Fault Tolerance, Coverage and Routing in Wireless Sensor Networks: A Survey

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Abstract: Wireless sensor networks is an emerging research field. Wireless sensor network monitors and route the data in a particular area of interest and finds the several applications in military, scientific, biological areas. Coverage and routing are one among the prime area of research in wireless sensor networks and it plays a vital role in the quality of service that can be provided by a particular Sensor Network. In other words, how good, how far the area is under observation of the wireless sensor nodes and how efficiently data is being routed. The aim of current research is to discuss the various strategies by which the various issues like energy efficiency, power consumption, number of nodes, coverage area density, algorithm used, residual energy, fault tolerance related with coverage of WSN are tackled The efficiency of a wireless sensor network can be judged by the levels of coverage, power consumption and connectivity provided by them.

Keywords: *Wireless sensor nodes, Coverage, Routing, Wireless sensor nodes, Algorithms*

I. INTRODUCTION

Due to the broad set of application, the field of wireless sensor networks (WSN) emerges during last few decades. The application includes surveillance, tracking, traffic control, detection of intruders, disaster prevention etc. The WSN consists of one or more base stations and wireless sensor nodes. The nodes are used to monitor the area of interest or region of interest and detect parameters like distance, temperature etc.

To consume less power, the nodes are made very small in size. The intra-communication between the node is through RF signal with the help of in–built antennae. These nodes have four modes of operation. In active mode, sensor monitors the environment and make communication with other sensors. In sleep mode, a sensor neither monitors nor communicates with other nodes. Sleep mode of sensor is employed because of several constraints of sensor nodes like battery power, communication and computation capabilities. When a node awakes from sleep mode it enters the *listen mode*, where it listens to the environment to receive the signal otherwise it will enter the *wait mode*, till the signal comes. The Coverage is the most attracted field in WSN. The aim of Coverage is to cover the whole area of interest or region of interest (RoI) by at least one sensor node. It is the measure of quality of service (QoS). There is lot of work contributed towards coverage related issues in WSN. The work includes covering each point in the (RoI), surveillance and coverage versus connectivity issues when WSN is deployed. Much of the work is contributed to other applications as well but the main issue always remains is coverage. It is known that the sensor nodes have limited amount of energy so in order to make sensor nodes efficient power consumption has to be taken into consideration.

When the sensors are deployed, the algorithm is selected which will run through the network constituting the nodes in order to check the efficient coverage exists in the area. The algorithms are of two types one is centralized and the other is distributed algorithm. A centralized algorithm is that which runs on one or more nodes in a centralized location usually near the data sink in the region as shown in Fig. 1. A distributed algorithm runs in many nodes throughout the WSN as shown in Fig. 2. Distributed algorithm involves working together on multiple nodes to solve a computing problem. The special case of distributed algorithm is called localized algorithm and is made to run in many nodes. The localized algorithm implies that all or many nodes run the algorithm separately on information that each node gathered. Both algorithms spread the workload evenly than centralized algorithm. Distributed algorithms and localized algorithms are more complex than centralized algorithms because they are run on more than one nodes.

Fig. 1 Centralized Algorithms

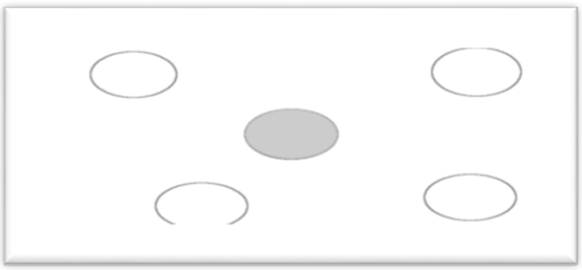

Fig. 2 Distributed Algorithms

The authors in [3] have developed centralized algorithm and distributed algorithm for k- coverage network and the result concludesthat the centralized algorithm and distributed algorithm returns a near optimal solution. The authors in [4] have run centralized and distributed version of their algorithms which consumes less energy than comparable algorithms. The authors in [13] developed a localized algorithm for barrier coverage and the results show that Localized Barrier Coverage Protocol (LBCP) provides near optimal performance while providing barrier coverage most of the time. The protocol does break down as the width of the barrier increases.

II. STRATEGIES FOR TACKLING COVERAGE PROBLEMS.

The various strategies that take place during deployment for solving coverage problems in WSN are:

a. Force based strategy
b. Grid based strategy
c. Computational Geometry based strategy

The description of each of these is as:

2.1. Force based strategy

The force based deployment strategy is based on the mobility of the sensors by using virtual attractive and repulsive forces. To achieve the full coverage, the nodes are forced to move towards or away from each other. Till the equilibrium is achieved i.e. when the attractive and repulsive forces are equal to each other and they cancel each other and total energy decreases with time, the sensor nodes keep on moving. The sensors and the object in the region of interest exert some virtual repulsive forces that push the sensors away from each other and also from the object so that their sensing area doesn't overlap. These sensors keep on moving until they reach the equilibrium state which is recognized by the decrease in the energy with time. The problem with this strategy is that it does not cover network connectivity.

2.2. Grid based strategy

In case of WSN deployment, these grid based strategy are deployed in two ways: either to determine sensor positions or to measure coverage. In this case the region of interest (ROI) is divided into square grids and the sensor can be placed only at the Centre of the square. There are three types of grids which are mainly used in networking. They include triangular lattice, square grid and hexagonal grid. Triangular lattice is the best among the three because it has the smallest overlapping area which implies that the grid requires the least number of sensors. The coverage in this strategy is estimated by the ratio of grid points covered to total no. of grid points in the ROI. The accuracy of the estimation is determined by the size of the grid. Smaller the grid size better is the accuracy of estimation. These grid points can also be used in predetermine deployment method, where in the sensor nodes are placed carefully at the designated grid points.

2.3. Computational Geometry based strategy

Computational geometry based strategy is often used in coverage optimization in WSN. Voronoi diagram and Delaunay triangulation are the most commonly used computational geometry approach.

2.3.1 Voronoi Diagram. The Voronoi diagram has been used as a model in various coverage algorithms. In case of sensor network this Voronoi diagram is a diagram of boundaries around each sensor so that every point that is within a sensor's boundary is closer to that sensor than any other sensor in the network [29], [30], [32].

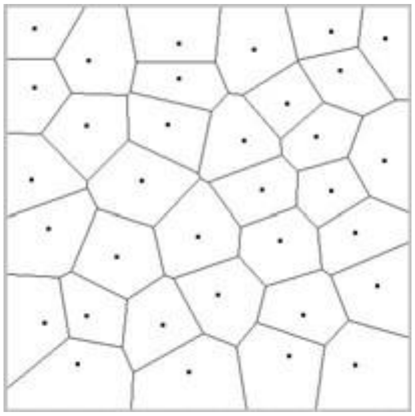

Fig. 6 Voronoi Diagram

Let $P = \{p1, p2, \ldots, pn\}$ be a set of points in a given plane. Then a Voronoi region $V(pi)$ is the set of all points which are closer to pi than any other point. Figure 6 shows a typical Voronoi diagram.

2.3.2 Delaunay Triangulation

There is a close relation between Delaunay triangulation and Voronoi Diagram. A Delaunay triangulation is defined as a triangulation of an area such that no other points in any triangle are located within the circumscribed circle of any other triangle in that area.

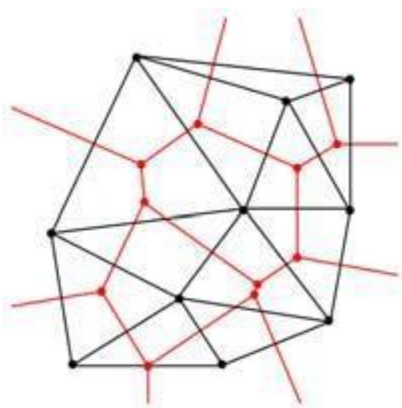

Fig.7 Delaunay Triangulation

This Delaunay triangulation can be made from Voronoi Diagram by drawing edges that connect the sensors that border one another. Figure 7 shows the example of Delaunay triangulation. This Delaunay triangulation is used to determine which two sites are closer to each other simply by finding the shortest edge in the triangle [35].

III. APPROACHES IN WIRELESS SENSOR Network Coverage

The wireless sensor network coverage faces huge challenges due to limited resources. To conserve network coverage various lifetime optimization and energy conservation strategies are presented. Clustering and virtual backbone are main approaches for network coverage. There are various approaches for coverages in WSN and which are as:

3.1 Worst or Best Case Coverage

The coverage in WSN can be considered either as best case or worst case coverage due to the reasons in [31], [33], [34]. In case of best case highly covered areas are considered while in case of worst case, lower coverage areas are considered. In best case the farthest distance that an agent must travel from the closest sensor along the path is considered while in worst case coverage the nearest distance that an agent must come to any sensor while travelling along the path is considered.

3.2 Disjoint sets

The disjoint coverage sets is a subset of sensors which is capable of covering the entire field of interest by itself. At a given time only the particular subset of sensors which are in the set cover are active and the other sensors which are not activated in the cover set are in sleep mode. This is done to preserve the energy. This approach where necessary sensors are turned off not only extends the network lifetime but also maintains the necessary coverage while preserving energy of the sensors in the given network.

3.3 Probabilistic Sensing

Probabilistic sensing approach is different from deterministic sensing approach. The deterministic sensing approach takes into account the effect of distance on the sensing ability of the sensor. In probabilistic sensing the concentric circles drawn around the sensor location are used to represent the change in detection probability with distance. Here each circle represents the probability of correctly receiving a signal with strength above the receiving threshold at distance equal to the radius of the circle.

IV. RELATED WORK

The aim of current research is to discuss the various strategies by which the various issues like energy efficiency, power consumption, number of nodes, coverage area density, algorithm used, residual energy, fault tolerance related with coverage of WSN are tackled The efficiency of a wireless sensor network can be judged by the levels of coverage, power consumption and connectivity provided by them. The coverage problem in WSN has been studied extensively in [1], [2], [3], [4], [5], [6], [7], [8], but the current studies suggest the coverage efficiency in terms of network lifetime and fault tolerance needs to be improved. Most of work is done on coverage density especially when combined with energy efficiency and connectivity [3], [16], [18], [20], [21]. Constructing a connected fully covered, fault tolerant and energy efficient sensor network is valuable for real world applications due to the limited resources like cost, number of sensor nodes and energy.

V. ROUTING ALGORITHMS

Population-based metaheuristics deal with a set (i.e. a population) of solutions rather than with a single solution. The most studied population-based methods are related to Evolutionary Computation (EC) and Swarm Intelligence (SI). EC algorithms are inspired by Darwin's evolutionary theory, where a population of individuals is modified through recombination and mutation operators. In SI, the idea is to produce computational intelligence by exploiting simple analogues of social interaction, rather than purely individual cognitive abilities. Several optimization algorithms inspired by the metaphors of swarming behavior in nature are proposed. Ant colony optimization, Particle Swarm Optimization, Bacterial foraging optimization, Bee Colony Optimization, Artificial Immune Systems and Biogeography-Based Optimization are examples to this effect. The analysis of three algorithms Particle swarm optimization (PSO), Ant Colony Optimization and Greedy Algorithm is done using NS2 platform to check the performance of the algorithms. The algorithms are compared with each other varying number of nodes (NN) and number of Point of Interests (NP). Here in the present work the number of nodes equal to 50 and point of interests equal to 10. Average residual energy and length of the set are taken into account and inferences prove Particle Swarm Particle (PSO) to be more efficient than Ant Colony Optimization and Greedy Algorithm as depicted in Fig. 8 and Fig. 9.

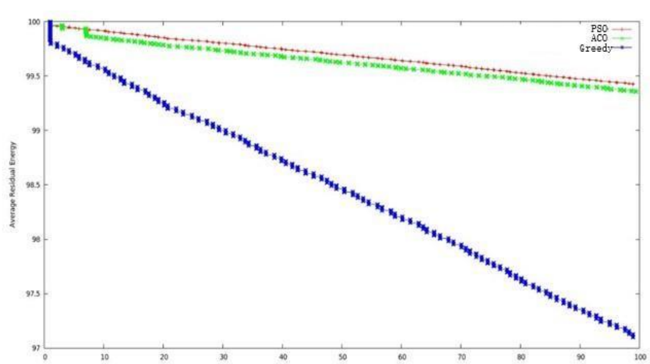

Fig. 8 Average Residual Energy

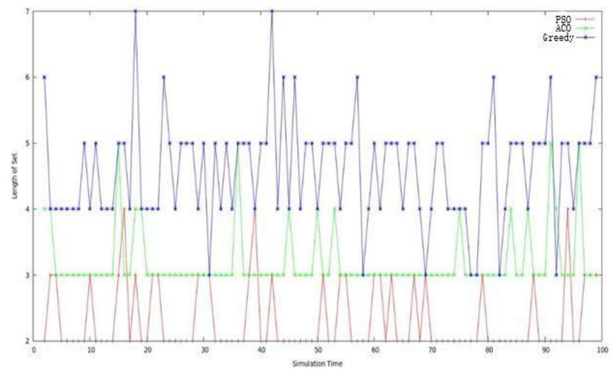

Fig. 9 Length of nodes in a set

Future Work

The current research is focused on tactics employed in order to increase the network lifetime. It is argued that PSO is both computationally efficient and also outperforms the conventional and existing algorithm in maximizing the network lifetime. Such more techniques and tactics are to be employed in this methodology to decrease the consumption of residual energy of sensor nodes in order to increase network lifetime.

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