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Role of Clustering in Achieving Energy Efficient Coverage in Wireless Sensor Network : A Short Review

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Abstract - *Wireless Sensor network (WSN) comprises of tiny sensor nodes with very limited initial energy and are deployed in sensing area of particular interest to fetch necessary environment data and sending it back to end user via base station. One of the major issue in WSN is energy efficient coverage in which major goal of routing protocol is to observe every possible physical space without any loss of data due to lack of energy or power in sensor node. Such situation may occur due to over burden on nodes when unbalanced clusters are formed leading to extra communication overhead. In this Paper we are discussing overview of WSN in first half and in second half of paper energy efficient coverage problem along with some popular routing protocol covering this issue has been discussed.*

Key Words: Wireless Sensor Network , Coverage , Clustering , Routing Protocol

1. Introduction

A Wireless Sensor Network (WSN) is a collection of tiny sensor nodes which are interconnected by wireless communication channels. Each sensor node is a small device that can collect data from its surrounding area, carry out simple computations and communicate with other sensors or with the base station (BS).The nodes are deployed in a monitoring field as shown in the following Figure 1.1 [1] and each of them capture data and sends data back to the base station or sink. Data are routed back to the sink by following direct or multi-hop dedicated path. The base station may communicate with the task manager via Internet or satellite. The information flow in typical WSN is explained in Figure 1.1. The design of WSN is influenced by many factors such as initial energy, scalability, production costs, sensing environment, network topology and power consumption of sensor nodes. Therefore designing wireless sensor network is a very challenging task when coverage along with network lifetime is considered. There exit a tradeoff between coverage and network lifetime because if we consider full coverage then network lifetime get reduced and if we try to increase network lifetime then coverage gets reduced.

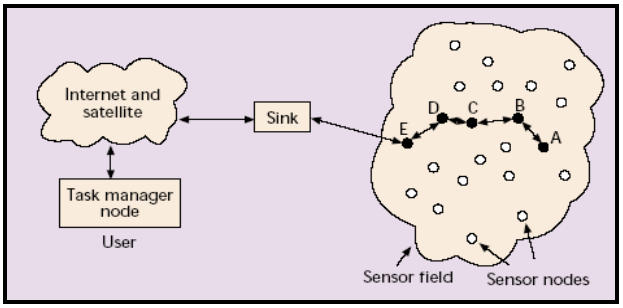

Figure 1.1: Information flow in wireless sensor network

1.1 Basic Components of Sensor Node

In any wireless sensor network, sensor node consists of four basic components, as shown in the following Figure 1.2 , a sensing unit, a processing unit, a transceiver unit, and a power unit. They may also have additional application dependent components such as a location finding system, power generator and mobilize.

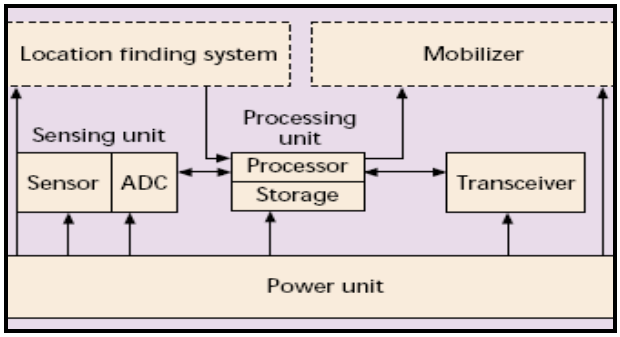

Figure 1.2: The components of a wireless sensor node

2. WSN vs ADHOC Networks

Although many algorithms and protocols have been proposed for traditional wireless adhoc networks like MANET, they are not well suited for wireless sensor networks because of the following differences between wireless sensor networks and ad-hoc networks like MANET [1]:

1) The number of wireless sensor nodes in a typical WSN are much higher than the nodes in a simple ad-hoc network.

2) Sensor nodes are densely deployed and the rate of node failure is much higher mainly due to limited initial energy at the time of deployment.
3) The topology of a WSN changes very frequently for specific applications.
4) Sensor nodes mainly use a broadcast communication, whereas most adhoc networks are using point to point communications.
5) Wireless Sensor nodes are limited in energy, computation and storage memory.
6) Absence of unique and global identification (ID's) because of the large amount of overhead and large number of nodes taking part in WSN resulting in inability to maintain database of sensor nodes.

Since wireless sensor nodes have limitation in terms of energy supply and bandwidth requirement for data transfer, such constraints when combined with one of the most important challenge in WSN, the coverage problem which includes monitoring efficiently and continuously a geographical area of interest, have posed many serious challenges to the design and management of wireless sensor networks. These challenges demands energy awareness at each layers of networking protocol stack. At the network layer, our main aim is to propose best energy efficient route setup and reliable transmission of data from the wireless sensor nodes to the base station so that the network lifetime could be maximized while maintaining the coverage for a longer duration. Hierarchical protocols help to develop clusters of the nodes thus initiating provisioning of the cluster head (CH). There might be a situation that presence of multiple sensors nodes may result in generation of same data within the vicinity of same sensing area, such coverage redundancy should be exploited by the new routing protocols in order to improve energy utilization and bandwidth utilization of WSN.

3. Coverage Issue and Clustering in WSN

In this section ,the notion of coverage is introduced very briefly and then the previous studies related to energy saving approaches towards cluster based data gathering in wireless sensor network are summarized.

Coverage problem is the basic problem of any type of WSN, and is the evaluation criteria of measuring sensor network quality of service (QoS). The core problem of sensor network coverage is "how strong that sensor network monitoring ability of observation in physical space?" The coverage problem is centered around one fundamental or basic question [2]: "How well do the sensors observe the physical space?" On some occasions, we need to consider about k coverage(Given any integer k, a monitored region R by WSN if and only if each point in R is covered by at least
k sensors). For example, in wireless sensor networks, because energy depletion, harsh environmental conditions, and malicious attacks may result in node failures or become inoperative at any time, it is desirable to have higher degrees of coverage. The goal is to include each location in the physical space of interest within the vicinity or sensing range of at least one sensor node. Depending on different objectives and application requirements, there are different factors analyzed in designing coverage schemes. In this way, a fair comparison among existing scheme has to be taken into consideration, since these factors affecting the coverage performance of WSN.As the wireless sensor network is based on the application of the network, different applications have different network structure and properties. Therefore the coverage problem in wireless sensor networks also has a variety of classification viz. deterministic and stochastic cover, static and dynamic cover, point, fence, and area coverage. Extensive research efforts have been made to develop energy efficient schemes integrating coverage and connectivity for WSN.

3.1 Types of Coverage and Clustering

Depended on the coverage objectives and applications, they can be roughly classified into three categories: area coverage, point coverage, and path coverage. They are briefly summarized here [9]:

I. Area coverage: Where the main objective of the sensor network is to cover (monitor) a region (the collection of all space points within the sensor field), and each point of the region need to be monitored.
II. Point coverage: Where the major objective is to cover a set of point (target) with known location that need to be monitored. The point coverage scheme focuses on determining sensor nodes' exact positions, where guarantee efficient coverage application for a limited number of immobile points (targets). Generally, it can be solved as a special case of the area coverage problem when sensor nodes' number may leave out of account
III. Path coverage: Where the goal is to minimize or maximize the probability of undetected penetration through the region.

Many protocols have been proposed for energy efficient coverage in WSN in the last few years. Clustering based schemes are believed to be the most energy efficient routing protocols for solving coverage problem. Clustering along with the reduction in energy consumption improves the network lifetime. In each cluster, one node is elected as the cluster head (CH) while the rest of the nodes are member nodes [8].

Along with clustering, the concept of hierarchical routing also plays a very important role in developing energy efficient schemes for WSN. One of the major objective of hierarchical routing algorithm is to maintain the efficient and well balanced energy consumption of sensor nodes in WSN by implementing multi-hop communication between nodes of a particular cluster. Cluster formation is typically

based on the energy reserve of sensors. Here, nodes having more energy can be used to process data and send information while low energy nodes can be used to perform sensing. Cluster based routing [8] is an efficient way for lowering energy consumption within a cluster. It is mainly a two-level routing where one level is used to select cluster heads and other is for routing as shown in Figure 3.1.1 [8]. Lower energy consumption within a cluster is achieved by data aggregation and fusion to decrease the number of transmittable messages. Also clustered Network allows energy efficient coverage of large sensing area of interest and additional load-balancing without degrading the performance of the overall network.

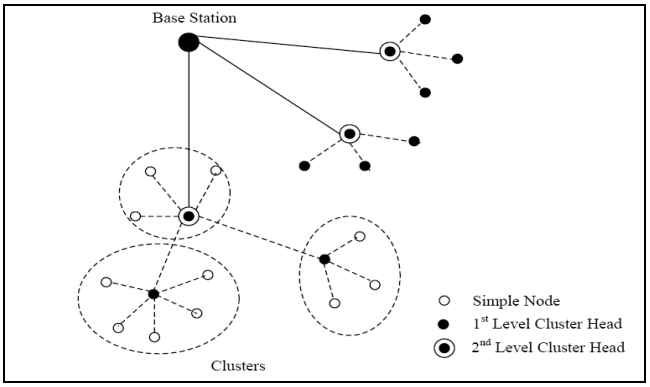

Figure 3.1: Hierarchical Network

3.2 Research Contribution by Researchers

A number of researches is currently underway on the energy efficient coverage in WSNs which will result from the selection of cluster-head by considering the distance between cluster heads, the size of the cluster and the inter and intra cluster communications. Some common clustering algorithms supporting coverage also are:

Wendi B. Hnzelman, A. Chandrakasan, and H. Balakrishnan have proposed LEACH [6]-Low Energy Adaptive Clustering Hierarchy which is one of the most successful clustering based routing algorithm for wireless sensor network. This is one of the first and best suited clustering approaches for wireless sensor networks. Majority of the data gathering schemes which are based on clustering concept are variants of LEACH which implements randomization to select cluster head during each round in order to achieve proper load balancing in clusters .In LEACH, the sensor nodes organize themselves into their specific clusters in every iteration , with one node acting as the local base station or cluster head (CH) after satisfying the threshold criteria. The CH receives all the data from sensor nodes within the respective cluster and aggregating this data into smaller set of useful information that describes the events the nodes are sensing. The whole working operation of LEACH is divided into many but limited rounds. LEACH also calculates the optimal number of clusters. Here the cluster head selection is random and the role of cluster heads rotates so as to balance the energy consumption through the network.

Wendi B. Henzelman et. al, proposed LEACH-C to implement centralized cluster formation algorithm for the formation of the clusters. The LEACH-C execution basically starts from the base station (BS) which first receives information about each node regarding their location along with energy level and then it runs the clustering algorithm for the formation of cluster heads (CH) and clusters. In LEAHC-C , number of CH is very limited and selection of CH is random. LEACH-C is not feasible for larger sensor networks in which wireless sensor nodes are located far away from the base station and they will have difficulty in sending their status to the base station [7].

O.Younis and S.Fahmy have proposed a scheme, Hybrid Energy Efficient Distributed Clustering (HEED).HEED periodically selects CH for cluster on the basis of residual energy and node degree resulting in optimal distributed clustering without any global knowledge about the distribution of sensor nodes or node capabilities. This routing protocol incurs very low overhead in terms of processing and messages exchanged during routing. A careful selection of the secondary clustering parameters can balance load among cluster-heads [4].

Amir Sepasi Zahmati, Ali A.B.Shirazi, and A.S.Bakhtiari have proposed a static protocol with hierarchical approach called Energy Efficient Protocol with Static Clustering (EEPSC). It partition the network into static clusters at once only, thus eliminating the overhead of dynamic cluster formation and utilizes temporary CH to distribute the energy load among high power wireless sensor nodes in order to extend the network lifetime [3].

As it can be verified easily that due to numerous advantages of clustering, a huge number of cluster-based protocols have been developed, but the problem of coverage preservation along with prolonging network lifetime has been addressed less.

Ali Kadhum et al. have proposed coverage optimization protocol [10] to improve the lifetime in heterogeneous energy wireless sensor networks. The area of interest is first divided into sub regions using a divide-and conquer method and then the sleep awake cycle is scheduled for similar sensor node for each sub region. The proposed scheduling considers rounds during which a small number of nodes, remaining active for sensing, is selected to ensure coverage. Each round consists in four phases: (i) Information Exchange, (ii) Leader Election, (iii) Decision, and (iv) Sensing. Simulation results show that the proposed approach can prolong the network lifetime and improve the coverage performance. As in LEACH [6], cluster head (CH) are formed through the collaborative efforts of sensor node. However these elected CH suffer with the double burden of collecting data from members of respective cluster and transferring it to the base station or sink. This approach reduces its probability to continue as a cluster head and thus initiate cluster head rotation

process. Even though a periodic rotation of cluster-head is possible, it results in change in cluster topology which introduces control overhead consuming energy.

S. Mini, Siba K. Udgata and Samrat L. Sabat have proposed another clustering algorithm for preserving coverage and maintaining energy efficiency [5]. The objective of the proposed algorithm is twofold. The first basic aim is to deploy wireless sensor nodes at optimal locations to increase overall network lifetime of. The second objective is to schedule sensor nodes within cluster such that the network attains the energy efficient coverage. Thus, the overall goal of this proposed scheme is to find optimal deployment locations of the particular sensor nodes having predefined sensing range using heuristic algorithm and to schedule similar nodes using another heuristic algorithm to improve network lifetime along with optimal coverage level.

4. CONCLUSION

In this paper we discussed overview of coverage issue and clustering in Wireless sensor network along with most successful routing algorithms dealing with energy efficient coverage, based on clustering approach. There exists both centralized and distributed coverage algorithm which are based on clustering in WSN. In large sensor networks distributed algorithm generally performs better than centralized algorithms in which all the decision based , computing and storage is done by only base station.

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