Finding Optimal Tour Length of Mobile Agent in WSN by using a hybrid of Minimal Spanning Tree and Midway Range based Method

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Abstract: **A Wireless Sensor Network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, humidity, motion or pollutants and to cooperatively pass their data through the network to the Base Station. The energy constraints of sensor nodes need an efficient way of making the mobile agents to provide their service in time. A Mobile Agent (MA) represents a mobile device that collects data in a sensor field by physically visiting the nodes in a sensor network.The MA computing model having many advantages over C/S computing model in WSN like: Decrease in the network data flow, Balance load in Network, Parallelism, High quality in fault tolerance etc. The MA collects data when it is in the proximity of a sensor node. Recently, research interest has increased in the design, development, and deployment of mobile agent systems in a wireless sensor network (WSN). In this paper we mainly concern about how to find out the minimum tour length (path length) of Mobile Agent in the Network for collecting the data from the sensor nodes.**

Keywords: **Wireless sensor Network (WSN), Mobile Agent (MA), Base Station (BS), Travelling Salesperson Problem (TSP), Minimal Spanning tree(MST)**

I. INTRODUCTION:

Wireless sensor networks (WSN) is an collection of a large number of small, energy- and resource-constrained tiny sensor nodes which have sensors and actuators to monitor and modify the state of our physical world. The nodes can communicate wirelessly and have sufficient computational resources to perform collaborative signal processing tasks[1]. A sensor node having parts like transceiver, Energy source like battery, processing memory, and electronic circuit. A sensor node can be simple and of small size or complex or of large size depending upon the applications.The main task of sensor unit in WSN is to sense the local phenomenon like temperature, pressure etc. and do the local processing then finally send the processed data to the Base station via the intermediate sensor nodes. Hence the power consumption of a sensor node can be divided into the following domain: Sensing, Data Processing and communication to or from the other sensor nodes. Hence in WSN power efficiency is one of the most important performance metric because it can directly affect the total life time of the sensor network. Some of the main application of sensor networks are: Fire detection in forest, Vehicle Tracking, Environmental control, Military Surveillance etc. A sensor network design may be affected by the factors like Energy consumption, Production Cost of the Network (Sensor), Scalability, Hardware constrained etc.

Client Server (C/S) computing model/paradigm is generally adopted by the WSN. According to work presented in [4] C/S paradigm having many flaws like Aimless energy consumption, unbalanced network load, Low quality in fault-tolerance, Low security. The Mobile Agent (MA) is a special type of mobile sensor node having more energy, more memory, better transceiver. In MA computing model the MA migrate from the base station, visit the required sensor node and collect the data from those nodes and finally return to the base station with the aggregated result. The MA computing model having many advantages over C/S computing model in WSN like: Decrease in the network data flow, Balance load in Network, Parallelism, High quality in fault tolerance etc.

II. LITERATURE SURVEY:

Energy consumption is one of the critical issue in WSN because lifetime of a WSN is indirectly proportional to the energy consumed by the sensors. Energy consumed by the sensors mainly due to sensing the data and Communication to the other sensor nodes. Mobile Agent

technology can decrease energy consumption and hence the lifetime of the network can increase but inadequate deployment of mobile agents might lead to network failure due to constraint bandwidth.

In [6] the algorithm is proposed for data collection by mobile agent is as follows. The mobile agent is a packet sent from the sink node to collect data at each node.The agent moves autonomously along its own decided route in the tree cluster. The user needs only to make the sink node send the agent for data collection request.This scheme has little impact on data collection efficiency while not requiring a route optimization as it is required for a conventional data collection technique. In [7] Nodes are divided in two category common sensor nodes, and sink nodes. The sink nodescan send the task for query. The sink nodes flood their query information to the fixed nodes around them at first. But the area of flooding are very limited, often a cell-grid. This can ensure the sink nodes find one node as their direct transmitting node at least. Then the sink nodes receive the answers from the transmitting nodes, sink choose one of them to be the direct transmitting node by their geographic position. This can make sure that the path to query is SPF (shortest path first). According to work presented in [8] by using multiple Mobile Agent redundant nodes can be eliminated, MA paths can be optimized and problem of excessive energy consumption with the help of threshold value processing. In [9] routing protocol for single mobile sink and multiple mobile sink for data gathering in WSN is proposed. In this process, a biased random walk method is used to determine the next position of the sink. In [10] Artificial Bee Colony Algorithm is used for finding the optimal path length of MA in WSN. Artificial Bee Colony is a very effective optimization technique for optimization problems.

According to work presented in[11] that a WSN may become spatially separated into multiple sub networks. They discuss how to utilize a mobile mule to visit these sub networks to collect sensing data in an efficient way. Such separation may be due to several reasons like, the sensing field might be huge, such as farms or mountain areas. The traveling path of the mobile mule may reflect the data gathering latency and the energy consumption of the mule. Minimizing the perround total traversal time of the mule can be formulated as a MPDG (minimum-path data-gathering) problem, which is a generalization of the Euclidean Traveling Salesman Problem (ETSP). According to work presented in [2] travelling path length of Mobile Agent is one of the major issues in the field of Mobile Agent Based Wireless Sensor Network. In that paper Travelling Salesperson Problem (TSP) and Ranged based Method for path length calculation of Mobile Agent are compared. Based on the results Ranged Based Method is a better algorithm for calculating the optimal tour length of MA in WSN.

III. PROBLEM STATEMENT:

A WSN deployed in a two dimensional square with 'n' number of sensor nodes. Without loss of generality we consider that location of Base station will be decided by the user. Assume that the base station can identified each sensor nodes deployed in the sensor network with its universal node id (unique). Each node id is associated with its geographical location (X-coordinate and Y-coordinate). A mobile Agent will be scheduled from the base station to visit the specific nodes in the WSN. The MA should visit the nodes in such a manner so that the total path travelled by the MA should be minimum. Hence main objective is "finding the Minimum Tour Length of a Mobile Agent in Wireless Sensor Network". From the Base station mobile agent will be scheduled to visit specified nodes. Suppose X-coordinate and Y-coordinate of the respective node is given in the following table

Node_Id	X-cord	Y-cord	Energy
1	42	68	0.5
2	35	1	0.5
3	70	25	0.5
:	:	:	:
:	:	:	:
N	X	Y	0.5

The distance between two sensor nodes can be calculated by the distance formula

Suppose the location of base station is node '2' and mobile agent have to visit node numbers (between 1 to n) 5, 6, 9, 24, 7, 4.Hence Mobile agent will be schedule from the Base station to visit all the desired nodes. Suppose one of the possible order to visit the nodes is (2-> 5->6->9->24->7->4->2).Here the length of the tour will be given by length of the tour = $d_{2,5}$+ $d_{5,6}$+ $d_{6,9}$+ $d_{9,24}$ + $d_{24,7}$ + $d_{7,4}$ + $d_{4,2}$

Here $d_{2,5}$represent the distance between the node 2 and 5.

Hence we have to schedule the Mobile Agent in such a manner such that the length of the tour should me minimum.

IV. METHODOLOGY:

The Travelling Salesperson Problem algorithm is the one of the basic methodology for finding the minimum tour length of the Mobile Agent in Wireless Sensor

Networks. But this algorithm having some drawback which is explained in this section.The three different methods for the scheduling of Mobile Agents in Wireless Sensor Networks are as follows:-

Travelling Salesperson Problem:-

Here the MA will be treated as a salesperson and nodes to be visited as cities. So the MA has to visit each node exactly once for collecting the data in such a manner so that the total path travelled by the MA should be minimum.

- **Issue with the TSP algorithm:-**

In TSP algorithm for collecting the data by the MA from the sensor nodes, MA has to go to each node individually. But in Wireless Sensor Network the Mobile Agent can collect the data from the nodes which are in the specific range of the Mobile Agent. Hence travelling to each node individually by the Mobile agent is overhead. Hence TSP algorithm is not practically suitable for the WSN. Hence Ranged Based method is introduced for overcoming this issue.

Range Based Method for Tour Length calculation:-

Here MA will not go to each node individually for collecting the data, instead it will go to some specific nodes and collect the data from those nodes which are in the range of that MA. Again the MA will go to the next node and will collect the data from all those nodes who are in the range. Similarly it will visit the nodes till it not collect the data from all specified nodes.

- **Advantage of Ranged Based Method:-**

Since in this algorithm the Mobile Agent can collect the data without going to those nodes which are in the range of the Mobile Agent. Hence here Mobile Agent doesn't have to visit each node individually and due to that the distance travelled by the Mobile Agent is less with comparison to the TSP algorithm.

Hybrid of Minimal Spanning Tree and Midway Range Based Method for Tour Length calculation:-

This algorithm is also known as Midway Range based method. Here the Mobile Agent will not go to exact coordinate point of the sensor nodes, instead of that it will go to that node for collecting the data in such a manner so that the mobile agent will be at a distance 'R' (communication range of the mobile agent) from the sensor node and its new coordinates point will be in between the old location of mobile agent and the target sensor node coordinate. Now from this new location mobile agent will collect the data from those nodes whose distance from the mobile agent is less than or equal to 'R'.Now again the Mobile Agent will be scheduled for the next node among the remaining unvisited nodes by using the algorithm of Minimal Spanning Tree (MST). The Mobile Agent will be scheduled for the next node among the remaining unvisited node whose distance from the current location of the MA is minimum. This process is repeated until the no any nodes remain unvisited.

- **Algorithm:-**

Inputs:-

Grid size of the WSN (200x200), Total number of sensor nodes(200)

Initial location of Mobile Agent is Base Station.

Number of Nodes and node number (V1, V2, V3,.....,Vn)to be visited is collected into an array.

Range (R) of the Mobile Agent in which mobile agent can collect the data.

Step1.

Calculate the distance between the Base Station and the Nodes to be visited and mobile agent will be scheduled for the node (suppose Vi) with minimum distance. So mobile agent will have destination point in between Base Station and nearest node at a distance of 'R' from the nearest node.

Step2.

2.1. Now calculate the distance between the MA and the nodes to be visited in the visited array.

2.2. The MA will destine for the nearest node from the MA in following manner.

Let (old_MA_Xcord, old_MA_Ycord) are the coordinates of current location of mobile agent and (new_MA_Xcord, new_MA_Ycord) will be the coordinates of new location of mobile agent.Consider (x,y) are the coordinates of nearest node to be visited. Hence by using segment formula.

$new\_MA\_Xcord = x - t*(x - old\_MA\_Xcord) ;$

$new\_MA\_Ycord = x - t*(y - old\_MA\_Ycord) ;$

$where\ t = R/sqrt((old\_MA\_Xcord - x)* (old\_MA\_Xcord - x) + (old\_MA\_Xcord - x)* (old\_MA\_Xcord - x)) ;$

2.3. Mark the nodes as visited in the array whose distance from the new location of mobile agent is less than 'R'.

2.4. Distance travelled by the mobile agent is

$Dist = Dist + sqrt ((old\_MA\_Xcord - new\_MA\_Xcord) * (old\_MA\_Xcord - new\_MA\_Xcord) + (old\_MA\_Ycord - new\_MA\_Ycord)* (old\_MA\_Ycord - new\_MA\_Ycord))$

Step3.

Repeat step 2 until all the nodes are marked as visited.

End.

V. RESULTS AND ANALYSIS:-

Assume that the Wireless Sensor Network (WSN) is deployed in 200 x 200 grid size with total 200 numbers of sensor nodes. Suppose the initial position of the Mobile Agent is at node id=1. The sensor nodes' id and other information from where data should be collected is stored into the Mobile Agent's memory. Now the Mobilecollected is stored into the Mobile Agent's memory. Now the Mobile Agent (MA) is scheduled from Base Station (BS) according to the following algorithms:-

Travelling Salesperson Problem (TSP):-

In Travelling Salesperson Problem (TSP), a salesperson has to visit a list of cities in such a fashion such that the total travelling cost of the salesperson should be optimum and each city should be visited exactly once. Here in Mobile Agent model based Wireless Sensor Network we considered MA as a salesperson and nodes to be visited for data collection by the MA are considered as cities. Hence the total distance travelled by the MA with respect to different scenarios is shown in the table and graph.

But the TSP algorithm is not suitable as per the nature of the Wireless Sensor Networks because according to this algorithm the Mobile Agent will have to visit each node individually without considering the communication range. Because the Mobile Agent can collect the data from those nodes without going to it which are in the communication range of its.

Range Based Method for Tour Length calculation:-

Due to nature of Wireless Sensor Network (WSN), the Travelling Salesperson Problem can be changed to Range Based Method for tour length calculation, because the Mobile Agent can communicate with the nodes which are in communication range. Here the Mobile Agent will be scheduled for the node which is nearest and out of communication range of the Mobile Agent. Now at this new location again the mobile agent will collect the data from the node falling in its communication range and will be scheduled to the next location.

Hence the total length travelled by the Mobile Agent according to the algorithm Range Based Tour Length calculation will be less in comparison with the algorithm Travelling Salesperson Problem. Here the total length travelled by the Mobile Agent according to the algorithms Range Based Tour Length calculation & Travelling Salesperson Problem is compared the graph and table.

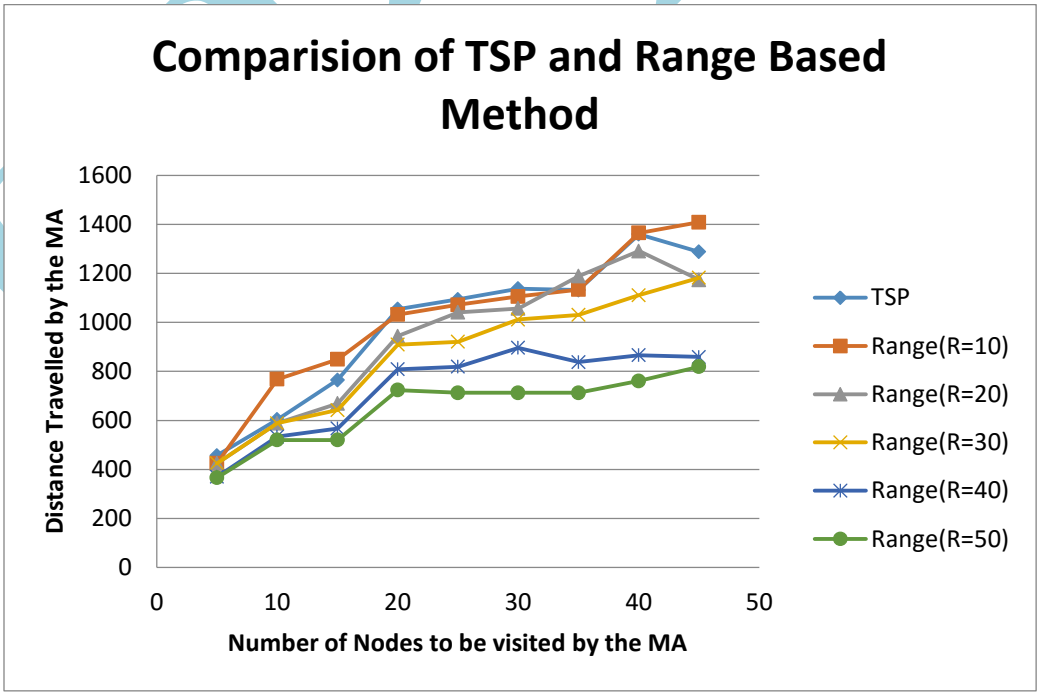

Figure 1 Comparison of TSP and Range Based Method

The distance travelled by the Mobile Agent in the Range Based Methodis less than the Travelling salesperson Problem. When the communication range of the Mobile Agent is increased the distance travelled by its

decreasing because it can cover the larger range and can collect the data from the nodes falling in that communication range. But when the range of the Mobile Agent is decreased then the total distance travelled by its increased. The main reason behind this phenomenon is that when the communication range is decreased then may be a single node is present in a communication range. Hence here Mobile Agent has to visit each node individually. This special case of Ranged Based Method is considered same as the Travelling Salesperson Problem.

5.3 Midway Range Based Method:-

Since Wireless Sensor Network having range based communication in nature. Hence the Mobile Agent may need not have to travel till the actual position of the next node which it wants to visit next for the data collection, instead of that it will go to that node for collecting the data in such a manner so that the mobile agent will be at a distance 'R' (range of the mobile agent) from the sensor node and its new coordinates point will be in between the old location of mobile agent and the target sensor node coordinate. Now again here the Mobile Agent will communicate with those nodes which are in the communication range and will collect the data. This procedure will be continuing till no any listed nodes remain unvisited by the Mobile Agent. The distance travelled by the Mobile Agent in Ranged based Method and Midway Ranged Based Method is compared in different scenario in the chart-1.

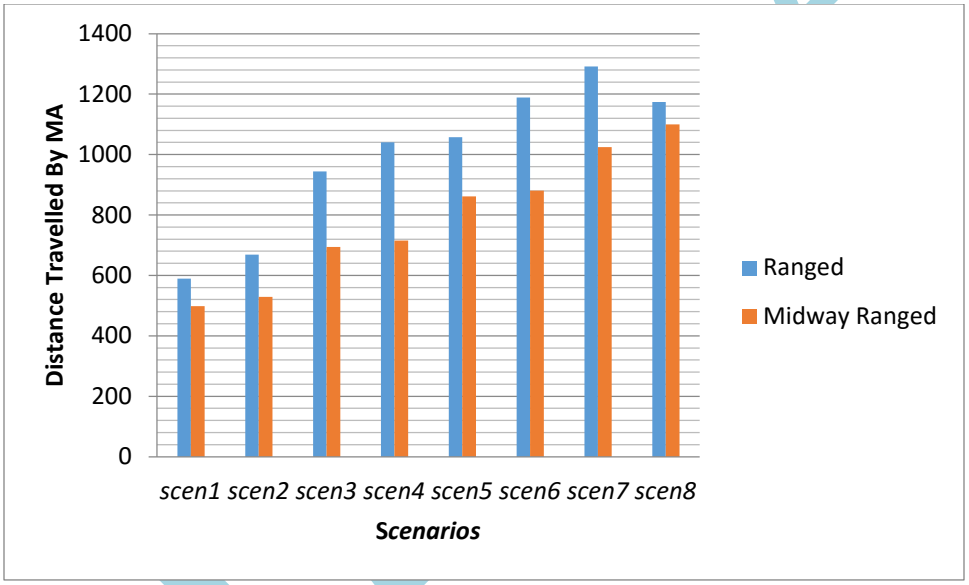

Figure 1Comparison of distance travelled by the Mobile Agent in Range Based Method and Midway Range based method

Scenario1:-

The WSN is deployed in 200x200 square areas with 200 number of sensor nodes. The Mobile Agent is scheduled from the node id=1, to visit the total number of sensor nodes = 10. The node ids of those nodes are 2, 4, 6, 8, 10, 12, 14, 16, 18 & 20. The communication range of the Mobile Agent is 20 units.

Scenario2:-

A WSN is deployed in 200x200 square areas with 200 number of sensor nodes. The Mobile Agent is scheduled from the node id=1, to visit the total number of sensor nodes = 15.The communication range of the Mobile Agent is 20 units.

Scenario3:-

The WSN is deployed in 200x200 square areas with 200 number of sensor nodes. The Mobile Agent is scheduled from the node id=1, to visit the total number of sensor nodes = 20. The node ids of those nodes are 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28,30 ,32, 34, 36, 38 & 40. The communication range of the Mobile Agent is 20 units.

Scenario4:-

The WSN is deployed in 200x200 square areas with 200 number of sensor nodes. The Mobile Agent is scheduled from the node id=1, to visit the total number of sensor nodes = 25.The communication range of the Mobile Agent is 20 units.

Scenario5:-

The WSN is deployed in 200x200 square areas with 200 number of sensor nodes. The Mobile Agent is scheduled from the node id=1, to visit the total number of sensor nodes = 30.The communication range of the Mobile Agent is 20 units.

Scenario6:-

A WSN is deployed in 200x200 square areas with 200 number of sensor nodes. The Mobile Agent is scheduled from the node id=1, to visit the total number of sensor nodes = 35.The communication range of the Mobile Agent is 20 units.

Scenario7:-

A WSN is deployed in 200x200 square areas with 200 number of sensor nodes. The Mobile Agent is scheduled from the node id=1, to visit the total number of sensor nodes = 40.The communication range of the Mobile Agent is 20 units.

Scenario8:-

A WSN is deployed in 200x200 square areas with 200 number of sensor nodes. The Mobile Agent is scheduled from the node id=1, to visit the total number of sensor nodes = 50.The communication range of the Mobile Agent is 20 units.

From the result of Figure 2.4, we can say that the Midway Range Base Method is better than the Range Based Method in terms of the distance travelled by the Mobile Agent. The total distance travelled by the Mobile Agent in the Midway Range Based Method in average 20.68% less distance than the Range Based Method. The main reason is whenever the Mobile Agent is scheduled to visit the next node, the Mobile Agent have to travelled 'R' distance less in comparison to the Range Based Method. Hence the Midway Range Based Method is a better algorithm for the Mobile Agent in comparison to the Ranged Based Method.

- **Impact of the Algorithm:-**

Since the distance travelled by the Mobile Agent is reduced, hence the energy consumption for the travelling will also reduce.

5.4 Overhead Calculation:-

Total number of execution of the algorithm by the mobile agent and the total number of nodes to which the Mobile Agent is communicated during the data collection from the listed sensor nodes are considered as the overhead.

5.4.1. Total number of execution of algorithm by the Mobile Agent:-

Here The MA is scheduled from the base station to visit the set of nodes for data collection. The MA will go to a specific position and run the algorithm to collect the data from the nodes falling in the communication range of it, and then scheduled for the next location. Again the MA will run the algorithm for doing the same procedure until all the listed nodes are visited. Hence the total number of execution of the algorithm is calculated based on both the algorithm. This result is shown as chart below.

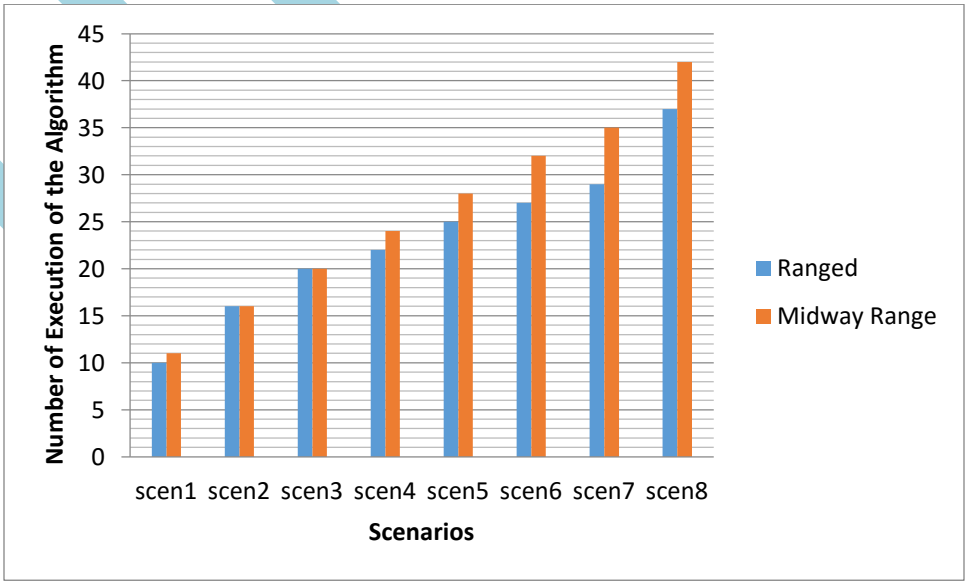

Figure 2 Comparison of number of execution of the algorithm.

5.4.2. Total number of communication:-

The Mobile Agent is scheduled from the base station. Here main aim is to calculate the total number of nodes to which the MA agent communicated during the data collection from the specific nodes.

When the MA will come to a specific node for data collection then the MA will communicate to that entire node which is in the range of the MA and again it will be scheduled to the next node according to algorithm. Hence here the total number of communication is the total number of nodes which are falling in the range of MA during the visit of list of nodes.

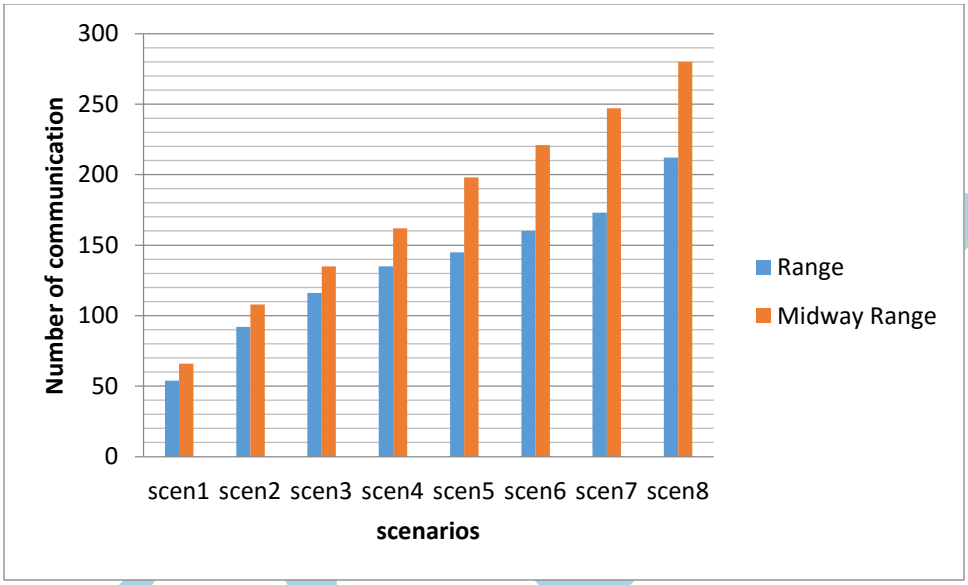

Figure 3 Comparison of number of messages during the data collection.

Here communication cost for the Midway Range Based Method is more in compare with the Range Based Method because in Midway Range Based Method the number of execution of the algorithm by the Mobile Agent is more and in each execution the Mobile Agent is communicating with the nodes falling in the communication range of its.

5.5 Comparison of algorithms for the worst case scenario:-

This is the special scenario when in one communication range maximum one node will be present. Hence the Mobile Agent can't collect data from more than a single node at a time in any communication range. Hence here the Range based algorithm will work same as the Travelling Salesperson Problem algorithm.

Here the objective of the algorithms is to cover the whole area by the Mobile Agent with the minimum distance travelled by the Mobile Agent. In the Figure 3.5 each circle represents one communication range and we considered that each circular area shown in the diagram contains a sensor node (Green colored) at their center.

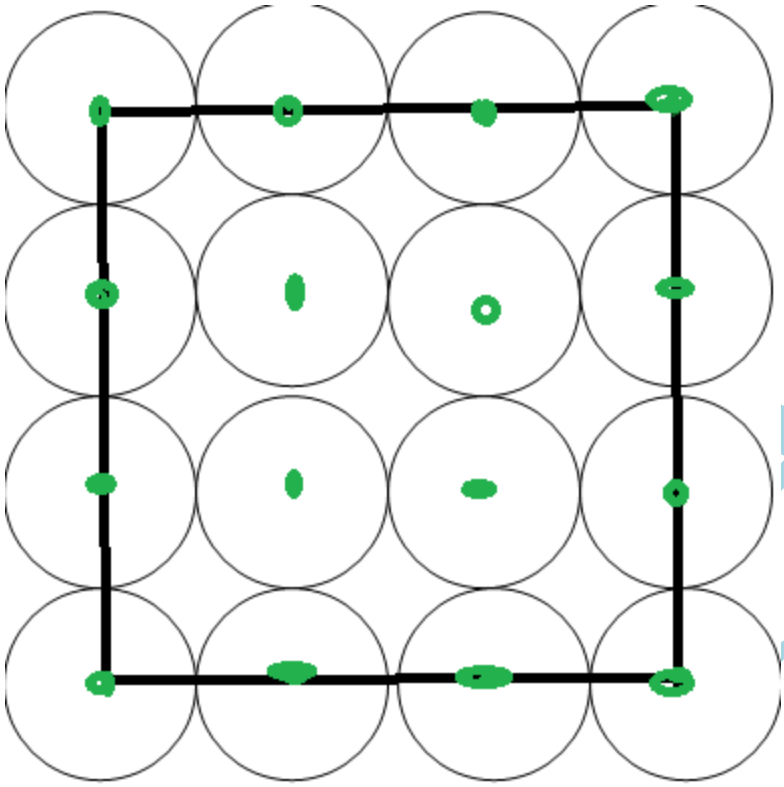

Figure 4 Worst Case Scenario

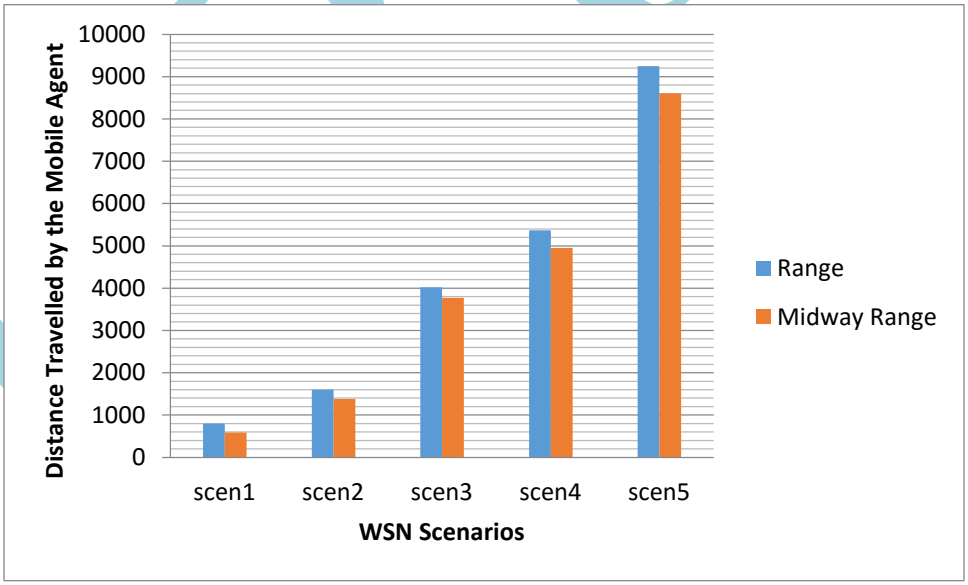

Figure 5Comparison of distance travelled by the Mobile Agent in Worst Case scenarios according to Range Based algorithm and Midway Range Based algorithm

Scenario1:-

The WSN is deployed in 100x100 area with a total number of nodes is equals to 36 is deployed in such a manner so that the number of nodes present in a communication range of Mobile Agent is at most one. The communication range of the MA is 20 units. Now the Mobile Agent scheduled to collect the data from all the nodes, it means the Mobile Agent will have to cover the whole area.

Scenario 2:-

The WSN is deployed in 200x200 area with a total number of nodes is equals to 36 is deployed in such a manner so that the number of nodes present in a communication range of Mobile Agent is at most one. The communication range of the MA is 20 units. Now the Mobile Agent scheduled to collect the data from all the nodes, it means the Mobile Agent will have to cover the whole area.

Scenario 3:-

The WSN is deployed in 300x300 area with a total number of nodes is equals to 121 is deployed in such a manner so that the number of nodes present in a communication range of Mobile Agent is at most one. The communication range of the MA is 15 units. Now the Mobile Agent scheduled to collect the data from all the nodes, it means the Mobile Agent will have to cover the whole area.

Scenario 4:-

The WSN is deployed in 400x400 area with a total number of nodes is equals to 121 is deployed in such a manner so that the number of nodes present in a communication range of Mobile Agent is at most one. The communication range of the MA is 20 units. Now the Mobile Agent scheduled to collect the data from all the nodes.

Scenario 5:-

The WSN is deployed in 600x600 area with a total number of nodes is equals to 257 is deployed in such a manner so that the number of nodes present in a communication range of Mobile Agent is at most one. The communication range of the MA is 20 units. Now the Mobile Agent scheduled to collect the data from all the nodes.

From the Figure 10 it is clear that the Midway Range based Method is better than the Range based Method also in worst case scenario in terms of distance travelled by the Mobile Agent. In scenario 1, the distance travelled by the Mobile Agent according to Midway Range Based Method is 27% less than in comparison with the Range Based Method and it is 13.625%& 6.28% with respect to the scenario 2 and scenario 3.

VI. CONCLUSION AND FUTURE WORK

Replacement of battery of a sensor node technique is under development. Hence saving energy of individual nodes by reducing the communication cost is a better option for increasing the life time of the network. In mobile agent Paradigm the main aim is to move the computation to data rather than then data to the computation. Optimal scheduling algorithm for mobile agent is very important for the success of the Mobile Agent technique in Wireless Sensor Network. Three different algorithms (Travelling Salesperson Problem, Ranged Based Method, and Midway Range Based Method) have implemented and results have observed. Based on the results in the previous section Midway Ranged Based Method is better algorithm among these three algorithms.The total distances travelled by the Mobile Agent in the Midway Range Based Method in average 20.68 % less than in comparison with the distance travelled by the Mobile Agent according to Range Based Method.

Communication overhead in the Midway Range Based Algorithm is more in comparison with the Range Based algorithm. Hence Midway Range Based algorithm can be improved to reduce the communication overhead.

REFERENCES

[1] I.F. Akyildiz, W. Su*, Y. Sankarasubramaniam, E. Cayirci “Wireless sensor networks: a survey” Broadband and Wireless Networking Laboratory, School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA 30332, USA Received 12 December 2001; accepted 20 December 2001.

[2] Mahto, Anil Kumar, Ajay Prasad, and PrityKumari. "Finding Optimal Tour Length of Mobile Agent in Wireless Sensor Network." Proceedings of the Conference on Advances in Communication and Control Systems-2013. Atlantis Press, 2013.

[3] Ian Downard Naval Research Laboratory Code 5523 4555 Overlook Ave Washington DC, 20375-5337 “simulating sensor networks in NS-2.

[4] Wang Jietai, XuJiadong, Yang Shaojun, “Research on Mechanism of Mobile Agent for Wireless Sensor Networks”, 1-4244-1312-5/07 IEEE 2007.

[5] Zhengwei, Liu sanyang, Kou xiaoli, Qi xiaogang(2010) ”Mobile agent routing algorithm in dynamic sensor network” 2010 International Conference on Communications and Mobile Computing.

[6]T.; Matsunaga, S.; Torikai, T.; Furukawa, H., "Effective data collection scheme by mobile agent over Wireless Sensor Network," *Information Networking (ICOIN), 2015 International Conference on* , vol., no., pp.1,6, 12-14 Jan. 2015.

[7] Yan Zhao; Qianping Wang; Dong Jiang; Wanrong Wu; Li Hao; Ke Wang, "An Agent-based Routing Protocol with Mobile Sink for WSN in Coal Mine," *Pervasive Computing and Applications, 2008. ICPCA 2008. Third International Conference on* , vol.2, no., pp.857,862, 6-8 Oct. 2008.

[8] Dang Xiao-chao; Hao Zhan-Jun, "A research of multiple Mobile Agents routing algorithm based on redundancy for wireless sensor network," *Awareness Science and Technology and Ubi-Media Computing*

(iCAST-UMEDIA), 2013 International Joint Conference on , vol., no., pp.740,747, 2-4 Nov. 2013

[9] Madhumathy, P.; Sivakumar, D., "Enabling energy efficient sensory data collection using multiple mobile sink," *Communications, China* , vol.11, no.10, pp.29,37, Oct. 2014

[10] SelvaBharathi, R.; Priyadharshni, R.; Ramesh, S., "Artificial Bee Colony algorithm to find optimum path for mobile agents in Wireless Sensor Networks," *Advanced Communication Control and Computing Technologies (ICACCCT), 2014 International Conference on* , vol., no., pp.842,846, 8-10 May 2014

[11]Fang-Jing Wu, Chi-Fu Huang, and Yu-Chee Tseng "Data Gathering by Mobile Mules in a Spatially SeparatedWireless Sensor Network" 2009 Tenth International Conference on Mobile Data Management: Systems, Services and Middleware.

[12]http://en.wikipedia.org/wiki/Minimum_spanning_tree.

[13] http://en.wikipedia.org/wiki/Line_segment

