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Energy Efficient Cluster Head Selection for Data Aggregation in Wireless Sensor Networks

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Abstract: ***Data gathering is a common but critical operation in many applications of wireless sensor networks. However, a WSN is a power constrained system, since nodes run on limited power batteries which shorten its lifespan. Clustering is an effective topology control approach in wireless sensor networks, which can increase network scalability and lifetime. Prolonging the network lifetime depends on efficient management of sensing node energy resource. Energy consumption is therefore one of the most crucial design issues in WSN. Hierarchical routing protocols are best known in regard to energy efficiency. Most of the research in energy efficient data gathering in data centric applications of wireless sensor networks is motivated by LEACH scheme which by allowing rotation of cluster head role among the sensor nodes tries to distribute the energy consumption over the network. Selection of sensor node for such role rotations greatly affects the energy efficiency of the network. Some of the routing protocol has a drawback that the cluster is not evenly distributed due to its randomized rotation of local cluster head. We have presented several existing methods for selecting energy efficient cluster head in wireless sensor networks.***

Keywords: ENERGY, WSN, CH, BS, LEACH

I. Introduction

Wireless Sensor Network is an emerging field with lot of applications. Due to its wide applications in the field of defense security, civilian applications and medical research, there is lot of research going on. Nodes in WSN can be deployed in a wide geographical space to monitor the changes in the environment. One of the advantages of wireless sensors networks (WSNs) is their ability to operate unattended in harsh environments in which contemporary human-in-the-loop monitoring schemes are risky, inefficient and sometimes infeasible. Therefore, sensors are expected to be deployed randomly in the area of interest by a relatively uncontrolled means, e.g. dropped by a helicopter, and to collectively form a network in an ad-hoc manner [1, 2]. Sensors are energy constrained and their batteries cannot be recharged.

Therefore, designing energy-aware algorithms becomes an important factor for extending the lifetime of sensors. Other application centric design objectives, e.g. high fidelity target detection and classification, are also considered [3].

Energy is the one of the important factor one should consider while designing security measures for sensor nodes. It is very important to limit the energy consumption and thereby extend the battery life. However, adding security measures to sensor networks necessarily has a significant impact on its energy consumption, for example, to perform the encryption and decryption functions, to store, manage and send the encryption keys etc.

The rest of the paper is organized as follow: Section 2 describes cluster protocol model for wireless sensor network. Section 3 describes motivation behind this idea. Section 4 describes various techniques for energy efficient cluster head selection. Finally conclusion is presented in the last section.

II. Cluster Protocol Model

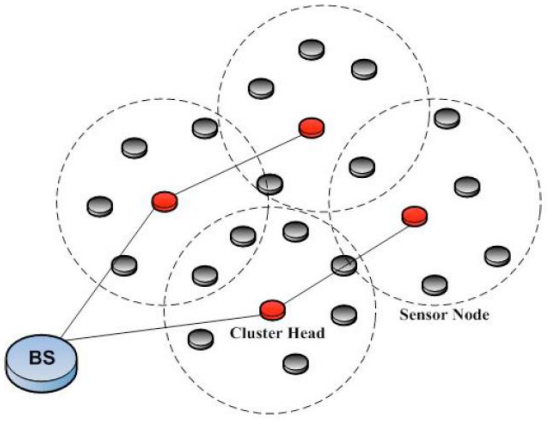

Fig. 2.1 Cluster Protocol Model

The process of grouping of sensor nodes in a densely deployed large-scale sensor network is known as clustering. The intelligent way to combined and compress the data belonging to a single cluster is known as data aggregation. There are some issues involved with the process of clustering in a wireless sensor network. First issue is, how many clusters should be formed that could optimize some performance parameter. Second could be how many nodes should be taken into a single cluster. Third important issue is the selection procedure of cluster-head in a cluster. Another issue that has been focused in many research papers is to introduce heterogeneity in the network. It means that user can put some more powerful nodes, in terms of energy, in the network which can act as a cluster-head and other simple node work as cluster-member only. Considering the above issues, many protocols have been proposed which deals with each individual issue.

III. Motivation

Wireless sensor nodes are resource limited devices. The goal is to increase the battery lifetime and ultimately the network lifetime. In a clustering protocol, cluster head sends query to all nodes in its cluster, aggregates data from all the nodes and report it to the base station. The cluster head spends more energy than other nodes in the networks, so its energy decreases sharply. The node that has less energy cannot become a cluster head. So the goal is how to select a cluster head so that the network lifetime increases.

IV. Related Work

In this section we will focus on the related work that has been done previously by several researchers. Energy Efficiency for prolonging the WSN has received much focused attention.

4.1 Low Energy Adaptive Clustering Hierarchy [5]

Low Energy Adaptive Clustering Hierarchy (LEACH) protocol has attracted intensive attention because of its energy efficient, simplicity and load balancing properties. LEACH is a cluster based protocol. The numbers of cluster heads and cluster members generated by LEACH are important parameters for achieving better performance. LEACH organizes nodes into clusters with one node from each cluster serving as a cluster-head (CH). It randomly selects some predetermined number of nodes as cluster heads. CHs then advertise themselves and other nodes join one of those cluster heads whose signal they found strongest (i.e. the CH which is nearest to them). In this way a cluster is formed. The CH then makes a Time Division Multiple Access (TDMA) schedule for the nodes under its cluster. The communication between different clusters is done through CHs in a Code Division Multiple Access (CDMA) manner. The CHs collect the data from their clusters and aggregate it before sending it to the other CHs or base station (BS). After a predetermined time lapse, the cluster formation step is repeated so that different nodes are given a chance to become CHs and energy consumption is thus uniformly distributed.

LEACH operation is broken into rounds, with each round having a set-up phase and a steady state phase. In Set-up phase, each node decides whether or not to be a cluster-head based on its remaining energy and a globally known desired percentage of cluster heads. Each node electing itself as a cluster-head broadcasts an advertisement message announcing its intention. Non cluster head nodes receive possibly several advertisements and pick one cluster to join based on the signal strength of the advertisement received from the corresponding cluster-head. In Steady-state phase, each cluster-head waits to receive data from all nodes in its cluster and then sends the aggregated or compressed result back to a BS.

Clustering is a good approach which, if implemented properly, can lead to energy efficient networking in WSNs. Despite the significant overall energy savings, however, the assumptions made by the protocol raise a number of issues as explained in [4]: LEACH assumes that all nodes can communicate with each other and are able to reach the sink (therefore, it is only suitable for small size networks), LEACH assumes that all nodes have data to send and so assign a time slot for a node even though some nodes might not have data to transmit, LEACH assumes that all nearby nodes have correlated data which is not always true, LEACH requires that all nodes are continuously listening (this is not realistic in a random distribution of the sensor nodes, for example, where cluster-heads would be located at the edge of the network), there is no mechanism to ensure that the elected cluster-heads will be uniformly distributed over the network (hence, there is the possibility that all cluster heads will be concentrated in one part of the network), periodic dynamic clustering carries significant overhead which may off-set energy gains derived by the clustering option.

4.2 Random competition based clustering (RCC) [6]

Although RCC is designed for mobile ad hoc networks, it is also applicable to WSNs. RCC mainly focuses at cluster stability in order to support mobile nodes. The RCC algorithm applies the First Declaration Wins rule, in which any node can ‘‘govern’’ the rest of the nodes in its radio coverage if it is the first to claim being a CH. After hearing the claim which is broadcasted by the first node, neighboring nodes join its cluster as member and give up their right to be a CH. To maintain clusters, every CH in the network broadcast a CH claim packet periodically. Since there is a time delay between broadcasting a claim packet and receiving it, concurrent broadcast can possibly create a conflict. Being unaware of on-going claims, many neighboring nodes may broadcast CH claim packets concurrently. To avoid such a problem RCC explicitly employs a random timer and uses the node ID for arbitration. Each node in the network reset its random time value, every time before broadcasting its CH claim packet. During this random time if it receives a broadcast message carrying CH claim packet from another node, it simply ceases the transmission of its CH claim. Since random timer is not a complete solution, RCC resolve further the concurrent broadcast problems by using the node ID. If the conflict persists, node having lower ID will become the CH. Although frequent node mobility still has direct effect, RCC is shown to be more stable than conventional clustering schemes.

4.3 PEGASIS: Power-Efficient Gathering in Sensor Information System [7]

By this author proposed algorithm PEGASIS that is a chain based protocol provide improvement over LEACH algorithms. In PEGASIS, each node communicates only with a close neighbor and takes turns transmitting to the base

station, thus reducing the amount of energy spent per round. Using greedy algorithm, the nodes will be organized to form a chain, after that BS can compute this chain and broadcast it to all the sensor nodes. Energy saving in PEGASIS over LEACH takes place by many stages: First, in the local data gathering, the distances that most of the sensor nodes transmit are much less compared to transmitting to a cluster-head in LEACH. Second, only one node transmits to the BS in each round of communication. PEGASIS outperforms LEACH by limiting the number of transmissions, eliminating the overhead of dynamic.

The main idea in PEGASIS is for each node to receive from and transmit to close neighbors and take sums being the leader for transmission to the BS. This approach distributes the energy load evenly among the sensor nodes in the network. The author initially places the nodes randomly in the play field, and therefore, the i-th node is at a random location. The node will be organized to form a chain, which can either be accomplished by the sensor nodes themselves using a greedy algorithm starting from some node. Alternatively, the BS can compute this chain and broadcast it to all the sensor nodes.

4.4 EECS: Energy Efficient Clustering Schemes [8]

Authors proposed an algorithm in which cluster formation is different from LEACH protocol. In LEACH protocol cluster formation takes place on the basis of a minimum distance of nodes to their corresponding cluster head. In EECS, dynamic sizing of clusters takes place which is based on cluster distance from the base station. The results are an algorithm that addresses the problem that clusters at a greater distance from the sink requires more energy for transmission than those that are closer. Ultimately it provides equal distribution of energy in the networks, resulting in network lifetime. Thus main advantage of this algorithm is the full connectivity can be achieved for a longer duration. So we can say it provides reliable sensing capabilities at a larger range of networks for a longer period of time. It provides a 35 percent improvement in network life time over LEACH algorithm.

EECS is a LEACH-like clustering scheme, where the network is partitioned into a set of clusters with one cluster head in each cluster. Communication between the cluster head and BS is direct (single-hop). Each node can compute its approximate distance to the BS based on the received signal strength. This helps nodes to select the proper power level when they communicate with the BS. As will be shown in the cluster formation phase, the author uses this distance to balance the load among cluster heads. In the cluster head election phase, well distributed cluster heads are elected with a little control overhead. And in the cluster formation phase, a novel weighted function is introduced to construct load balanced clusters.

4.5 Energy Efficient Chain Based Routing [9]

The proposed protocol organizes sensor nodes as a set of horizontal chains and a vertical chain. In each chain, a node is selected as chain head. For selecting the chain heads in horizontal chains, EECRP considers residual energy of nodes and distance of nodes from the header of upper level that does not need to reselect leader of the vertical chain. This causes time and energy saving. In each horizontal chain, sensor nodes transmit their data to their own chain head based on chain routing mechanism. EECRP also adopts a chain based data transmission mechanism for sending data packets from the chain heads to the base station.

In the proposed protocol, the network is divided to a set of strips. It is assumed that "h" is height of each strip and there are "k" strips in the sensor network, computed by "k=L/h", where "L" is length of wireless sensor network.

In each strip, a chain is formed among the sensor nodes and a chain head is selected. In order to balance energy consumption among all sensor nodes in the network, the chain head's role should be rotated among the sensor nodes to prevent their exhaustion.

4.6 Distance Based Cluster Head Selection Method [10]

The author [10] has proposed an algorithm that selects cluster head as per the following steps:

(1) Calculate the distance of one node to all nodes.
(2) Calculate the sum of all distance from one to all nodes.
(3) Calculate distance from BS to each node for all nodes.
(4) Calculate the net distance with base station for each node
(5) Select the cluster head with minimum net distance value.

4.7 MST-PSO: Minimum Spanning Tree-PSO [10]

Authors proposed a minimum spanning tree-PSO based clustering algorithm of the weighted graph of the WSNs. The optimized route between the nodes and its cluster heads is searched from the entire optimal tree on the basis of energy consumption. Election of cluster head is based on the energy available to nodes and Euclidean distance to its neighbor node in the optimal tree. Others have concluded that network life time does not depend on the base station location or residual energy of the node. Once the topology decided to then network life time becomes almost settled. Author's shows two techniques for improving network life time: reduce the startup energy consumption of the transmitter and receiver, and optimized the network topology.

4.8 GROUP [11]

GROUP clustering algorithms based on clustering algorithm that provides scalable and efficient packet routing for large-scale WSNs. Only some parts of total number of sensor nodes participate in formation of cluster heads (CHs). In this, cluster heads are arranged in a grid manner and primary sink (One of the sink), dynamically and randomly builds the cluster grid. Greed Seed (GS) is a node within a given radius from the primary sink. Any queries from sink to nodes are propagated from greed seed to its cluster heads and so on.

All sensor nodes are stationary and aware of their own locations. The number of sinks may vary over time. All sinks can communicate with each other through tethered network or satellite. Each sensor node is able to adjust its wireless transceiver's power consumption. The cluster heads communication with each other through long-range radios while other sensor nodes communication with respective cluster head through short-range radios. In GROUP, all sensor nodes are divided into several clusters dynamically. One node is selected as the cluster head (CH) in each cluster. And all cluster heads form a virtual cluster grid. The data queries will be transmitted from sinks to all nodes via cluster heads. And the data matched the query are routed back to sinks via cluster heads too. The application-specific data aggregation policy can be applied in cluster heads.

V. Conclusion

In this paper we have presented several existing methods for cluster head selection. The existing methods can be improved by taking mobility into consideration. Security is an important and vital requirement. It can be made secure by bringing in some security features. One can improve the distance of cluster head communication with cluster member via a hierarchical tree and also inside the cluster in more efficient manner.

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