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Heuristic Technique Based Sensor Node Localization for the Internet of Things

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Abstract*: Localizing a sensor node is one of the critical issue for wireless sensor networks and hence Internet of Things. For effective use and importance of data, the position, from where the data is originated, is very important for various applications. The number of methods has been developed for identifying the location of a sensor node in the network. One of the widely used methods is Multidimensional scaling. In this paper location of the sensor, the node has been identified with the algorithm using the heuristic technique. The heuristic technique is applied to calculate the distance matrix. To increase the accuracy distance approximation is used. It is mandatory to have an efficient, economic and scalable sensor node position estimation process, the results obtained, experimentally, proves the accuracy and effectiveness of the methods discussed for use in Internet of Things with variable topology and

***Index Terms*: Heuristic Technique, Internet of Things, Multidimensional Scaling, Wireless Sensor Networks.**

I. INTRODUCTION

A spatially dispersed and dedicated group of sensors for gathering information and transmitting them to a centralized location is a wireless sensor network [1]. The performance of wireless sensor networks depends upon, how accurately the position of a sensor can be estimated. Sensor nodes are used nowadays in almost every field like military applications, agriculture, traffic monitoring, etc [2]. The data captured by the sensors is useless until the position of a node is not identified. Identifying the sensor node position in the network is known as localization. The nodes in the network can be equipped with GPS, for accurate position's but it is a costly and power consuming option. The performance of the localization process depends upon various components like topology, node density, range, area, routing, etc. The network of physical things like vehicles, room, building, instruments, machine, etc. [5] equipped with sensors and capable of collecting and exchanging the data is called the Internet of Things [4]. The collected data are then converted into analog or digital data that can be processed for analysis of various features of the activities taking place in the network. The gathered information is transmitted to sink nodes [3]. The processed and analyzed data is then sent to the user's through the means of internet or satellite communication. Multidimensional scaling [9] is one of the forms of data analysis technique that has been used for various applications like research, marketing, mathematical computations, etc. MDS[10] helps in making the data more meaningful and data can be clustered and also the dimensionality of the data can be reduced. For localization of sensor nodes, MDS is an efficient process. The paper contents are as follows. Part 2, a brief introduction to WSN and IoT. Part 3, the Working process of multidimensional scaling. Part 4, heuristic technique based proposed algorithm. Part 5, results and Part 6, the paper is concluded with the outcomes.

II. WIRELESS SENSOR NETWORKS

The wireless sensor network[1] is formed by deploying a huge quantity of sensor nodes in the specified area randomly. The main purpose of the network is sensing the required parameter for any specific application[2]. Monitoring is also one of the utilization of the WSN. The data sensed by the nodes are used for further processing and hence for making decisions. The expense bearing capability of the individual or any group allows the use of large number of sensors for different applications as per the requirement. The WSN may work in centralized or in distributed manner and also the configuration of the network may be static or dynamic in nature. In centralized network all the sensors sends the collected data to a base station and in case of distributed the sensors are capable of doing the processing. The centralized structure is more durable and cost effective. Static configuration doesn't allow any scaling or movement of sensor nodes, where as in dynamic real time application requirements are fulfilled but again the issue of costing is there.

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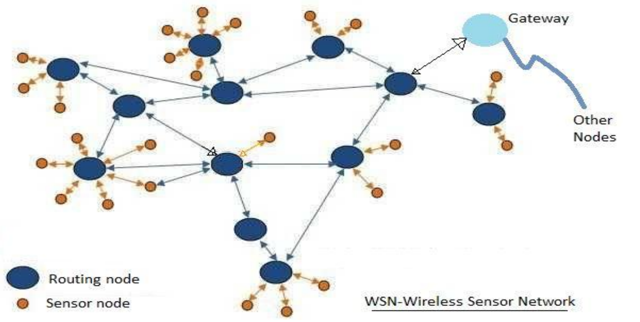

Fig. 1. Wireless Sensor Network

WSN [1] is used for observing physical and nonphysical conditions. Sensors are capable of gathering the data and transmitting them to sink for further processing. Transmission can be unidirectional and bidirectional. Now the sensor nodes are smart enough to perform the computation work, so that the work at the sink side can be reduced. The smart entities capable of sensing, processing and communication, deployed for any specific application is called Internet of Things. The technology Internet of Things [4] has a great impact over many areas of daily life namely education, agriculture, social life, etc [5]. The IoT helps in living a smart life in all circumstances. In IoT entities are capable of identifying the other entities or devices in the same proximity and also they can establish a healthy communication. These devices are capable of performing data aggregation and can also use the data provided by others or can add data to other services. Figure 1 shows that in IoT anything available in the given area, which can interact with internet can communicate with each other at any time stamp and hence forms a different and smart application capable of performing many task all together. It helps in achieving a great saving of resources, energy and the cost, and hence making the entire network economic. The IoT enabled devices can contribute in other applications also.

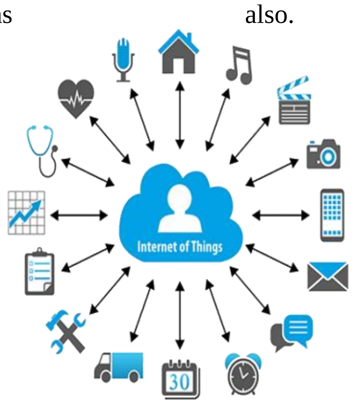

Fig. 2. Internet of Things

III. Localization Process

Localization is the most critical part of a WSN and IoT. Localization [3] is a process to obtain the positions of sensor nodes according to the data provided as input, which may be a relative or absolute position of nodes. Different techniques [3][4] were used for localization like range free[17], range based[18], neural network[19], multidimensional scaling[9-11], etc., to obtain the relative positions and the absolute positions of nodes. localization is performed in two steps:

1. In the first step the nodes estimate their relative positions using anchor nodes[8] or any other such reference points and
2. In the second step, the absolute location of the nodes is estimated.

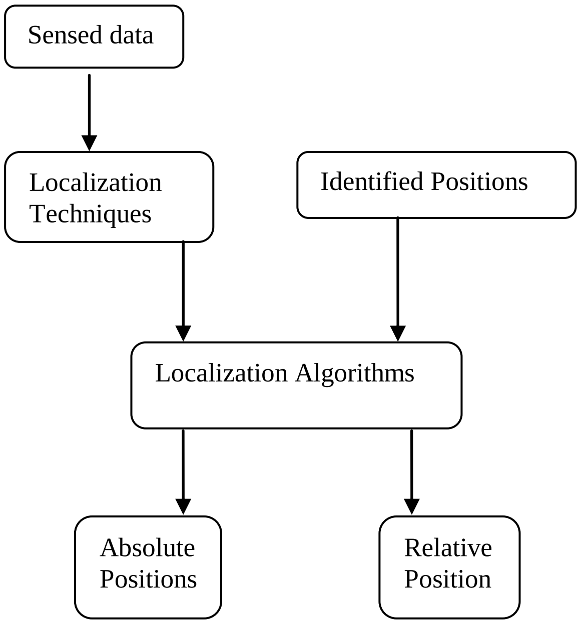

Fig. 3. Localization Process

IV. MULTIDIMENSIONAL SCALING

Multidimensional scaling[10][11] is a technique used to reduce the magnitude of the gathered data. MDS uses the distance between each pair of vertex and produces points in two dimensions or in three dimensions as output. Comparing to other techniques, MDS can achieve very accurate localization results (except for sparse networks), but at the outlay of higher computational costs. Local maps are created by every node in the network than these small maps are brought together to create a complete inclusive map. If the WSN consists of a sufficiently large number of nodes, the actual positions of the nodes can be obtained and a global map can be transformed to map with absolute positions.

Multidimensional scaling for IoT, as a technique follows three steps [15]:

1. Generate a distance matrix
2. Apply multidimensional scaling and obtain a relative location for sensor nodes.
3. Transformation of relative positions to an absolute position.

V. SHORTEST PATH ALGORITHMS

A SPA[12] is to compute a pathway with the optimal cost connecting two vertices in a graph or in a network. The SPP is one of the most critical in graph theory, which can further be utilized in networks.

A path with the minimal cost from a source node to a destination can be described as the shortest path [14].

A. Dijkstra's Algorithm

Dijkstra's algorithm[12] solves the SSSP problem. It can obtain an optimal path from the source vertex to every vertex in the network. Directed graph with positive weights can be processed with Dijkstra algorithm,to find the path with minimal cost[14].

Dijkstra algorithm performs an exhaustive to find the optimal path.

Dijkstra(G,V,E,S)
for every vertex p in V
Dist[p]=∞
Prev[p]=Null
if p!=S add p to Q
Dist[s]=0
repeat till Q is not empty
q=min {Q}
For every yet not visited neighbor vertex q of p
TemDist=Dist[q]+Ed_Wght(q,p)
if TemDist<Dist[p]
Dist[p]=TemDist
Prev[p]=q
Return Dist, Prev The algorithm achieves a complexity of $O(n^2)$. Fredman and Tarjan improved over and achieved the running time complexity of O(E+V*log V), which may further be optimized to O(E+V*logV/loglogV).

B. Iterative A* Algorithm

It is a technique which finds a minimum cost path between two given nodes (out of one or more possible goals). As A* proceeds, it selects a path with optimal heuristic values (minimum cost). The nodes already visited are kept in a priority queue with the obtained heuristic values for later use due to this it is considered to be more accurate than the Dijkstra algorithm. The function used is f(n) = g(n) + h(n) where g(n) is the total distance from the source to required goal, h(n) is the heuristic value, which is used for approximating the distance between the goal and the current node and n is the node in the network. The more accurate the heuristic the better the faster the goal state is reached and with much more accuracy.

Steps for A* algorithm:

Procedure AStar(Start,Goal)

1. Closed = empty
2. set Q = MakeQueue(path(Start))
3. while Q is not Empty
4. do P = RemoveFirst(Q)
5. x = LastNode(P)
6. if x in Closed then
7. end if
8. if x = Goal then
9. return P
10. end if
11. add x to closed
12. for y ← successor(x) do
13. enqueue(Q, P, y)
14. end for
15. return F ailure
16. end while
17. end

To record the areas covered or evaluated a closed list is maintained and to record areas adjacent to already covered area an open list or fringe list is prepared. The above-mentioned algorithm is executed |V| times for every node as a source node to obtain a distance matrix.

VI. RESULTS

Algorithm	Time Complexity	Space Complexity
Dijkstra's	O(E+V*logV)	O(V)
Iterative A*	O(V*log*h(x))	O(V)

Table 1. Complexities of shortest path algorithms

Running time complexity comparison in Table 1 shows that the A* algorithm is optimal and determined to find the shortest path between any two given sensors.

Dijkstra and A* algorithm's are used to obtain the distance matrix and used with classical multidimensional scaling for sensor node localization with the following configuration.

Parameters / Method	**CMDS**	**IA-CMDS**
No of Sensor Nodes	**10, 50, 100**	**10, 50, 100**
Area	**100*100mtr**	**100*100 mtr**

Table 2: Parameters for single-source shortest path algorithms

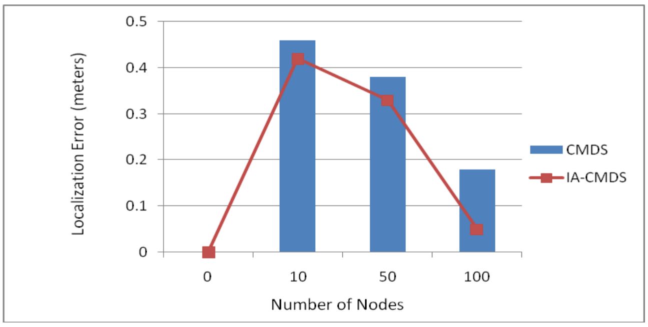

Fig. 3. Localization Error: Dijkstra and A* algorithm

Figure 3 shows the average localization error achieved with Dijkstra and A* algorithm. The performance of A* algorithm can be improved with an effective and accurate heuristic function. The heuristic value used is the distance between the current node and the destination node.

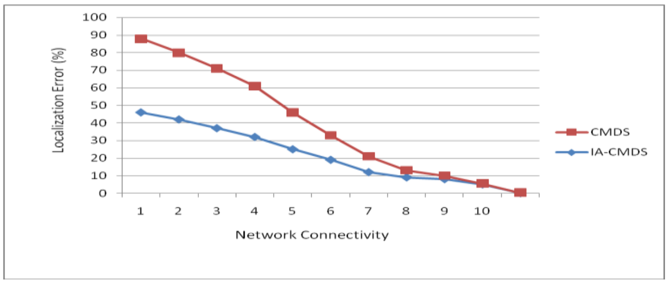

Fig. 4. Localization Error vs Network connectivity

Figure 4 shows the effect of network connectivity on the localization error. As the connectivity of the nodes increases, the localization error is decreased. When the network connectivity is 5, the localization errors are 25% and 46% for A* and Dijkstra algorithms respectively. After the network connectivity of 7.8 the performance of both the algorithm based localization process is identical and localization error keeps on reducing to 0.54% for network connectivity of 9 and more than 9.

VII. CONCLUSION

This paper, presents a IA-CMDS algorithm. The newly proposed method proved to be better than the previous one, which uses the Dijkstra algorithm for distance matrix calculation. As accurate and efficient calculation of distance matrix is very crucial for the localization method, using multidimensional scaling. Comparison in figure 3 and 4 shows that the A* algorithm based approach is better when the network connectivity is limited. Improving the network connectivity is not cost efficient, though the performance of the network will be better and both algorithm based localization works equally. So when the number of nodes in the network increases A* algorithm based approach achieves less localization error and also with the network connectivity between 2 and 5, A* algorithm based approach is better. The result shows that the heuristic based A* algorithm gives the better result and further can be improved with an optimal heuristic function.

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