

Step 6: Connected WSN

2.2. MODULE 2: RSSI STATISTICAL MODEL IMPLEMENTATION WITH AIES

RSSI estimates the distance traversed by a signal to the receiver by measuring the power of received signal. Radio signal attenuates as the distance between the transmitter and receiver increases. With the increase in distance, strength of radio signal decreases exponentially. The attenuation in signal strength is measured by the receivers received signal strength indicator (RSSI) circuit. The advantages of this method is that it requires no additional hardware and the energy consumption, sensor size and cost does not affect the functioning of the WSN. The main disadvantage being that it is sussceptible to interference and noise. A radio propagation model ideally predicts the distance d as in equation (1),

$$\bar{P}(d) = P_0 - 10 n_p \log \frac{d}{d_0}, \quad \text{-------------} \quad (1)$$

Where P_o is the received power in dBm at a short reference distance d_o. The log-normal model is based on measurement results and analytical analysis (Rasool & Kemp, 2013). The standard deviation of the received power is expressed as σ_{dB} , it is relatively constant with disatnce and has a low of two and a high of four. Thus, the received power at *i*, when transmitted by a sensor *j*, $P_{i,j}$ is represented as in equation (2),

$$f(P_{i,j}=p \mid \Theta) = N(p; P(d_{i,j}), \sigma_{dB}^2) \text{ ------------ } (2)$$

where $P(d_{i,j})$ is the mean and σ_{dB}^2 is the variance.

From the log-normal model the variance determined are proportional to the distances.

The actual transmitter – reciever seperation distance $d_{i,j}$ is given by equation (3),

$$d_{i,j} = \sqrt{(x_i-x_j)^2 + (y_i-y_j)^2} \text{ ----------- } (3)$$

Lastly, the computation of the RMSE is achieved to determine the localization performance as in equation (4),

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(Loc_{real}^{i} - Loc_{est}^{i})^2}{n}} \text{ ----------- } (4)$$

Algorithm :

Step 1: Deployment of Sensor nodes

Step 2: Selection of subset

Step 3:Representation of received power using RSSI model

Step 4: Estimation of Θ-variances are determined

Step 5: Calculation of Fisher Information Submatrices

Step 6: Merge Submatrices to form the FIM

Step 7: Invert FIM to obtain variance of the estimators.

Step 8: Compute RMSE

3. SIMULATION RESULTS:

To determine the range estimates, simulation using MATLAB is considered by varying the network parameters that affect the localization error - RMSE.

The parameters that affect localization are -

3.1. NODE DENSITY (NN) These are the total number of nodes in a network, and in this simulation study they are varied from 10 to 1000 nodes.

3.2. ANCHOR NODES (AN) These are the nodes whose location is known and are deployed grid-wise; they are varied from 3 to 20.

3.3. COMMUNICATION RANGE (CR) This is the range or the propagation distance to the rest of the nodes. It is varied from 5 to 50.

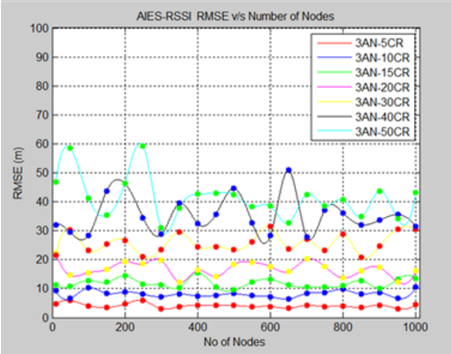
In this study, considering NN which is a parameter which affects localization-By varying NN in the range 10 to 1000 and keeping the ANs and CRs as constants – a set of graphs - No. of Nodes Vs RMSE are plotted Graphs.

Case 1: Considering AN=3 and varying CR=5,10,15,20,30,40,50, a set of values by varying NN and the corresponding RMSE values are tabulated in table 1.

Table 1. Consolidated values for AN=3 and varying CR=5,10,15,20,30,40,50

Sl. No.	AN=3	RMSE						
	NN	C-R=5	C-R=10	C-R=15	C-R=20	C-R=30	C-R=40	C-R=50
1.	10	4.689823	9.379647	11.222919	22.293520	21.639575	32.081579	46.898234
2.	50	5.850683	6.621864	10.778320	14.613407	30.396069	29.486182	58.506831
3.	100	4.129315	10.332925	12.844453	15.539755	23.182152	28.389982	41.293148
4.	150	3.528408	8.419622	12.169192	16.564998	25.384151	43.711966	35.284083
5.	200	4.644475	8.838858	14.456028	19.388504	26.712344	46.361579	46.444750
6.	250	5.934898	8.131369	11.657202	18.494193	20.977518	34.527011	59.348978
7.	300	3.099903	7.219092	11.316567	19.778157	23.387240	28.720971	30.999033
8.	350	3.785846	8.173923	10.352421	12.223201	29.490595	39.505365	37.858462
9.	400	4.263560	7.445523	15.533493	16.327953	24.395727	32.533335	42.635596
10.	450	4.301457	7.709474	10.689130	14.113746	24.484259	35.629348	43.014574
11.	500	4.249854	8.309317	9.543640	18.347678	23.432651	44.563495	42.498536
12.	550	3.825277	7.572370	12.214504	19.195183	26.235732	32.822879	38.252774
13.	600	3.853955	7.227446	13.232110	17.646440	31.396238	28.314040	38.539547
14.	650	3.278519	6.451693	11.224708	15.888734	23.709346	50.965545	32.785187
15.	700	4.254227	8.719034	10.530592	20.194651	27.203561	27.908908	42.542270
16.	750	3.864141	8.352778	10.574815	17.711039	23.335098	37.210648	38.641410
17.	800	4.067999	9.737915	11.050698	13.696462	28.926874	36.222293	40.679991
18.	850	3.483938	6.638761	12.710891	16.060501	20.877824	32.069251	34.839382
19.	900	4.370296	8.672254	10.190921	17.394510	24.654388	33.598085	35.272181
20.	950	3.142395	8.100096	13.179737	12.382364	30.558395	35.544245	34.092676
21.	1000	4.468398	10.535057	13.533628	16.086724	30.486163	31.497493	36.368345

Corresponding plot of NN v/s RMSE of the table 1 is depicted below in graph 1.



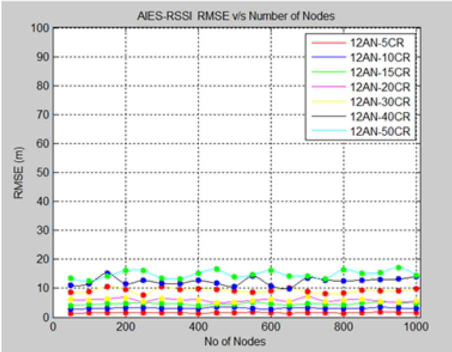
Graph 1. Plot of NN v/s RMSE for AN=3 and varying CR=5,10,15,20,30,40,50

Case 2: Considering AN=12 and varying CR=5,10,15,20,30,40,50, a set of values by varying NN and the corresponding RMSE values are tabulated in table 2.

Table 2. Consolidated values for AN=12 and varying CR=5,10,15,20,30,40,50

Sl.	AN=12	RMSE						
No.	NN	C-R=5	C-R=10	C-R=15	C-R=20	C-R=30	C-R=40	C-R=50
1.	50	1.371113	2.742226	4.113339	6.088284	8.663080	11.082179	13.576259
2.	100	1.483444	2.966888	4.450331	6.064067	8.769889	11.546806	12.458551
3.	150	1.560272	3.120545	4.680817	6.387373	10.663244	15.233605	14.234392
4.	200	1.617797	3.235595	4.853392	6.792680	9.684760	11.621622	16.070909
5.	250	1.682225	3.364450	5.046675	5.397556	7.659911	12.698596	16.100754
6.	300	1.556320	3.112639	4.668959	6.506198	10.653238	11.703363	13.555042
7.	350	1.562282	3.124564	4.686846	6.019843	9.536986	11.626046	13.356263
8.	400	1.352442	2.979788	4.057325	6.071014	9.945431	12.707025	15.218667
9.	450	1.523324	3.621493	4.569972	5.029150	9.564599	11.698244	16.550953
10.	500	1.475236	3.415614	4.425709	5.335775	9.096589	10.677619	13.917808
11.	550	1.759537	3.040052	5.278611	5.798858	8.721680	14.151370	14.651373
12.	600	1.551961	2.801161	4.655884	6.264874	9.179344	10.937802	16.219288
13.	650	1.438043	3.358684	4.314128	5.504929	10.111201	9.924933	14.278645
14.	700	1.542972	3.309309	4.628917	7.057323	8.876028	13.619087	14.311271
15.	750	1.537351	3.008443	4.612054	5.506233	8.120688	12.877629	13.319886
16.	800	1.450256	2.951754	4.350767	6.000280	8.290222	12.471457	16.531969
17.	850	1.640725	3.011142	4.922174	6.195034	9.288669	12.819675	15.185577
18.	900	1.722597	3.445809	5.167792	5.545514	9.166835	12.955368	15.419280
19.	950	1.700299	3.219503	5.100897	5.177055	9.218885	13.143830	17.152520
20.	1000	1.597368	2.955384	4.792104	5.648881	9.779457	14.110200	14.356205

Corresponding plot of NN v/s RMSE of the table 2 is depicted below in graph 2.



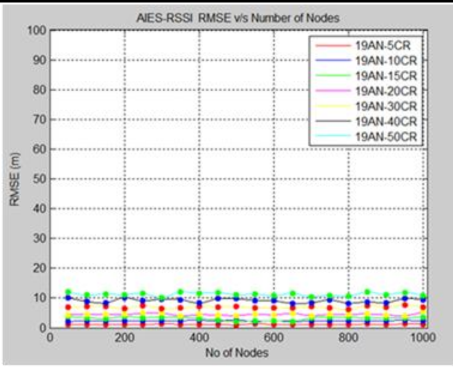
Graph 2. Plot of NN v/s RMSE for AN=12 and varying CR=5,10,15,20,30,40,50

Case 3: Considering AN=19 and varying CR=5,10,15,20,30,40,50, a set of values by varying NN and the corresponding RMSE values are tabulated in table 3.

Table 3. Consolidated values for AN=19 and varying CR=5,10,15,20,30,40,50

Sl.	**AN=19**	**RMSE**						
No.	NN	C-R=5	C-R=10	C-R=15	C-R=20	C-R=30	C-R=40	C-R=50
1.	50	1.151680	2.120921	3.793668	4.366354	5.864322	10.116447	12.024657
2.	100	1.031253	2.311409	3.340206	4.521250	6.189372	8.907217	10.992864
3.	150	1.164853	2.422101	3.118111	4.613888	6.491622	8.314964	11.391735
4.	200	1.108039	2.380194	3.800770	4.430136	5.643024	10.135386	11.092730
5.	250	1.119907	2.258717	3.381407	4.913114	6.022508	9.017084	11.587081
6.	300	1.264748	2.396634	3.626721	4.999565	5.766625	9.671257	10.126699
7.	350	1.190324	2.385223	3.557435	3.992938	6.296037	9.486494	11.957689
8.	400	1.174373	2.518563	3.109826	4.383286	6.118934	8.292871	11.639134
9.	450	1.139432	2.282072	2.619029	4.293861	6.024025	9.737583	11.834116
10.	500	0.944209	2.669067	2.110466	4.088831	6.135601	9.754586	11.121809
11.	550	1.349188	2.117465	2.295957	4.614315	5.293662	9.160147	11.252681
12.	600	1.127747	2.430473	2.355592	4.320955	6.076182	9.036559	10.827320
13.	650	1.203434	2.179286	2.123595	4.864805	5.448215	8.224421	11.537457
14.	700	1.170584	2.239350	3.281931	4.092940	5.598376	8.386665	10.421198
15.	750	1.213134	2.334241	3.537526	4.512915	5.835602	9.346246	10.936025
16.	800	1.093603	2.339662	3.538222	4.521961	5.526644	8.268584	10.542691
17.	850	1.240715	2.406165	3.270202	4.661068	6.117682	8.704743	12.030616
18.	900	1.051455	2.366701	3.225226	4.335255	5.512758	8.414364	11.105623
19.	950	1.285072	2.482360	3.284509	4.053207	5.096645	9.747692	11.889496
20.	1000	1.188520	2.209373	3.637135	5.418657	6.046156	9.290146	10.768745

Corresponding plot of NN v/s RMSE of the table 3 is depicted below in graph 3.



Graph 3. Plot of NN v/s RMSE for AN=19 and varying CR=5,10,15,20,30,40,50

From the above graphs, it is observed that as the number of nodes increases for different communication ranges, the RMSE values slightly changes but maintains an average value. Also, as the number of Anchor Nodes increases, RMSE values decreases for the corresponding communication ranges.

CONCLUSION

To estimate positions of sensor nodes for the evaluation of localization errors, the range based technique RSSI was employed. For the simulation results using MATLAB,various localization parameters are considered like sensor nodes deployment area, number of nodes to be deployed, number of anchor nodes and communication range. Since localization error is the deviation of the estimated node location from the actual node location, the metric RMSE was computed as represented. Using the statistical RSSI model based on the pairwise measurements, distances are estimated. Case studies- for different ANs and CRs were considered and graphs for NNs versus RMSE are plotted. The simulation results using MATLAB indicate an optimization of NNs to maintain an average RMSE error for different scenarios, to determine range estimates using RSSI. This indicates minimization in localization errors of the sensor nodes used in the wireless sensor network.

References

1. Amitangshu Pal. (2010). Localization algorithms in wireless sensor networks: Current approaches and future challenges. *Network Protocols and Algorithms*. 2(1), 45-73.
2. Boukerche, A., Oliveira, H.A.B.F., Nakamura, E.F., & Loureiro, A.A.F. (2007). Localization systems for wireless sensor networks. *IEEE Wireless Communications*, 14(6), 6-12.
3. Cheng, L., Wu, C., Zhang, Y., Wu, H., Li, M., & Maple, C. (2012). A survey of localization in wireless sensor network. *International Journal of Distributed Sensor Networks*, Volume. 2012, Article ID 962523. pp.1-12. doi.10.1155/2012/962523
4. Li, X., Shi, H., & Shang, Y. (2004). A Partial-Range-Aware Localization Algorithm for Ad-hoc Wireless Sensor Networks. *Proceedings of the 29th Annual IEEE International Conference on Local Computer Networks, LCN* '04. pp. 1-7. doi:10.1109/LCN.2004.8

5. Ewa Niewiadomska-Szynkiewicz. (2012). Localization in wireless sensor networks: Classification and evaluation of techniques. *International Journal of Applied Mathematics and Computer Science*, 22(2), 281-297. doi.10.2478/v10006-012-0021-x
6. Wang, Y., Wang, X., Wang, D., & Agrawal, D.P. (2009). Range-Free Localization Using Expected Hop Progress In Wireless Sensor Networks. *IEEE Transactions on Parallel and Distributed Systems*, 20(10), 1540-1552. doi:10.1109/TPDS.2008.239
7. Niculescu, D., & Nath, B. (2003b). Localized positioning in ad-hoc networks. *Proceedings of the 1st IEEE International Workshop on Sensor Network Protocols and Applications, Anchorage*, AK, USA. pp. 42-50. doi.10.1109/SNPA.2003.1203355
8. Pandey, S., & Varma, S. (2016). A range based localization system in multihop wireless sensor networks: A distributed cooperative approach. *Wireless Personal Communications*, 86, 615-634. doi.10.1007/s11277-015-2948-3
9. Patwari, N., Ash, J.N., Kyperountas, S., Hero, A.O., Moses, R.L., & Correal, N.S. (2005). Locating the nodes: Cooperative localization in wireless sensor networks. *IEEE Signal Processing Magazine*, 22(4), 54-69. doi.10.1109/MSP.2005.1458287
10. Paul, A.K., & Sato, T. (2017). Localization in wireless sensor networks: A survey on algorithms, measurement techniques, applications and challenges. *Journal of Sensor and Actuator Networks*, 6(4), 24. doi:10.3390/jsan6040024
11. Rasool, I., & Kemp, A.H. (2013). Statistical analysis of wireless sensor network gaussian range estimation errors. *IET Wireless Sensor Systems*, 3(1), 57-68. doi.10.1049/iet-wss.2012.0073
12. Ruz, M.L., Garrido, J., Jimenez, J., Virrankoski, R., & Vazquez, F. (2019). Simulation tool for the analysis of cooperative localization algorithms for wireless sensor networks. *Sensors*, 19(13), 2866. doi:10.3390/s19132866