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A COMPARATIVE REVIEW ON LEACH ROUTING PROTOCOL AND ITS VARIANTS IN WSN

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Abstract: Due to the extensive range of applications the use of wireless sensor networks (WSNs) in past few years have increased a lot and it has become a hot research area now a days. One of the important issues in wireless sensor network is the intrinsic limited battery power in network sensor nodes. Since most of the energy is consumed by the transmission and reception, energy efficient routing protocol is required to enhance the lifetime of WSN. In this paper we have outlined the advantages of clustering for WSNs, and survey of the energy-efficient hierarchical cluster-based routing protocols based on Low-Energy Adaptive Clustering Hierarchy (LEACH) which is the first and most popular energy-efficient hierarchical clustering algorithm for WSNs.
Keywords: WSN, Clustering Process Hierarchical Routing, LEACH Protocol

I. INTRODUCTION

A wireless sensor network is a set of sensors deployed in a sensor field, to monitor specific characteristics of the environment, measure those characteristics and collect the data related to that phenomena. The sensors are small devices with limited resources: limited battery power, low memory, little computing capability, very low data rates, low bandwidth processing, variable link quality, etc. Despite their constraints, when the sensors are deployed in large numbers, they can provide us with a very real picture of the field being sensed. WSN can provide an area coverage that was not possible with other wired and wireless networks. They can be deployed in different environments and can be permanently attended or can be left unattended once they have been deployed in the field.

However, it is necessary to implement mechanisms or procedures to deal with the sensor constraints. Using clustering techniques in WSN can help solving some of those constraints, by allowing the organization of the sensors in a hierarchical manner, grouping them into clusters and assigning specific task to the sensor in the clusters, before moving the information to higher levels. Clustering techniques have been proposed in WSNs in order to achieve high energy efficiency and assure long network lifetime, for bandwidth reuse, for data gathering and target tracking. Clustering is particularly useful for applications that require scalability to hundreds or thousands of nodes. Also, many routing protocols can use clustering to create a hierarchical structure and minimize the path cost when communicating with the base station.

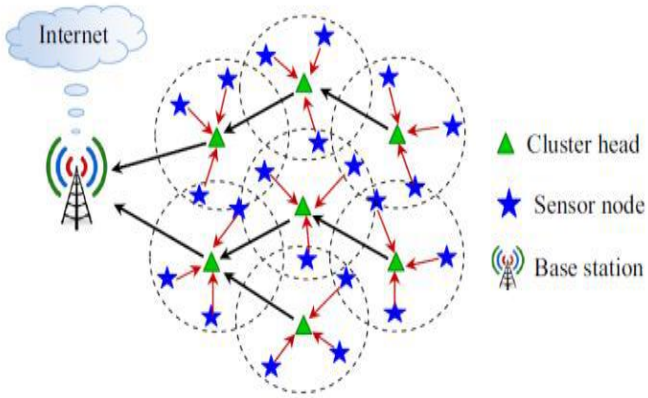

Figure 1: Wireless Sensor Network Model

1.1 KEY CHALLENGES IN WSN:

- Scalability
- Fault-tolerance
- Energy Consumption
- Data aggregation/fusion
- Load balancing
- Maximal network lifetime

1.2 CLUSTERING PROCESS IN WSN: Clustering [11] in Wireless Networks is the process of dividing the nodes of network into different groups where each group agrees on center node which is known as cluster head. Cluster head is responsible for collecting the data of cluster members and aggregate that data and send it to the base station. Clustering is used to resolve some constraints as:

- Scalability
- Load Balancing
- Efficient resource utilization
- Data aggregation or fusion
- Resilience
- Power Consumption

In general, there are three main different elements in the WSN: sensor nodes (SNs), base station (BS) and cluster heads (CH). The SNs are the set of sensors present in the network, arranged to sense the environment and collect the data. But the BS is the data processing point for the data received from the sensor nodes, and where the data is accessed by the end-user. It is generally considered fixed and at a far distance from the sensor nodes. The CH acts as a gateway between the SNs and the BS. The function of the cluster head is to perform common functions for all the nodes in the cluster, like aggregating the data before sending it to the BS. In order to sachieve high energy efficiency and

increase the network scalability clustering routing protocol can be used. The main aim of hierarchical routing is to efficiently maintain the energy consumption of sensor nodes by involving them in multihop communication within a particular cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the sink.

II. HIERARCHICAL ROUTING

In hierarchical [7]routing protocols, clusters are created and a head node is assigned to each clusters. Description and the comparison of the descendants of Leach protocol is discussed in the next subsections:

2.1 LEACH PROTOCOL IN WSN: LEACH [1] is one of the first hierarchical routing approaches for sensors networks. Operation of LEACH is based on rounds and each round consists of two phases - setup phase and steady state phase. In setup phase CHs and clusters are created. Some nodes independently elect themselves as CHs based on some probability P and their previous record as a CH. All nodes which were not CHs in previous 1/p rounds, generate a number from 0 to 1 and if it is less than a threshold T (n) then these nodes become CHs . Threshold value is set by the given formula:

$$T(n) = \frac{p}{1 - p\left(r \bmod \frac{1}{p}\right)} \text{ if } n \in G$$

T(n) = 0 : otherwise (1)

In formula (1) G is set of nodes that have not been selected as CHs in previous 1/p rounds, P is suggested percentage of CH, r is current round . After that a steady state phase nodes transmit data to their CHs during the allocated time slots. otherwise they remain in sleep mode increasing battery lifetime. After receiving data from all the members CHs will aggregate the data and transmit to the BS.

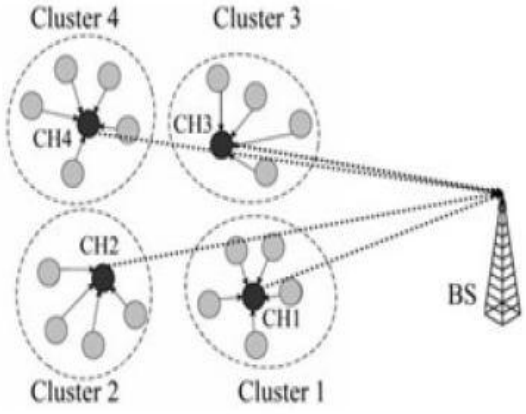

Figure 2: Leach clustering hierarchical model

Though, LEACH [13] consumes less energy and designed as low energy consumptive protocol, it also has some disadvantages They are as follows:

• LEACH does not provide the precise location of sensor nodes and the total number of CHs in the network.

• CH will directly communicate with the member nodes irrespective of the distance. So, if the distance is more, it will end in more energy consumption.

• CH nodes will be responsible for data transmission and collection so there will be more power consumption compared to the other sensor nodes. Thus, the CH nodes' life will end early than the other nodes.

• CH node will always be in the working state unlike other nodes. So it loses its energy in very short time. When, Cluster head node dies then there is no meaning of cluster because without CH node, the data transmission can't be done and whole cluster becomes useless.

III. VARIANTS OF LEACH PROTOCOL

LEACH protocol has many descendants which outperforms the LEACH in terms of energy consumption or life of the sensor nodes. These kind of approaches are proposed and described in as:

3.1 Multi-hop LEACH (M-LEACH): If network's diameter [8] is increased beyond a certain limit, then LEACH routing protocol cannot handle the situation because distance between CH and BS is increased enormously. In this case, single-hop energy dissipation of CH is not reasonable. To solve this problem, Multi-hop LEACH is proposed

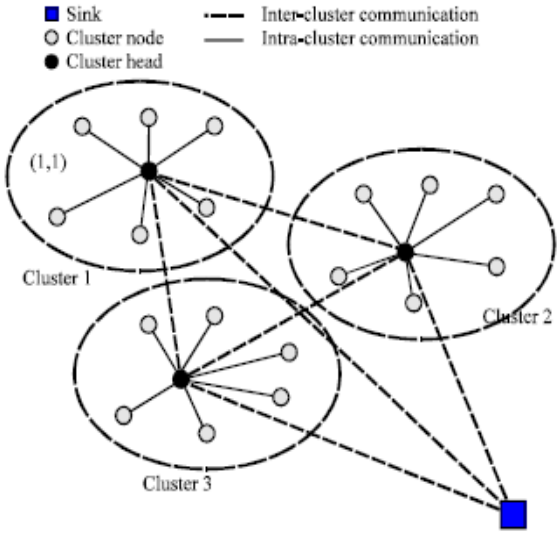

Figure 3: Multi-hop LEACH

It is a distributed clustering based routing protocol. Setup phase is same as LEACH. In steady state phase CH collects data from all member nodes and transmit the aggregated data directly or indirectly through other CHs to the BS. There are two types of possible communication in Multi-hop LEACH. In inter-cluster communication the CHs of different clusters communicate among each other. In intra-cluster communication the member nodes of each cluster send their sensed data to their corresponding CH. The algorithm selects the best path with minimum hop count between the CH and BS.

3.2 LEACH-Centralized (LEACH-C): It is a centralized clustering algorithm based on LEACH [14]. During the set-up phase each node sends information about current location and energy level to the base station (BS). BS will determine

clusters, CH node and member nodes of each cluster. The BS utilizes the global information about the network to produce better clusters which require less energy for data transmission. In LEACH-C the number of CHs in each round equals a predetermined optimal value unlike LEACH where the number of CHs may vary among different rounds due to lack of global coordination among nodes. Optimal formation of clusters are possible but to achieve this communication with the BS in each round by all the sensor nodes is required. It is less reliable due to single point of failure and can cause hotspot problem.

3.3 LEACH with Fixed Cluster (LEACH-F):
In LEACH-F [7] clusters that are formed once are fixed. Then, the cluster head position rotates among the nodes within that cluster. The advantage of LEACH-F is that there is no set-up overhead at the beginning of each round due to reclustering. To build clusters LEACH-F uses the same centralized concept of LEACH-C algorithm. The method lacks scalability since fixed clusters do not allow new nodes to be added and the lifespan of such network is very less because it never adjusts the clusters as nodes dye.

3.4 Balanced LEACH (LEACH- B):
Leach-B uses [9] the decentralized algorithms of cluster formation where each sensor node only knows about its own position and the final receiver and does not know about the position of all the sensor nodes. Leach-B involves Cluster head selection algorithm, Cluster formation and data transmission with multiple access . By evaluating the energy dissipated in the path between final receiver and itself, each of the sensor node chooses its cluster head. Efficiency of Leach-B is better than Leach.

3.5 Energy LEACH (LEACH-E):
Energy-LEACH improves[11] the CH selection procedure in LEACH. It makes residual energy of node as the main metric which decides whether the nodes turn into CH or not after the first round. The operation of E-LEACH is divided into rounds, in the first round, every node has the same probability to turn into CH, that mean nodes are randomly selected as CHs, in the next rounds, the residual energy of each node is different after one round communication and taken into account for the selection of the CHs. That mean nodes have more energy will become a CHs rather than nodes with less energy.
V-LEACH

3.6 Vice CH-LEACH (V-LEACH): V-LEACH [10]
is a new version of LEACH Protocol which aims to reduce energy consumption within the wireless network. The main concept behind V-LEACH is that besides having a CH in the cluster, there is a vice-CH that takes the role of the CH when the CH dies. By doing this, cluster nodes data will always reach the BS; no need to elect a new CH each time the CH dies which will extend the overall network life time.

3.7 Optimized-LEACH (Op-LEACH):
Op-LEACH [2]improves the performance of LEACH algorithm in terms of energy and time delay in real time networks. Every sensor node does not have data all the time. The data is available in randomly. The sensors may be event driven, so data may be available only when they sense the event. This method is utilizing the slots belonging to the node having no data to send. This method turns free slots into useful slots without making any changes in the TDMA schedule. This will reduce the waiting time for sensor nodes because now sensor nodes can get more than one slot per frame. It will reduce the data transmission delay and increase throughput of the network. It works in rounds. Each round consists of following two phases: cluster setup phase and steady state transmission phase. Cluster set-up phase includes grouping of clusters and cluster head selection. Steady state phase includes transmission of data.

3.8 A New LEACH (NEW LEACH): A New LEACH[1] improves the CH selection procedure in LEACH. To make the network more energy efficient it considered heterogeneous network with,nodes having two different energy levels - normal node having less energy will be treated as the cluster members and advanced node possessing more energy will be elected as cluster heads. Initially the CHs will be selected from the set of advanced nodes following the same process of LEACH.
But during reclustering a threshold value will be used to decide whether the CH will be replaced or not. The threshold defines the minimum energy level which must be possessed by a CH to communicate with the BS directly. Here for simplicity it has considered static threshold which is equal to be half of the initial energy of the normal nodes. This method will not only use the remaining CH energy but also decrease the overhead associated with a new CH formation in each round. Since if a new CH is selected then whole process of cluster formation will take place. It shows that this protocol performs better in considering the network lifetime and throughput.

TABLE 1.COMPARISON OF LEACH AND IMPROVED VERSIONS

Clusterig Protocol	Data Fusion	Scal-ability	Centra-lised	Distributed	Energy Dissipation	Base station	Hopcount	Homo-geneous	Simulation Tools
LEACH	Yes	Limited	No	Yes	High	Stationary	Single hop	Yes	MATLAB
LEACH-M	Yes	Very Good	No	Yes	Very High	Stationary	Multi hop	Yes	MATLAB
LEACH-C	Yes	Good	Yes	No	Very High	Stationary	Single hop	Yes	NS-2
LEACH-F	Yes	Limited	Yes	No	Very High	Stationary	Single hop	Yes	MATLAB
LEACH-B	Yes	Very Good	No	Yes	Very High	Stationary	Single hop	Yes	MATLAB
V-LEACH	Yes	Very good	No	Yes	Very High	Stationary	Single hops	Yes	OMNET++
LEACH-E	Yes	Very good	No	Yes	Very High	Stationary	Single hop	No	MATLAB
Op-LEACH	Yes	Very good	No	Yes	Very High	Stationary	Single hop	Yes	OMNET++
NEW-LEACH	Yes	Very good	No	Yes	Very High	Stationary	Multi hop	No	MATLAB

IV. CONCLUSION AND FUTURE WORK:

Network lifetime is crucial in Wireless Sensor Network systems since recharging or exchanging the sensors is difficult and expensive. Clustering techniques provide an interface for WSN topology management to extend network lifetime Existing clustering algorithms can significantly reduce the power consumption on each sensor and thus prolog the network lifetime. The various LEACH-based routing algorithms discussed above have different assumptions. They have their own advantages and disadvantages. Each of them has its own application domain where it can perform better than the other. So which method should be used that depends on the situation itself. Further research can be done to find the best possible optimal routing algorithm which will be promising in terms of energy efficiency as well as provide the required Quality of Service (QoS) posed by real-time applications.

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