A Study on Sensor Deployment strategies

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***Abstract*- AWireless Sensor Network is composed of many tiny, low-power nodes that integrate sensing units, transceivers, and processing unit and wireless communication capabilities. These devices are deployed in a region of interested area to collect the information from the environment, which will be sent to a remote base station. Wireless Sensor Networks are used for many applications, such as surveillance, biological detection, and traffic, pollution, civil infrastructure monitoring, health care, fire detection and disaster management. This paper studies and surveys various sensor deployment methodologies with their pros and cons.**

***Keywords*- Wireless sensor network, Sensor deployment, efficiency coverage area ratio, Network life time,**

I. Introduction

The most interesting and important issues in the wireless sensor network is how to deploy a sensor in a region of interest. The efficiency of a wireless sensor network is depended on Sensor deployment and it also reflects the cost and detection capability. A good deployment strategy should be considering both coverage and connectivity of the network. Coverage means that every location in the region of interest is monitored by at least one sensor. Connectivity means that each node in network should be involved in Communication with base station and network is not separated in terms of node communication. Sensor deployments are classified into two types, random and deterministic deployment. In random deployment, sensors are deployed randomly by using airplane or helicopters where human cannot able to reach the target area. In deterministic deployment, exact locations are predetermined to deploy the sensor. Sensor deployments are divided into two types which are sparse deployment and dense deployment. Sparse deployment method is used when less number of sensors is required to monitor the region of interest.

Dense deployment method is used when every event is important to detect in the targeted area, in dense deployment has more number of sensors.

II. Literature Survey

Naregalkal et al. [1]discusses about coverage problem, analyze the three types of sensor deploymentsand compute their efficient coverage areas, relation between the number of sensors and efficient coverage area ratio. A formula is presented to calculate the efficient coverage area and efficient coverage area ratio. Three kinds of sensor deployments are analyzed:1) Sensor Deployments Based on Square 2) Sensor Deployments Based on Equilateral Triangle 3) Sensor Deployments Based on Hexagon. It is concluded that Triangular lattice is the best among the three kinds of grids as it has the smallest overlapping area and hence this grid requires the least number of sensors.Squaregrid provides fairly good performance for any parameters while hexagonal grid is the worst among all since it has the biggest overlapping area. Wan Norsyafizan et. al. [2] presents the approach of hexagonal shaped cell for wireless sensor network as it proves to provide better transmission for the signal that also can reduce the number of sensor nodes in the cell. The gain in hexagonal shaped cell is higher than the gain in omnidirectional cell. Therefore, when the gain is higher, it is capable to transmit and receives signal efficiently. Higher gain will also allow more transmitted power to be sent indirection of receiver. This will reduce the number of sensor nodes in such area. Hexagonal shaped cell is effective in achieving a good coverage of a given region of interest and reduces the number of sensor nodes in the area. It also increases the received signal strength and provides better signal level. Sectorized antenna in hexagonal shaped cell can cover maximum area and it appears to be favored its particular directions.

Glen Takahara et al. [3]propose an efficient triangular grid-based sensor deployment to solve the coverage problem in Wireless Sensor Networks. Random deployment errors affect the coverage quality of the network.Deployment errors may arise for a number of reasons, including natural or man-made obstacles in the target surface, timing errors in the deployment device mechanism, errors due to human factors, and atmospheric effects. The average coverage percentage of the sensing field is derived as a function of the length of the grid tiles and the radius of the random error disks. Expressions for the average coverage percentage are computed numerically and verified by simulations. Simulation results shows that the triangular grid based sensor deployment is effective method for solving coverage problem and it requires less number of sensor nodes and resilient to the random errors.Chao Ma et. al. [4]discusses data fusion based deployment strategy in Wireless Sensor Networks and focus on two regular deployment patterns, equilateral triangle and square. First, the location of least covered point in respective grid is determined through theoretical analysis, instead of numerical or approximate solutions. In this paper,deployment technique efficiencies with coverage and connectivity are discussed. A Back-off based Grid Fusion Algorithm is presented to implement fusion and can restrain unnecessary fusion frames from broadcasting and save energy. Simulation and numerical results shows that the efficiency of deployment is better in triangular pattern compare with the square pattern.Jiong Wang et al. [5]propose a mesh construction and coverage improvement technique for sensing coverage of Wireless Sensor Networks. This technique provides energy-balancing and energy-efficiency for sensor networks with guaranteed full coverage. To provide energy balancing, the mesh is reconstructed periodically by randomly picking up an initiator from the network. To avoid redundant coverage, the virtual mesh and shifting correction technique is applied to the activation chain between neighboring sensors during the mesh construction. As a result, a set of active sensors are selected to best approximate the square mesh or equilateral-triangular mesh regardless of the location of the initiator and local shifting errors. To guarantee full coverage, a hole detection and recovery process is applied locally to neighboring cells.

Weitao et al. [6] discussesconnectivity problem in Wireless Sensor Networks. A star deployment strategy scheme is proposed to improve connectivity probability for Wireless Sensor Networks. This paper presents star deployment strategy model enhance the connectivity probability based on batch based deployment model, deployment distribution for sensor node and selecting of deployment point. Star deployment networks have a significant local and global connectivity probability advantage compared with random and Poisson networks. Simulation experimental setup shows that the proposed method improves the performance of the network and connectivity probability compared with other existing deployment methods. Rabie et. al. [7] consider sensor deployment problems such as connectivity and coverage and how these problems can be solved using the circle packing approaches in terms of small scale problems.This paper proposes a novel algorithm called Sequential Packing-based Deployment Algorithm (SPDA) for the deployment of heterogeneous sensors, which increase the coverage of the region of interest and connectivity of the deployed sensors. You-Chiun et. al. [8] considers the sensing field as an arbitrary shaped region possibly with obstacles of any shape.This paper discusses partitioningof the given sensing field and deployment of sensors in various regions with boundaries and obstacles.

Nor Azlina et al. [9]proposed a common method to solve the coverage problem in WSN. Coverage is the most important issues in WSN.This factor determines the quality of service of wireless sensor network and coverage problem also influences the life time of a network. Coverage problem occurs in WSN due to mainly three reasons 1) Lack of number of sensor nodes to cover the given targeted area. 2) Random deployment of sensors 3) Sensing range of sensor is limited. To solve coverage problem three deployment techniques are proposed.Force based deployment strategies rely on the sensors mobility, using virtual repulsive and attractive forces.The sensors are forced to move away or towards each other so that full coverage is achieved. The sensors will keep moving until equilibrium state is achieved where repulsive and attractive forces are equal and thus they end up cancelling each other.

Grid points are used in two ways in WSN deployment, either to measure coverage or to determine sensors positions.Computational geometryis most frequently used in WSN to solve coverage problem.The most commonly used computational geometry approaches are Voronoi diagram and Delaunay triangulation. These two approaches are used to estimate the best case and worst case coverage. Voronoi diagram can be used as determining WSN coverage; with the sensors act as the sites. Delaunay triangulation is used on how to add sensor after initial deployment so that the coverage is increased.Benyuan Liu et. al. [10]considers grid-based sensor networks where sensors are deployed in a square lattice and random Sensor networks where sensors are deployed at random locations in a field. The paper characterizes the asymptotic behaviors of the coverage and detectability of sensor networks. The requirements of the sensor density to achieve target area coverage can be derived. Grid-based sensor networks provide efficient area coverage, and random networks offer robustness and reliability upon sensor failures at the cost of coverage redundancy. For a random sensor network, it is observed that less number of sensors is covered by other sensors when the density is less. NasimKhazan et al. [11]proposesa method to optimize the number of sensors, to lower power consumption and to determine node placement to support a distributed sensor network in asymmetric area. The algorithm recognizes whether a node is located within convex hull or not. This method reduces the number of sensor required to cover the target area and also reduces energy consumption. GaoJun Fan et al. [12]proposeto solve the point-coverage problem in wireless sensor network where a given set of n points requires to be covered in the two-dimension with k sensors. The main Objective of this work is to place less number of sensors such that coverage points in the field can be covered by at least k sensors. By combining Computational Geometry and Combinatorics techniques, the paper demonstrated an important relationship between coverage points and sensors, and developed an efficient algorithm called the method of non-exact placement for 1-coverage problem. This approach can easily solve k-coverage problem based on 1-coverage.

Zhang et al. [13], proposed an effective wireless sensor network deployment method. By using K means clustering algorithm, initial number and location of the mobile nodes can be determined and selected effectively. Simulation results show that the method can cover all the fixed nodes with the least number of mobile nodes, and initialize the location of each mobile node to repair the failed nodes in assigned time.Li-Mei Penget al. [14] discussed several efficient node deployment schemes for AOFSN (All Optical Fiber Sensor Networks) networks which require regular and simple sensor node deployment, so as to construct a simple but efficient sensor network topology. The efficiency of the node deployment schemes was mainly evaluated in terms of the sensing coverage ratio under the requirement of minimum overlapping ratio, so as to reduce the sensing cost. The close-packing and closest-packing based node deployment schemes, called CPSD and CestPSD, were proposed for the two dimensional AOFSN applications. The CestPSD showed to have the highest sensing efficiency, with the highest coverage ratio, no overlapping and lower node density. Then, the CestPSD scheme was extended to the three dimensional AOFSN applications and it can also achieve a high coverage ratio which approaches to the full coverage while maintaining no overlapping ratio.James et al. [15] considered the Bus Sensor Deployment Problem (BSDP) to select the bus routes on which sensors are deployed, and Chemical Reaction Optimization (CRO) to solve BSDP. This paper proposed a novel air pollution monitoring system by deploying sensors in a public transportation system. A new optimization problem is formulated for selecting the buses to deploy the sensors, called BSDP. The CRO is used to solve this optimization problem. Simulation results show that the proper selection of coverage threshold has great impact on the final optimization result, the total number of sensors required, the area coverage percentage, and data accuracy.Zhaohui et al. [16] consider sensor deployment problem for collaborative target detection. The paper proposes a data fusion centric target detection model that forms effective collaborations between sensors, and analyzes the relationship between the density of sensors and the fusion range. A clustering based deployment algorithm is proposed based on density of sensor to find out the number of sensors requires and locations to cover the target area. The simulation results show that proposed algorithm can find smaller number of sensors and their locations to achieve the target area compare with generic greedy heuristic algorithm.

Seema et al. [17]discusses the existing techniques of wireless sensor network deployment. The paper focuses on the detection and removal of the communication hole while deploying sensors in a heterogeneous wireless sensor networks. While deploying sensors in wireless sensor network three types of holes will be evolved. Communication holes are area not covered by any node, due to random deployment creating gaps, presence of obstructions, and node failures. Routing holes are created in sensor network where either nodes are not available or the available nodes cannot involved in the routing of the data due to gaps in sensor deployment or failure of sensor nodes. Jamming holes are created due to when objects are equipped with the jammers that capable of jamming radio frequency being used for communication amid the sensor nodes during the application tracking.The paper discusses a First virtual force based (vfa) algorithm as sensor deployment method to increase area of coverage in given region of interest. After an initial random deployment of sensors, vfa increases the sensor coverage using a combination of attractive and repulsive forces. In vfa algorithm, it finds the virtual position to where to move the sensor. Once determined the position physical movement of sensor is carried out to redeploy the sensors at detected position. In the basic protocols method, nodes move repeatedly to reach the final destination. In each of the iteration,sensor detects communication holes and calculates the locations to remove those holes by using Voronoi diagram. In the virtual movement protocols method, it determines the target locations and then moves to the virtual locations with the sensors which would be their neighbors if they had actually moved. Indra et al. [18] discusses coverage holes reduction in wireless sensor networks. The efficiency of network depends on coverage area and connectivity between nodes. To solve the connectivity problem, the possible network partitions are detected earlier by detecting the cut-vertices which are the critical nodes in the network whose failure leads to network partition. These points are identified through Cut-vertex determination algorithm. The failure handler set, which is used to restore the connectivity failure due to failure of any cut-vertex, is determined by Connected Dominating Set algorithm. The connectivity problem in the network is resolved by utilizing the controlled mobility feature of the sensor nodes. The coverage gaps are introduced in the network due to the total movement of such failure handler set. To minimize the number of coverage holes, the failure handler is placed nearer to the position of failed node without affecting the connectivity. This method is named as Minimum Movement Technique (MMT). To restore the connectivity, the nodes in the failure handling set move towards the feasible points. These points are calculated by MMT. The Simulation results show that the proposed MMT minimizes the total mobility distance required to reach these points and the coverage holes in the network.

Hu Yu et al. [19]considers redeployment problem in Wireless Sensor Network to increase the performance and lifetime of the network.The paper formulates the event occurrence probability distribution of redeployment problem in WSN as Binomial Distribution and use Bayesian Estimation to estimate the probability of each node’s sensing area. The proposed MFCSU-static algorithm solves the problem under static routing schemes, increases the performance of the network and improves the network lifetime.Sanjeev et al. [20] discusses estimating network life in heterogeneous Wireless Sensor Network. Deployment of sensor nodes in a sensor network is an important task as deployment should be optimum to increase network lifetime. In Wireless Sensor Network, there are two types of networks, namely, homogeneous and heterogeneous. In heterogeneous network, sensor nodes are different in term of battery energy and its functionality. Deployed sensor nodes are heterogeneous on the basis of energy they dissipate while transmitting data. For estimating energy dissipation by nodes, the paper proposes communication model. Based on energy dissipation by nodes, the best and worst case scenario of deployment of sensor nodes could be analyzed. Simulation setup results provide benefits of heterogeneity.Chu-Fu Wang [21] considered a sensor deployment problem of a hierarchical cluster-based wireless sensor network, Sensor clusters distributed over a targeted area. A network optimization problem called the OSCDP (Optimum SensorCluster Deployment Problem) is formulated. Given a fixed quantity oftotal energy power of sensors for deployment and a staticrouting scheme, the OSCDP calculates the amountof energy deployed in each cluster, such that the networklifetime is maximized.

An exact algorithm to calculate the optimum solution of the OSCDP is also proposed. The simulation results show that proposed algorithm performs better than other conventional deployment schemes.

Salah et al. [22] discusses the Sensor deployment strategies. These strategies can be classified into two classes which are deterministic and autonomous deployment. In the deterministic deployment, the deployment field is assumed accessible as well as the number of sensors is small to be manually deployed in specific locations. On the other hand, with large number of sensors and in inaccessible fields, the random deployment to the sensors turns out to be the solution. However, random deployment requires sensors to be automatically located for coverage and connectivity purposes. In addition, after a period of time, the sensors topology might change due to some sensor hardware failure or deplaned energy. Therefore, redeployment process is required. Yet, energy consumption for sensor mobility and load balancing are important factors to be considered during the initial deployment and redeployment processes. This paper proposes two deployment algorithms to manage these situations.The Cluster-Based Redeployment Algorithm (CBRA) and Energy Aware Relocation Algorithm (EARA) achieve sensor energy balancing and small amount of deployment energy consumption.Kriengsak et al. [23] proposed an efficient node deployment strategy in sparse sensor networks called DATFM/DF (Data Acquisition and Transmission with Fixed and Mobile node with deliberate Deployment of Fixed nodes). The performance of sensing and data gathering becomes significantly low in a sparse network. To solve this problem, the paper proposed a DATFM strategy which uses two types of sensors, fixed sensor and mobile sensor and its performance depends on the position of fixed nodes. Based on analysis of DATFM, five guidelines are provided to deploy sensor nodes, and then another deployment called DATFM/DF is proposed to improve the efficiencies of sensing and data gathering. Simulation experimental setup is conducted to evaluate performance of the DATFM/DF and compare its performance with DATFM, Routing Assisted by Moving Objects method, uncoordinated mobile nodes method.Chuyu et al. [24]proposes a virtual grid partition deployment method and implements the parallel particle swarm optimization (PPSO) algorithm for the mobile nodes movement control strategy to guarantee the reliability of the data transmission. The experimental results show that the movement control strategy can not only raise the coverage rate of network, but also solve the defects of instable communication and the low utilization ratio of the neighbor nodes caused by the random movement mobile nodes.

III. Conclusion

The sensor deployment methods are very critical in the overall performance of the wireless sensor networks. This paper surveys the different sensor deployment schemes and makes a comparison among them.

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