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Improving Target Coverage and Network Connectivity of Mobile Sensor Networks

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Abstract: ***Mobile sensor network is the collection of independent and scattered sensors with capacity of mobility. In recent years, Mobility of Sensors has been utilized to improve the target coverage quality and network connectivity in randomly deployed mobile sensor networks. Target coverage and Network connectivity are two main challenging issues of mobile sensor networks. Target coverage covers a set of specified points of interest in the randomly deployed MSNs. Target coverage is usually interpreted as how well a sensor network will cover an area of interest. Network Connectivity is defined as the ability of the sensor nodes to collect data and report data to the sink node. Target Coverage and Network Connectivity may also affect the quality of network. In this paper, for target coverage, two algorithms i.e. basic algorithm based on clique partitions and TV Greedy algorithm based on voronoi diagrams of target are proposed. For network Connectivity, an optimal solution based on Steiner tree concept is proposed. In addition, LZW compression algorithm is used to compress data, due to which energy consumption is minimized.***

Keywords: Mobility, Mobile sensor networks, Target Coverage, Network connectivity, Voronoi diagrams.

1. Introduction

In recent years, Wireless Sensor Network (WSN) has arisen as efficient technology for wide range of applications. The applications of wireless sensor network include environmental monitoring, object tracking, traffic management, emergency navigation, etc. A wireless sensor network is a set of physically distributed sensor nodes. Sensor node is a small wireless device with limited battery life, radio transmission range and storage size. A sensor node performs the task of collecting important data, processing the data, monitoring the environment, etc. Sensor nodes in the network communicate with each other using radio transmitter and receiver. Generally sensor nodes have three units: Sensing unit, Communication unit and processing unit. Sensor node collects relevant data from the environment send it to the sink node or base station via single hop or multi hop communication. Base station is the central authority in the network. Base station has ability to monitor the sensor nodes. At the base station data is aggregated. Sensor nodes can be mobile or static.

Mobile Sensor network is the group of moving sensor nodes. Mobile sensor networks have additional capacity of Mobility. Mobility consists of different functions in sensor network like better network lifetime, better use of resources, relocation, etc. In the mobile sensor networks, Sensor nodes may change their location after initial deployment. Mobility can apply to all nodes or only to subgroups of nodes. Mobility can be active or passive. In active mobility the sensors are able to find their path and move while in passive sensors they may be moved by human or environmental assistance. Mobility of the sensor nodes can affect the overall performance of the network. Sensor Deployment is another issue in mobile sensor networks, because it not only determines the cost of constructing the network but also affects how well a location is monitored by a sensor node. Sensor deployment can affect the quality of coverage and connectivity.

Target coverage and Network connectivity are two major issues of Mobile sensor networks. Target coverage covers a set of interested points in deployment area of mobile sensor networks. It guarantees that every target is covered by at least one mobile sensor. Network Connectivity guarantees that there must be sufficient routing paths between sensors. Target Coverage is affected by a sensor's sensing range, whereas Network Connectivity is decided by a sensor's communication range. Target coverage and Network connectivity may also affects the performance of Network. In this work, to solve target coverage problem two algorithms are used: basic algorithm and TV-greedy algorithm. Basic algorithm uses minimum number of sensors to be moved but that may increase the total movement of sensors. To minimize sensors' movement TV-Greedy algorithm is used. TV-Greedy algorithm selects sensor which is very close to target to cover that target.

The remainder of this paper is organized as follows. Section II consists of related work. Section III provides a brief idea about the methodology used for evaluating the performance of proposed algorithms. Section IV deals with a detailed description of proposed technique and finally Section V concludes the paper.

2. Related Work

Mobility is the additional capacity of mobile sensor networks. Movement of sensors consumes more energy than sensing. Hence, movement of sensors need to be reduced to conserve energy. In [2] and [3], authors address a problem of minimizing the movement of sensor nodes to achieve target coverage in mobile sensor networks. Target coverage is divided into two cases: special and general case. In a special case of Target Coverage, targets disperse from each other farther than double of the coverage radius. For this case, an exact algorithm based on the Hungarian method is proposed to find the optimal solution. For general cases of Target coverage, two heuristic algorithms, the Basic algorithm based on clique partition and the TV-Greedy algorithm based on Voronoi partition of the deployment region, are proposed to reduce the total movement of sensor nodes. Network Connectivity is also a major issue. This issue of connectivity

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by minimizing the movement distance of sensors is addressed in [3].]. In this paper, for the Network Connectivity, first an edge length constrained Steiner tree is constructed to calculate the Steiner points that are needed to connect the coverage sensors and the sink node, then the Ex- Hungarian method is used to find the optimal sensors to move these points.

Sensor deployment is another major issue in Mobile sensor networks. Sensor deployment adds more key challenges in mobile sensor networks. In [5], Authors finds a hybrid approach to achieve both energy conservation and fault tolerance through multiple sensor coverage by exploring the redundancy in sensor deployment. Authors address this problem as an NP-complete Connected M-Set Coverage problem, whose goal is to divide the network properly into M subsets in space such that each subset is able to covers the entire region and maintains its own connectivity. In this paper, the necessary and satisfactory condition for proving the coverage of a 2D continuous region is derived. Paper [6] introduces best deployment algorithm for sensors in a given deployment region to provide targeted coverage and connectivity for a wireless sensor network. In this paper, the proposed method partitions the given area of interest into two different regions: central and edge regions. In each region, a single method is used to calculate the number and location of sensors to cover the entire coverage while keeping network connectivity. Mobility of the sensor nodes can affect the overall network performance [8], [9].WSN coverage and connectivity can be improved by using sensor's mobility [7]. In [7], a distributed algorithm (C2 algorithm) is proposed that improves coverage and connectivity in the wireless sensor network, performing organized relocation of mobile sensor nodes. Initially C2 algorithm organizes the network in a clustered topology, assuming Hexagonal grid structure. The Cluster Heads are placed in the centres of hexagonal cells designed according the nodes transmission range. The C2 rearranges the sensor nodes between the adjacent hexagonal cells and equally distributes them within the cells, thus enhancing the target coverage. The optimal nodes are chosen to perform the movements and thus maintaining the network connectivity and minimizing the energy consumption.

Target coverage and network connectivity may also affect the overall performance of the wireless sensor network. Since the sensor nodes have limited battery life, sensors may fail during the operation. Due to sensor's failure whole network connectivity may break or holes may be created. One of the way to handle this problem is to deploy mobile sensors in the network, so that these mobile sensors can be relocated to heal the holes or maintain the network connectivity. In [11], an Adaptively Hole Connected Healing (AHCH) algorithm is introduced to adaptively heal the holes with the guarantee of network connectivity. This AHCH algorithm calculates the movement schedule of mobile sensors as soon as holes appear. This algorithm also reduces the energy consumption and maintains the network connectivity. Later, AHCH algorithm is extended into Insufficient AHCH (InAHCH) and General AHCH (GenAHCH) algorithms to handle insufficient mobile sensors and disconnected coverage regions respectively. Authors in [12] propose a new algorithm to achieve improved coverage with lower complexity. This algorithm uses Fuzzy Inference System (FIS) in order to achieve the coverage in the WSNs. The proposed FIS is used by Base Station to plan which nodes are active or in the sleep mode. All calculations are done in Base Station. In this multi-hopping is used for data transmission between active nodes.

Connected Cover Set based on Identity of node (CCSID) solution is also used to solve the problem of coverage and connectivity [13]. This CCSID makes use of the Graph Theory concept and Minimum Connected Dominating Sets (MCDS) to build coverage sets. The CCSID divides the set of deployed nodes into different subsets. In each subset, a minimum number of active nodes are selected to ensure coverage and connectivity. Greedy Iterative Energy-Efficient Connected Coverage (GIECC) algorithm is introduced to maintain the network connectivity in wireless sensor networks [17]. The GIECC algorithm operates in different phases: coverage phase and connectivity phase, redundancy phase. GIECC algorithm finds an active set of sensors to maintain the network connectivity.

3. Methodology

For Target coverage problem, two algorithms are used: basic algorithm based on clique partition and TV-greedy algorithm based on Voronoi diagrams.

3.1 Basic algorithm based on Clique Partitions

Initially after deployment of sensors some targets may have been already covered. There is need to cover the uncovered targets. Firstly, basic algorithm constructs the graph of uncovered targets. After the graph is constructed, minimum number of clique partitions is determined. Every clique partition represents the set of targets that can be covered by same sensor node. Thus, for the targets from same clique, only one mobile sensor is dispatched to cover those targets. Hence, the basic algorithm minimizes the number of sensors that need to be moved.

3.2 TV-Greedy algorithm based on Voronoi Diagrams

TV-Greedy algorithm minimizes the total movement of sensors. It determines the Voronoi diagrams according to static targets. The Sensor node which is located in a voronoi polygon of target is called server of that target and the target is considered as client of that sensor. The set of target's all servers is called own server group of that target. The nearest server in target's own server group is called chief server of that target. If two targets are neighbors then the chief server of one target is the aid server of another target. Candidate server group is the union of aid and chief servers. First, this algorithm generates the voronoi diagrams of targets using the coordinate information of targets. Then using the information about the vertices of voronoi polygons neighbors for each target are determined. Second, chief servers and aid servers for each target is determined from their own server groups. Then the candidate server group of target is determined. The closest sensor to the intersection of two targets from the candidate

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server group of those targets is selected to move and to cover both targets. In this way, TV-Greedy algorithm reduces the total movement of sensors and target coverage is achieved.

Figure.1 shows the flow diagram of project. To cover uncovered targets, basic algorithm constructs the graph of targets. After the graph is constructed, minimum clique partition of the constructed graph are determined. Thus, for the targets from same clique, only one mobile sensor is dispatched to cover those targets. Hence, the basic algorithm minimizes the number of sensors that need to be moved, but it may increase the total movement of sensors. TV-greedy algorithm minimizes the total movement by grouping the sensors according to proximity to targets. TV-Greedy algorithm determines the Voronoi diagrams according to static targets. Since targets are statics, re-computation after every operation is not needed. Voronoi diagrams group sensors according to proximity of sensors to the targets. After that the sensor which is very close to sensor is selected to cover that target. Target coverage aims that at least one sensor can cover the one or many targets. TV-greedy algorithm finds the sensor which is on the intersection of two targets and close to both target than other sensor nodes. The basic idea behind network connectivity is to use rest of mobile sensors to maintain connectivity. The basic idea behind network connectivity is to use rest of mobile sensors to maintain connectivity. Network connectivity is necessary for sensor node to collect data and send it to the sink node. Network connectivity aims to find the optimal route for sensor node to communicate with sink node or base station. Here Steiner tree concept is used to maintain network connectivity, where Sink node or base station is root and all the sensors are leaf nodes. Here First, an edge length constrained Steiner tree spanning all the coverage sensors and the sink is constructed, such that each tree edge length is not greater than the communication radius rc. Then the rest mobile sensors are relocated to the generated Steiner points to connect the sensors and the sink node. Sensor node collects the data from targets and send that data to the sink node. This requires the maximum energy and time. Here LZW compression algorithm is used to compress data and hence to minimize energy consumption and maximize the computation speed of transmission.

An algorithm for proposed system is described as follows:
1. Start
2. Initialize the mobile sensors in the targeted region
3. Locate the targets in the region
4. Construct the graphs of uncovered targets.
5. Determine the voronoi diagrams of targets.
6. Determines the chief servers and aid servers of each target.
7. Determine the candidate server group of target.
8. Determine the sensor from CSG which is on the intersection of two targets.
9. Select that sensor to achieve both targets.
10. Relocate the rest mobile sensors to achieve network connectivity.
11. Apply LZW compression algorithm while sending data from sensor node to sink node.
12. End.

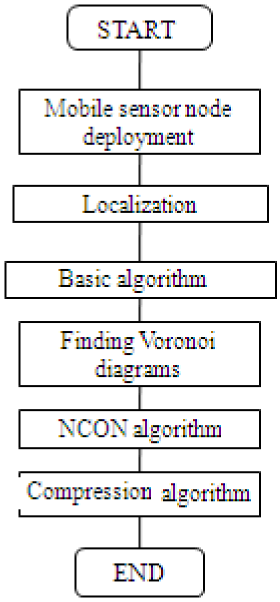

Figure 1: Flow Diagram

4. Simulation Results

Figure 2 shows the simulation results obtained from proposed system. Figure 2 (a) shows the initial position of targets and sensors. After randomly deploying the sensors, some targets are already covered.TV-greedy algorithms find the Voronoi diagrams of static targets, due to which there is no need of re-computation after each round of sensor movement. Figure 2 (b) shows the Voronoi diagrams of targets. According to proximity to target, sensors are grouped. TV-greedy algorithm selects the sensor which is very close to target, to cover that target; hence the movement of sensor is minimized. Figure 2 (c) shows the illustration of algorithms and shows final result. Here, Sensor node 4 is on the intersection of target 1 and target 2 and hence sensor node 4 achieves both the target 1 and target 2. On the same way, sensor node 5 covers target 2 and target 3. Algorithm selects the sensor which is very close to target; due to this sensor's movement is minimized. And one sensor can achieve more than one target; due to this minimum number of sensors are required to cover the target. Minimizing movement of sensors increases the network lifetime.

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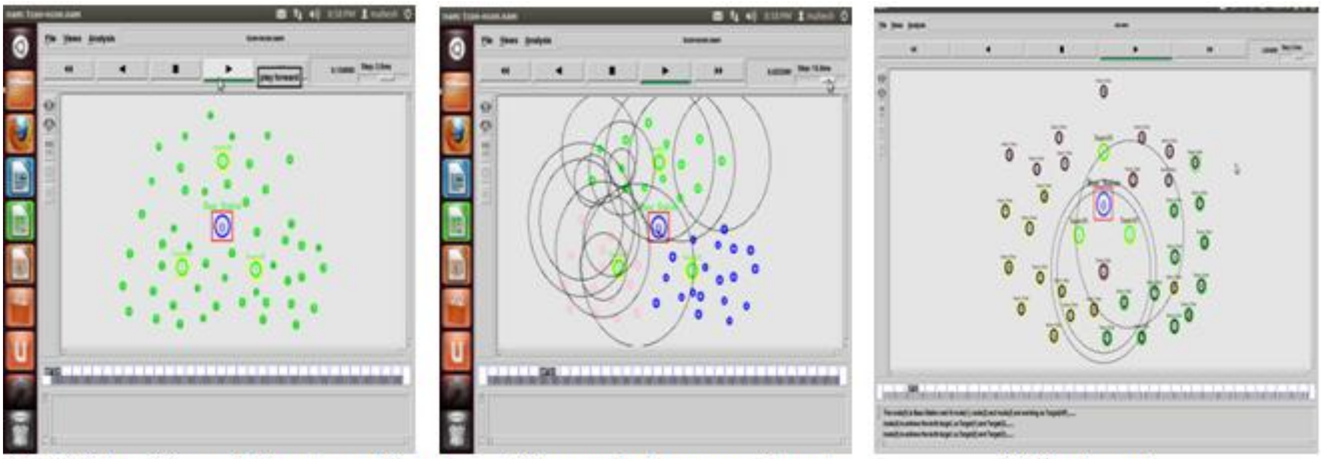

(a) Initial positions of Targets and Sensors (b) voronoi diagrams of targets (c) Final result

Figure 2: Simulation results obtained from proposed algorithms

Figure.3 shows the comparison between three algorithms: Basic, TV-Greedy and EX-Hungarian method. The movement distance increases when targets increase. Ex-Hungarian and basic algorithm performs very close to each other. Basic algorithm uses the minimum number of coverage sensors. The number of coverage sensors used by TV-Greedy is between the other two algorithms. TV-Greedy achieves less movement than other two algorithms. This is because of TV-Greedy uses smart strategy to choose coverage sensors. This algorithm groups sensors according to their proximity to the targets, and uses the nearest sensor to cover a target. This effectively minimizes the total movement distance to cover all the targets.

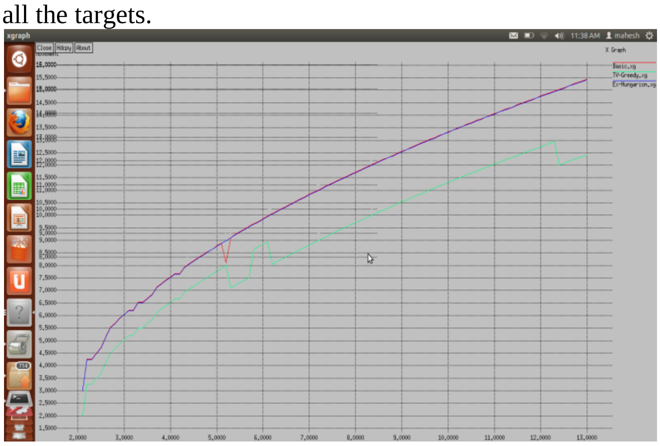

Figure 3: Comparison of Basic, TV-Greedy and Ex-Hungarian method

Figure 4 shows the compressibility. LZW compression algorithm is used to compress data. Sensors collect the data from targets and that data is sent to base station for further process. LZW algorithm compresses data and then that compressed data is sent to base station.

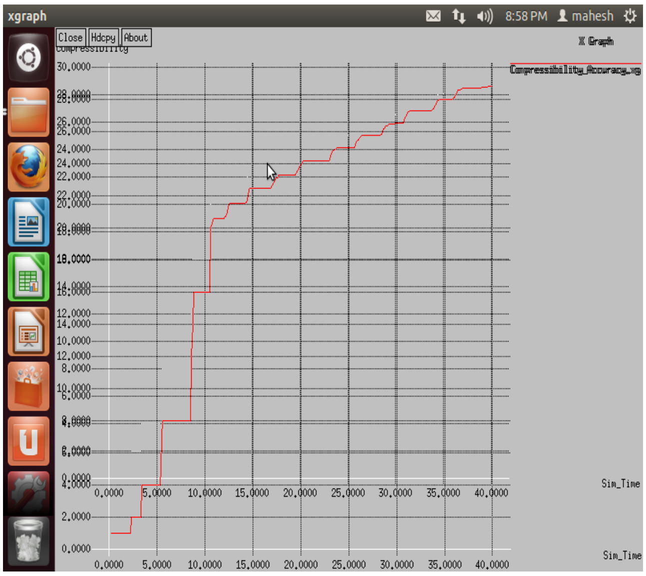

Figure 4: Compressibility

5. Conclusion

In this paper, the issues of target coverage and network Connectivity in mobile sensor network are taken into consideration. Target coverage covers a set of interested point in the deployment area of mobile sensor networks. Network connectivity is necessary for sensors to communicate with sink node. To solve the Target Coverage problem two algorithms are proposed: Basic algorithm based on clique partitions and TV-Greedy algorithm based on Voronoi diagrams. Sensors ‘movement is minimized. TV-Greedy algorithm achieves less movement than basic algorithm because it selects the sensor which is very close to target to achieve that target. LZW compression algorithm is applied while sending data from sensor node to sink node, hence the computation speed of transmission is maximized. Simulation result obtained validates the performance of the proposed algorithm. Hence, the proposed scheme successfully overcomes the issues of Target coverage and Network Connectivity in Mobile Sensor Networks and increases the network lifetime

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