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A Novel Technique for Beacon Localization in Indoor Environments

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Abstract— **In a typical localization technique, beacon nodes whose locations are known apriori, act as reference in estimating the location of user nodes. Placement of these beacons in the indoor environments has strong impact on the quality of the localization technique. When the operating environment is an indoor environment such as an office or building, the placement of beacons is very important due to the presence of obstructions which often result in non-uniform signal propagation error and self interference of beacon nodes. Besides, the structure of indoor environment keeps changing with time, affecting the beacon infrastructure. Readjustment of beacon nodes is time consuming and might interrupt the localization service. Hence, it is ideal to minimize the number of readjustments of the beacon nodes as far as possible. To address this issue, we propose an algorithm to minimize the number of the readjustments of beacon nodes and the interruption in localization service.**

Keywords— **Wireless sensor network, Beacon nodes, User nodes, Localization system, Network devices.**

I. INTRODUCTION

Wireless sensor networks (WSNs) are developed for monitoring a host for environmental characteristics across the area of deployment, such as temperature, sound, light, pressure, electromagnetic field, vibration and others. Most of these gathered data in these type of networks have the characteristic, such that all the information is useful only when we know the context and the position of the data. So, most of the sensor data will be stamped with the position information. Typical applications of WSNs include monitoring, tracking, and controlling. Some of the specific applications are habitat monitoring, object tracking, nuclear reactor controlling, fire detection, traffic monitoring, etc[1]-[4].

In WSNs, we have two types of nodes named as beacon nodes and user nodes, where the beacon nodes positions are known and user nodes positions are unknown in the network. Perhaps the most important aspect of sensor networks that differentiates them from other networks is their aim. Generally sensor network's object is monitor a signal and tells to the sink or central base station. Since a sensor network is distributed for achieving a certain system-wide goal nodes collaborate instead of competing with each other. That if every nodes communication range has limited then they use a technique to send their data to the central i.e. sink called multi hop communication. This requires a routing strategy that ensures that the battery energy as well as the throughput is optimized in such a way that the duration of the correct functioning of the entire network, i.e., the network lifetime, is maximized [17]. So then all the nodes combined to archive a system-wide objective.

A typical wireless sensor network environment with beacon nodes in an indoor environment would have the beacon no des placed uniformly so as to optimize the number of beacon nodes for a given level of acceptable localization error. Incidentally, the building infrastructure would be subject to changes in which case the localization error might be very high in a few areas. The beacon node placement would also be non-optimal. Further, reorganization of the beacon nodes by regulating the level of the localization error would be a time consuming process. In the present work, a simple approach is proposed to move the beacon nodes efficiently which would optimize the movements of the beacon nodes and the number of beacons[6]-[9].

II. BEACON PLACEMENT APPROACH

We are using proximity based model to estimate the locality of user node, in which locality of user node can be defined as the communication region of all beacon no des it is hearing. There are two important factors that affect the locality of user node, one is beacon density and the other one is beacon placement [10]-[13].

A. Effect of Beacon Density on Localization

Consider Fig. 1, which shows the impact of density on localization technique in which shaded region represents the Locality of the user node. Fig. 1(a) and Fig. 1(b) show the locality when the number of beacons the user node is hearing is 3 and 6 respectively. It can be observed from these figures that if the beacon nodes increase then user node granularity decreases. Hence beacon density has significant impact on localization accuracy.

B. Effect of Beacon Placement on Localization

Placement of beacon nodes is also very important similar to the beacon density, from localization accuracy point of view. Consider Fig. 2, where we are having 3 beacon nodes. Fig. 2(a) and Fig. 2(b) depict the case where beacons are placed in a uniform and collinear manner respectively. The difference between the user node localities obtained in these cases can also be easily observed [14]-[15].

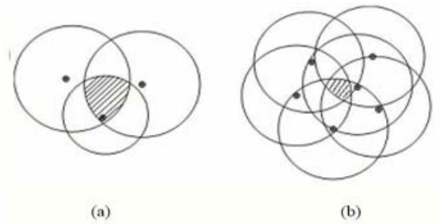

Fig. 1: Beacon density effect on localization.

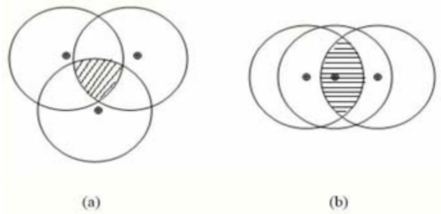

Fig. 2: Beacon placement effect on localization.

III. BEACON PLACEMENT ALGORITHMS

The goal of this algorithm is to determine candidate points for placement of an additional beacon, so as to maximize the gains obtained [18]. Generally it have two phases they are

1. UPP (Uniform Placement Phase)
2. AP (Augmentation Phase)

UPP is not enough to accomplish threshold degree condition in each and every pointing which effects in the bigness of the cells which are partially covered. Some more beacons are put in AP to enhance the coverage degree of these cells whose are partially covered. And we can find two problems in augmentation phase. Find out the cells whose are partially covered if they are existed in that then we find out their matching potential beacon cells. This is the first problem and the second one is pick a group of cells from that list where extra beacons should be placed so that all these cells are fully covered state. This problem decreases to adjust coverage problem. The approach which is used to solve this problem is greedy approach and in the later section we proposed an enhancement to this greedy approach which diminishes the required number of beacons.

A. Uniform Placement Phase

In this phase beacons are placed with threshold density. To find out this density for a given construction we need simulations to study the impact of beacon density on localization error presuming there are no obstacles on that construction by study the simulations we can say that beacon density is directly proportional to localization accuracy up to some rate and after the impact is minimal in this we can find out threshold density which is equal to saturation beacon density and by using equation p=n/a we can find out the number of beacons required for this phase by using random number generator we can find out the co –ordinates of this construction, where these beacons have to be directed. We can direct these beacons in those positions with the use of machine or by hand.

We can calculate the threshold degree by replacing the found threshold density in the formula $\mu_{thresh} = \rho_{thresh}.\Pi.R^2$.This beacon uniform infrastructure meets condition of threshold degree at each and every point if the environment is ideal. An ideal environment indicates absence of obstructions and visibility of the beacon to user node if and only if distance between them is less than the transmission range[5]. In case of practical situations like handling an obstructed environment some more beacons are add to this infrastructure in this AP (augmentation phase).

B. Augmentation Phase

1. Finding out the cells which are partially covered

To finds out the state of a cell coverage degree is used. To find the cells which are partially covered which are exists any we have to calculate this coverage degree for each and every cells .we can find out this one if we know the total amounts of beacons which are covered to the cell. If we know the cell position and beacon's positions placed in UPP (uniform placement phase), we can know that weather cell has covered by beacon or not by using formulae,

$$Pt\text{-}PL\ (d0)\text{-}10\eta\log\ (d/d0) - mi\ xi >= \rho_{thresh}.$$

For each and every cell which is partially covered we can find out their potential beacon cell by using above equation.

In the next section we explained in detail among all the potential beacon cells which one is selected to place additional beacons, so then each and every cell in a fully covered state.

2. Finding beacon cells by using Greedy algorithm

A group of cells has taken from potential beacon cells found in the earlier section to put the beacons so then they all converted to fully covered state. Based on the list of cells which are partially covered which indicated by the partially covered cells another list named potential beacon cell list has to be built indexed by the potential beacon cells in which each potential beacon cell contains all the cells which are partially covered that it can cover. Here our task is pick a group of potential beacon cells where we have to put extra beacons such that we have to increase coverage degree to threshold degree. We can say this in other words a subset of cells has to be selected from the given potential beacon cell list such that the list resulting from the union all operation of all lists corresponding to each of the selected potential beacon cell contains all the partially covered cells with a cardinality equal to the required coverage degree, where required coverage degree is difference between the threshold degree and current coverage degree of the cell. The overall problem has decreased to set cover problem which can be stated as fallows.

Let us take a universal set x and subsets set $y=\{y_1,y_2,y_3...y_n\}$ where everything in this set is sub to main x. The given problem is to pick a cover z which have small number of sets and union of all sets in that z is x.

Generally x contains all the cells which partially covered which cardinality is directly proportional to coverage degree and every potential beacon cell is attached by individual subset, which represents to lists by using greedy approach we can reduced our problem to set cover problem to put next beacon we can choose potential beacon cell as a candidate position. This covers maximum numbers of cells which are partially covered. This process has repeated again and again until we reach the goal i.e.; there is no cell which is in a state called partially covered state.

C. Enhancement of Greedy Algorithm:

To reduce the number of extra beacons we propose an enhancement to greedy approach by using greedy algorithm we can place redundant beacons. In this concept we will show an example where there redundancy occurs and then we have to make some changes in the greedy algorithm to avoid this redundancy.

In the potential beacon cell X_m is a potential beacon cell, which is used to cover a group of cells which are partially covered .we can define them Y_m and Z_m is their cardinality. X_i and X_j are their potential beacon cells down in the sorted order. and the group of cells which are covered them are Yi and YJ. These coordinates are Z_i and Z_j by based upon all these we can write some equations which are help full.

$$Z_i < Z_m, Z_j < Z_m$$
$$Y_i - Y_m \neq 0$$
$$Y_i \cup Y_j$$
$$Y_j - Y_m \neq 0$$

The first equation tells that X_i and X_j cardinality is less than X_m 's cardinality this means X_m proceeds X_j and X_i in the given list. The second equation tells that all the cells covered by beacon X_m is also covers any of the X_i or X_j which causes X_m is redundant. The last two equations said , potential beacon cells X_i and Xj cover some partially covered cells which cannot done by b_m. so from all this we can observed that these b_i and b_j are enough to make b_m redundant. Thus, there might exist instances which result in placement of redundant beacons with the application of greedy algorithm. So we need an enhancement to greedy algorithm to get rid of redundant placement. When the space between beacon and center point of cell is equal to r, then only the beacon can cover that cell. So the space between two beacons which cover the same cell is equal to 2r. So the possibility of redundant placement can be identified out by listing all the potential beacon cells that are preceding the cell which is at the top of the beacon cell list and these cells are at a distance 2r and they have to satisfy all above equations. If they satisfy all then they are at the top of the sorted beacon cell list and that is believed as redundant and we cannot put any beacon on that cell. So then by this we can assume that the required number of beacons decreased with this advanced greedy algorithm.

D. Proposed Algorithm:

The algorithm aims at reducing the interruption in the localization service and thus needs to minimize the number of replacements of beacons by minimizing the movements of the existing beacons. As we want to find the minimum replacements of the beacons, we have proposed an algorithm which will minimize the number of replacements of beacons with the help of the popularly known algorithm called closest pair of point's in a plane [16] algorithm. This closest pair of point's algorithm takes a set of points in a plane as input and returns the closest pair of points in the plane. Let us consider S1 as the set of beacon nodes which are already placed in the existing building infrastructure.

1. Now consider S2 as the set of beacon nodes that are to be placed for the modified building infrastructure with the density of ρ_{thresh} (The positions for this beacon node are calculated by using beacon placement algorithm [5]).
2. Merge the sets S1 and S2 and make it as set S3.
3. Define a distance ‘d’. If the Euclidean distance between the old beacon node and new beacon node is less than ‘d’ then we do not replace the old beacon node. If the Euclidean distance between the old beacon node and new beacon node is greater than `d' then we place the new beacon node at that point and remove the old one.

In each iteration we identify the closest pair of beacon points. If the two beacon points belong to different sets i.e., one beacon node is from the old building infrastructure and the other beacon node is from the new building infrastructure and they are separated by a distance of at most `d' then we do not need to replace the old beacon node by new beacon node. If the distance between the two beacon nodes is more than `d' then we replace the old beacon node with the new beacon node. If the two points are belonging to same set and the distance between the old beacon node and new beacon node is less than d and then there is a redundancy of beacon nodes and thus one of them can be ignored.

The proposed algorithm solves this problem in $O(n^2 \log n)$ time complexity.

$$T(n) = O(n).O(n\log n)$$

Where O(nlogn) is the time taken to identify the closest pair of points in a plane, and we repeat this process until the distance between two points is less than d. In the worst case, we need to find the all the n closest set of points, hence the time complexity of the algorithm is $O(n^2\log n)$. The algorithm is summarized as follows,

1. Let us consider S1 and S2 as the set of beacon nodes which are remaining beacon nodes that need to be modified in the old and new building infrastructure.
2. Do
(a) Consider each beacon node in S_2 and identify the closest beacon node in S_1 to move the old beacon node to the new beacon node position.
(b) If S_1 is empty before S_2 is empty then we can place new beacon nodes in the remaining S_2 positions.
(c) If S_2 is empty before S_1 is empty, then we can remove the beacon nodes from the positions in S_1.
3. Repeat this process until the set S_2 is empty.

IV. SIMULATION RESULTS

We have done simulation in MATLAB to simulate the working of the proposed algorithm. Size of the building was taken as 100×100 m^2 and beacons were placed by using the beacon placement algorithm. The communication range (R) of each beacon node is taken as

10 meters and the attenuation loss of each obstruction is assumed to be 5dB. The number of beacons estimated for the above building size (100 × 100 m2) was 400 (consider beacon density as 0.012). Consider two obstruction sets OBS1 and OBS2, which are randomly generated. We generate two random points and connect them to get an obstruction. These obstruction sets are imposed on the given building structure.

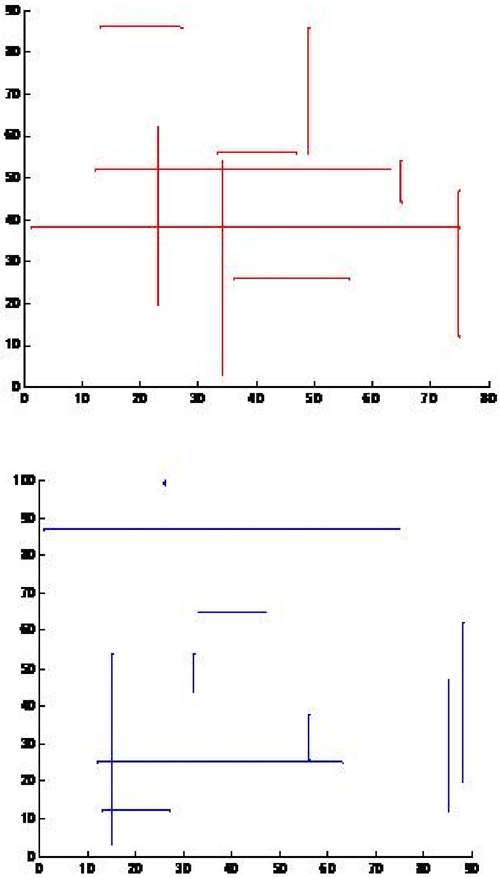

Fig. 3: Randomly generated two obstructions

Figure 3 shows the two obstructions generated randomly and are to be imposed on the building structure. Figure 4 shows the building with imposed obstructions. After imposing the obstruction sets OBS1 and OBS2 the corresponding numbers of beacons required have gone up to 472 and 437 respectively from 400. We consider 472 as old beacon set (S1) i.e. they are already placed in the existing building infrastructure and 437 as the new beacon set (S2) i.e. these are the positions at which beacons need to be placed in the modified building infrastructure.

After that we run the above algorithm on both the sets S1 and S2. Each time we find the closest points, we check the distance across these closest points and if this distance is less than d, then we do not place the new beacon node. The position of the old beacon node can be retained instead of the new beacon node. Otherwise, we move the beacon node from old position to new position. The table 1 shows the common points in both the sets. Here common points refer the points which are within the distance d. If distance increases, then the number of common points in both the sets also increases up to a point after which it remains stable.

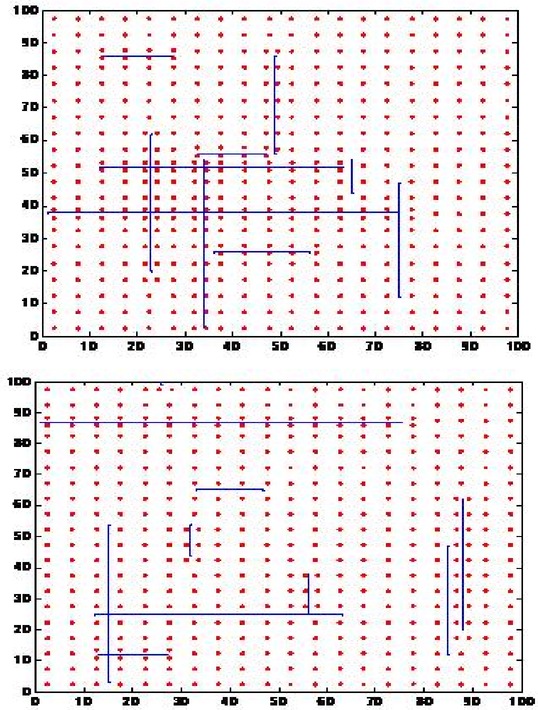

Fig. 4: Building structure after imposing the two obstructions.

Two sets of random data are generated and the closest pair of points algorithm is implemented on these two sets to find the closest pair of points. Figure 5 shows the output of the closest pair of points on a plane algorithm, where the points marked with blue color indicates the points in the two data sets and red color circle indicates the two points that closest among all the points in the two data sets.

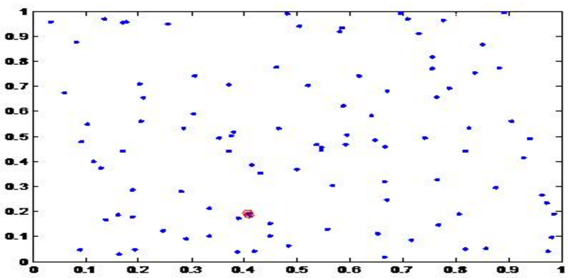

Fig. 5: Simulated result of closest pair of points algorithm.

Assuming a localization error of 0.872 is allowed, we allow a distance of up to 1 meter between the old and the new beacon nodes. As we increase the acceptable localization error rate, we can afford to allow more distance between the old and new beacon nodes. If the distance between the old and new beacon nodes is less than 1 meter then there is no need to position the new beacon nodes. However, if the distance is more than 1 meter we need to replace the beacons from its old beacon position to the new beacon position such that the distance moved by the old beacon node is minimum.

For each element of the set of beacons that are left over in the new beacon set we find the closest old beacon node position and move the corresponding old beacon node to the new beacon node position. Then, in case there are any beacon nodes left out, we remove all the remaining beacons in the set of old beacon nodes. Otherwise we can place new beacon nodes in the remaining positions.

Table 1: Distance Vs Common Beacon nodes in Two Environments.

Distance (in m)	Common beacon locations	Locations in B1	Locations in B2
0	310	162	127
0.5	339	133	88
1	400	72	37
1.5	407	65	30
2	407	65	30
2.5	409	63	28
3	410	62	27
3.5	410	62	27
4	410	62	27
4.5	410	62	27
5	409	61	26

Figure 7 shows the result of finding the closest beacon for each old beacon by applying the closest algorithm. Figure 7(a) indicates the beacons after imposing the two obstructions, Figure 7(b) shows the closest beacons for each old beacons i.e. between red and blue points in Figure 7(a). Figure 8(a) shows the remaining beacons in the building except the closest beacons and Figure 8(b) shows the beacons replacing the unnecessary beacons and placing the closest beacons.

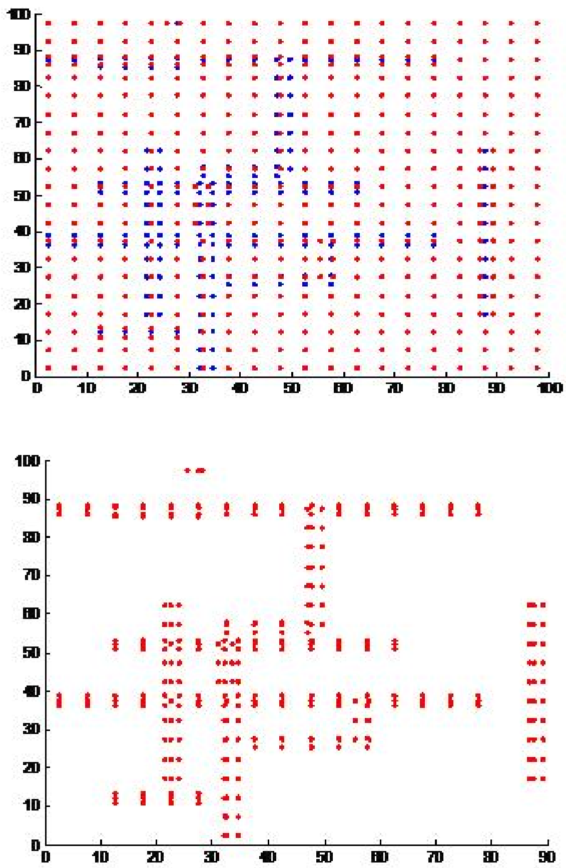

Fig. 7: Beacon positions after finding the closest beacons.

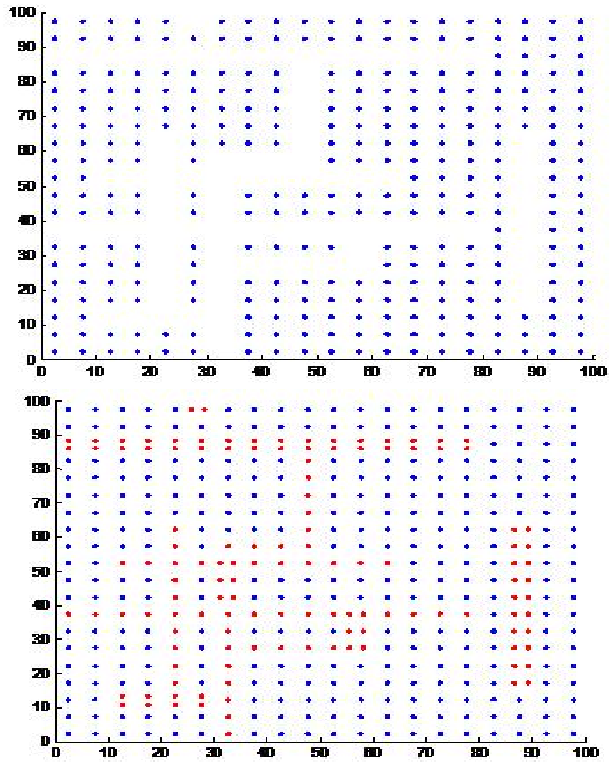

Fig. 8: Beacons in the building except the closest beacons and beacons replacing the unnecessary beacons and placing the closest beacons.

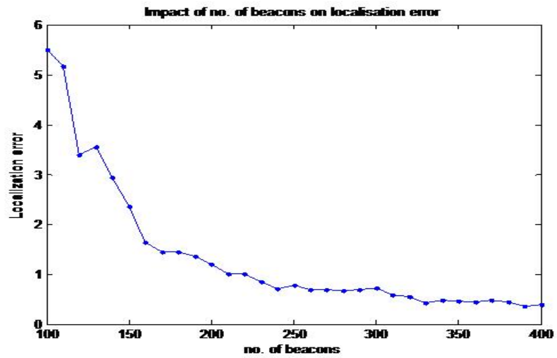

Fig. 9: Number of beacons Vs Localization error.

Figure 9 shows the impact of number of beacons on localization error. It shows if the beacon density (number of beacons) increases then the localization error decreases and saturate at some point. Initially the impact of beacon density on localization error was calculated under ideal conditions and the value of threshold density (ρ_{thresh}) was observed as 0.*012* [5].

A. Improvement in Algorithm

The Proposed algorithm worked with $O(n^2 \log n)$ time complexity. To reduce the time complexity in terms of number of computations we can divide the entire building layout into grids of a given size and we compare the corresponding grids in the old and new building structures.

In order to reduce the number of comparisons made, the building is partitioned into grids with respect to the old and new infrastructure and comparison is done across the grids instead of the whole building. Thus, with in a grid the time complexity remains $O(n^2 \log n)$ and the overall complexity reduces by a factor of the size of the grid if an appropriate size of the grid is chosen.

As shown in the table 2, the average deviation percentage for the 100 x 100 building infrastructure varies with the size of the grid. For this particular case, the error percentage is minimal for a grid size of 10 and then steadily increases for grid sizes greater than 10. This can be justified by the fact that the grid size of 10 would divide the indoor environment 100 x 100 m^2 into uniformly sized grids and in other cases, the size of the grids would differ which could increase the error rate.

Table 2: Deviation for different grid sizes

Grid Size (in m)	Deviation
8	0.0348
10	0.006
12	0.0138
14	0.0189
16	0.0264

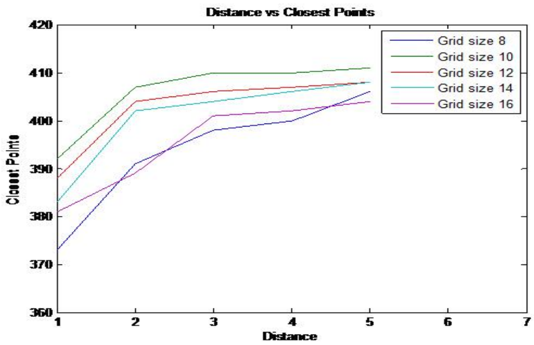

Fig. 10: Distance Vs Common Beacon node Positions for different grid sizes.

V. CONCLUSION

A typical wireless sensor network environment with beacon nodes in an indoor environment would have the beacon nodes placed uniformly so as to optimize the number of beacon nodes for a given level of acceptable localization error. Incidentally, the building infrastructure would be subject to changes in which case the localization error might be very high in a few areas. The beacon node placement would also be non-optimal. Further, reorganization of the beacon nodes by regulating the level of the localization error would be a time consuming process. In the present work, a simple approach is proposed to move the beacon nodes efficiently which would optimize the movements of the beacon nodes and the number of beacons.

REFERENCES

1. K. Pahlavan, X. Li, and J. Makela, “Indoor geolocation science and technology,” IEEE Communications Magazine, vol. 40, pp. 112-118, Feb 2002.
2. C. Savarese, J. Rabaey, and J. Beutel, “Robust positioning algorithms for distributed ad-hoc wireless sensor networks,” pp. 317-327, 2002.
3. P. Enge and P. Misra, “Special issue on global positioning system,” Proceedings of the IEEE, vol. 87, pp. 3-15, Jan 1999.
4. L. D. Chou, C. C. Lee, and C. Y. Lee, “A tour guide system for mobile learning in museums,” in WMTE '04: Proceedings of the 2nd IEEE International Workshop on Wireless and Mobile Technologies in Education (WMTE'04), (Washington, DC, USA), p. 195, IEEE Computer Society, 2004.
5. V. Sudha Rani and S. V Raghavan, “A Greedy approach to beacon placement for localization,” The First IFIP WIRELESS DAYS CONFERENCE, 2008.
6. R. Want, A. Hopper, F. Veronica, and J. Gibbons, “The active badge location system,” ACM Trans. Inf. Syst., vol. 10, no. 1, pp. 91-102, 1992.
7. A. Harter and A. Hopper, “A distributed location system for the active office,” Network, IEEE, vol. 8, pp. 62-70, Jan/Feb 1994.
8. A. Harter, A. Hopper, P. Steggles, A. Ward, and P. Webster, “The anatomy of a context- aware application,” in MobiCom '99: Proceedings of the 5th annual ACM/IEEE international conference on Mobile computing and networking, (New York, NY, USA), pp. 59-68, ACM, 1999.
9. N. B. Priyantha, A. Chakraborty, and H. Balakrishnan, “The cricket location-support system,” in MobiCom '00: Proceedings of the 6th annual international conference on Mobile computing and networking, (New York, NY, USA), pp. 32-43, ACM, 2000.
10. P. Bahl and V. Padmanabhan, “Radar: an in-building rf-based user location and tracking system,” vol. 2, pp. 775-784 vol.2, 2000.
11. A. M. Ladd, K. E. Bekris, A. Rudys, G. Marceau, L. E. Kavraki, and D. S. Wallach, “Robotics- based location sensing using wireless Ethernet,” in MobiCom '02: Proceedings of the 8th annual international conference on Mobile computing and networking, (New York, NY, USA), pp. 227- 238, ACM, 2002.
12. C. Savarese, J. M. Rabaey, and K. Langendoen, “Robust positioning algorithms for distributed ad-hoc wireless sensor networks,” in ATEC '02: Proceedings of the General Track of the annual conference on USENIX Annual Technical Conference, (Berkeley, CA, USA), pp. 317-327, USENIX Association, 2002.
13. A. Nasipuri and K. Li, “A directionality based location discovery scheme for wireless sensor networks,” in WSNA '02: Proceedings of the 1st ACM international workshop on Wireless sensor networks and applications, (New York, NY, USA), pp. 105-111, ACM, 2002.
14. T. He, C. Huang, B. M. Blum, J. A. Stankovic, and T. Abdelzaher, “Range-free localization schemes for large scale sensor networks,” in MobiCom '03: Proceedings of the 9th annual international conference on Mobile computing and networking, (New York, NY, USA), pp. 81-95, ACM Press, 2003.
15. V. Sudha Rani and S. V Raghavan, “Tail: Two-level approach for indoor localization,” The First IFIP International conference on Wireless Sensor and Actor Networks, 2007.
16. R. Cormen, Leiserson and Stein, Introduction to Algorithms. Mc.Graw-Hill, 2001.
17.Yingshuli, my T.thai,weili Wu (eds.), wireless sensor networks and applications, Springer, 2008.
18.Nirupama bulusu, JohnHiedemann, DeborahEstrin, Adaptive beacon placement, Distributed computing systems, April 2001.