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A Survey on Node Deployment Approaches in Wireless Sensor Networks

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Abstract: A Wireless Sensor Network (WSN) is composed of a large number of densely deployed sensor nodes. These nodes are powered by battery of limited energy for its operations and these batteries are not easily replaceable. So network lifetime is the main challenge of Wireless Sensor Networks. This paper represents a survey on various node deployment approaches used for energy conservation of the nodes to enhance the lifetime of Wireless Sensor Networks.

Keywords: WSN, node, deployment, co-operative node, relay, scheduling

I. INTRODUCTION

A sensor node is made up of five basic entities: sensors, processor, memory, radio, and power entity. They may also have application dependent additional components such as location finding system, a power generator and a mobilizer.

Sensors are electronic devices that are capable to detect environmental conditions such as temperature, sound, chemicals, or the presence of certain objects. They send detected values to the processor which runs the sensor operating system and manages the procedures required to carry out the assigned sensing task. This processor retrieves the application code from the memory unit which stores also the operating system and the sensed values [5].

The key element in a sensor node is the power entity which is generally composed of a couple of standard AA batteries. The size of these batteries usually determines the size of the sensor. Further, studies are currently under way to replace/integrate battery sources with some power scavenging methods such as solar cells. In fact, there are some limits about the actual effectiveness of such methods. For example, solar cells do not produce much energy indoor or when covered by tree foliage [2].

So various energy conservation approaches are investigated and proposed by various researchers. One of the approaches is node deployment. Placing of sensor nodes in the sensor field is called node deployment. There are two types of node deployment. e.g. Random deployment and planned deployment.

In some applications like battle field surveillance, border area surveillance etc. nodes are deployed randomly, where the exact location of the nodes is not predetermined. The nodes are just thrown by the airplane in the sensing field. For some specific applications like bridge monitoring, precision agriculture etc. the nodes are deployed in planned manner, where the position of a node is predetermined. In this paper various node deployment approaches for conserving energy of the nodes are used. That proposed deployment of spare nodes, co- operative nodes and relays and scheduling of the nodes into active / sleep states.

WSN lifetime is "the interval of time, starting with the very first transmission in the wireless network during the setup phase and ending when the percentage of reports from sensor nodes fall below a specific threshold, which is set according to the type of the application." [10].

Rest of the paper is organized as follow. Primary objectives of node deployment are given in section II. Section III is the discussion on various node deployment approaches. Finally the whole work is concluded in section IV.

II. PRIMARY OBJECTIVES OF NODE DEPLOYMENT

The positioning of nodes in a sensor network has received a noticeable attention in research. The localization and deployment are the fundamental issues. There are following primary objectives for sensor node deployment.

1) Area Coverage

The objective of maximal coverage of the monitoring area has invited the most attention in the literature. As mentioned earlier, optimized sensor placement is not an easy problem, even for deterministic deployment scenarios. Complexity is often introduced by the quest to employ the least number of sensors in order to meet the application requirements and by the uncertainty in a sensor's ability to detect an object due to distortion that may be caused by terrain or the sensor's presence in a harsh environment. [8].

2) Network Connectivity

Another objective in WSN design is the connectivity of the network. We say that the network is connected if any active node can communicate with any other active node (possibly using other nodes as relays). Network connectivity is necessary to ensure that messages are propagated to the appropriate base station and the loss of connectivity is often treated as the end of network life. This property is strongly connected with coverage and energy efficiency (the value of transmission range may vary according to transmission power). The relationship between coverage and connectivity results from sensing and transmission ranges. If the transmission range of a node is much longer than its sensing range then connectivity is not an issue, because the coverage ensures there is a way to communicate. Situation is different if the communication range is less than sensing range.

3) Network Longevity

One of the major challenges in the design of WSNs is the fact that energy resources are very limited. Recharging or replacing the battery of the sensors in the network may be difficult or impossible, causing severe limitations in the communication and processing time between all sensors in the network. Note that failure of regular sensors may not harm the overall functioning of a WSN, since neighboring sensors can take over, provided that their density is high. Therefore, the key parameter to optimize for is network lifetime – the time until the network gets partitioned in a way that is impossible to collect the data from a part of the network [7].

4) Data Fidelity

Ensuring the credibility of the gathered data is obviously an important design goal of WSNs. A sensor network basically provides a collective assessment of the detected phenomena by fusing the readings of multiple independent sensors. Data fusion boosts the fidelity of the reported incidents by lowering the probability of false alarms and of missing a detectable object. Increasing the number of sensors reporting in a particular region will surely boost the accuracy of the fused data. However, redundancy in coverage would require an increased node density, which can be undesirable due to increased *cost* or decreased survivability (the potential of detecting the sensors in a combat field) [7].

5) Energy Efficiency

This criterion is often used interchangeably with lifetime. Due to the limited energy resource in each sensor node, we need to utilize the sensors in an efficient manner so as to increase the lifetime of the network. There are at least two approaches to the problem of conserving energy in sensor networks connected with optimal placement. The first approach is to plan a schedule of active sensors that enables other sensors to go into a sleep mode utilizing overlaps among sensing ranges. The second approach is adjusting the sensing range of sensors for energy conservation

6) Node Density (Number of Nodes)

It represents the number of sensor nodes per square meter. This point could be easily managed in manual placed nodes. However, it seems to be difficult to manage in case of randomly deployed WSNs;

More the sensors are used the higher is the cost. Optimal node deployment approaches are considered to achieve the specified goals with minimum cost [4].

7) Fault Tolerance and Load Balancing

Fault tolerant design is required to prevent individual failures from shortening network lifetime. Many authors focus on forming *k*-connected WSNs. *K*-connectivity implies that there are *k* independent paths among every pair of nodes. For $k >= 2$, the network can tolerate some node and link failures. Due to many-to-one interaction pattern *k*-connectivity is especially important design factor in the neighborhood of base stations and guarantee certain communication capacity among nodes.

III. NODE DEPLOYMENT APPROACHES

In wireless sensor networks, battery drainage and network lifetime are the most serious problems. Proper management and scheduling of nodes setup an environment where energy is consumed only in useful data transmission to the sink by compressing the redundant data. So many researchers have done work to utilize the battery power by designing various deployment approaches to extend the lifetime of network. Here, a brief literature survey is presented that is focused on various node deployment approaches used to conserve energy the energy of the network to extend the lifetime of wireless sensor networks.

Random Deployment: In the random deployment, the nodes are randomly scattered with respect to the radial and angular directions from the BS as shown in the fig. 1(a) Sensors in the field have equal probability of being positioned independently of the other sensors. Though the, sensor nodes are homogenous, they have some equal parameters like energy, bandwidth etc., but uneven distance among them creates problem. This introduces data latency and uneven energy dissipation throughout the network.

Square Grid Deployment: In this deployment scheme, total field is covered with regular square shaped cells as shown in fig. 1(b) In a grid deployment the amount of connectivity and resilience of the sensor nodes against the adversaries when they are deployed in grid fashion. Grid deployment is conducted by dropping sensors row-by row using a moving carrier.

Tri-Hexagon Tiling: Tri-hexagon-tiling (THT) is formed by using a hexagon and six equilateral triangles with each edge of the hexagon. This pattern can be drawn by placing a hexagon as the centre and other six hexagons placed at each corner of the centre hexagon and as shown in fig. 1 (c) Sensors are placed at every grid point [3].

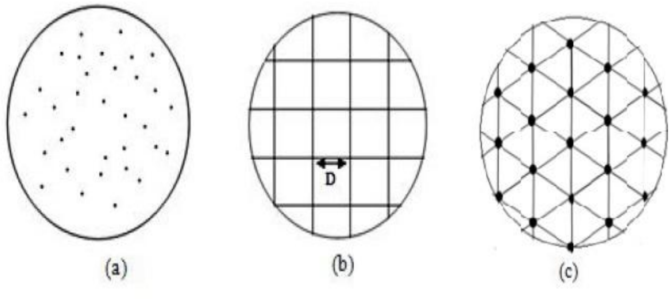

Fig. 1 Node deployment techniques (a) Random (b) Grid (c) THT

Group Based Deployment: Group deployment may be used in order to improve the coverage of the target region by sensors, as it provides more control over the physical distribution of sensors, and also a convenient way of carrying out the deployment, the main motivation for considering group deployment from the point of view of key distribution is the fact that the partial location knowledge it provides can be used in order to improve the connectivity of the network.

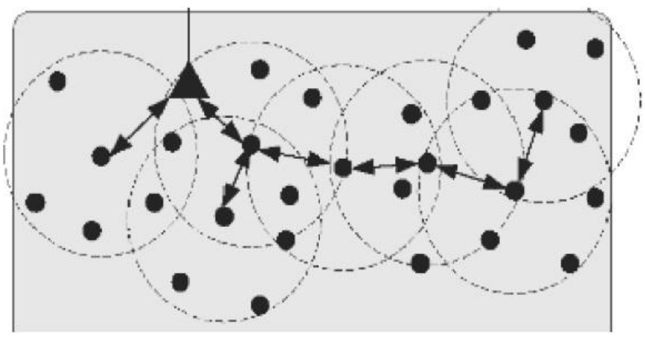

Fig. 2 Group based deployment

Grid Group Deployment; When nodes are deployed in a region, all nodes need not communicate with all other nodes in the network. Due to limited power, all nodes cannot communicate with all other nodes. So we divide the entire region into equal-sized squares or grids this scheme has the advantage that all nodes within a particular region can communicate with each other directly and nodes which lie in a different region can communicate via special nodes called agents which have more resources than the general nodes [3].

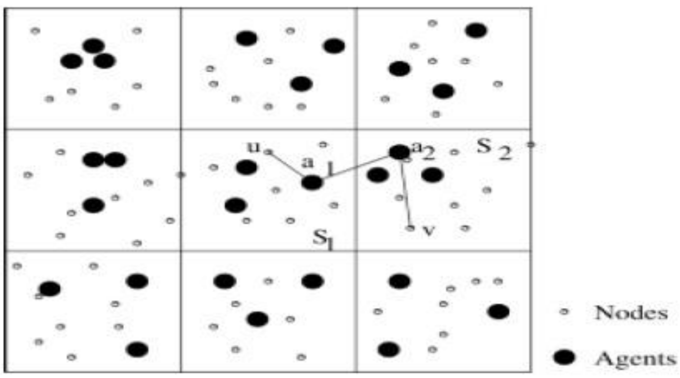

Fig. 3 Grid group deployment

An approach for tolerating faults in a two-dimensional mesh architecture. This approach is based on adding spare components (nodes) and extra links (edges) such that the resulting architecture can be reconfigured as a mesh in the presence of faults. Cost of the fault-tolerant mesh architecture is optimized by adding about one row of redundant nodes in addition to a set of **k** spare nodes (while tolerating up to k node faults) and minimizing the number of links per node. The degree of the fault-tolerant mesh is **k+5** for odd **k,** and **k+6** for even **k [**6**].**

Distribution of redundant sensor nodes in the network can prolong the life time of network. The optimal distribution of redundant nodes is achieved by dividing the sensor area into Regular Hexagonal Cells (RHCs) and predetermining the position of the sensor nodes in the monitoring area. Centralized monitoring is used for the nodes. If in a cell there are more than one node then one node goes in sleeping and after a node is depleted the redundant node wake up and assumes the role of previous node. Hence there is slightly improvement in energy dissipation. [1].

Deployment of both sensor and relays in the network reduces the work load of sensor nodes. Relays are deployed in controlled manner. Among the sensors DF (Decode & Forward) protocol is employed. . An algorithm is designed to determine, which sensor should cooperate and what amount of power is to allocate for operation. Best relay is chosen according to average SNR. As relay node has not sensing capability and it can only receive and transmit the incoming data. Hence energy is conserved of WSN [11].

Deploying some redundant nodes altogether with main nodes of the network before start up phase. The nodes can be used as helper to highly loaded nodes or replace dead nodes. During setup phase Base station collects the Ids of each node.

So Base station knows which one node is basic node or spare node. Centralized monitoring is used in this scheme. Initially spare nodes are not active the network keeps them for future use [9].

A two-tiered distributed relay node placement strategy used to achieve connectivity under the constraint of the expected network lifetime, while the number of relay nodes is effectively decreased. As some relay nodes can consume much more energy due to heavier traffic, affecting the balanced lifetime of the whole network. In this node placement strategy, by dynamically adapting the location and data amount of relay nodes, the sensor nodes and relay nodes consume the same amount of energy in each round of data transmission, thus ensuring a more balanced network lifetime [12].

Deployment of nodes with different node densities for regions near to sink and far from sink. So as to equalize the energy consumption rates off all the nodes. As energy depletion rate and traffic intensity are different for nodes close to sink and away from sink [13].

IV. CONCLUSION

This paper describes the basics of various node deployment approaches used to enhance the lifetime of wireless sensor networks. Primary objectives for node deployment are mentioned. It is concludes that proper management of nodes And scheduling of the redundant nodes into sleep and active modes conserve the network energy to some extent. Also redundant data transmission gets reduced doing this

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