

Optimization of Low Energy Adaptive Clustering Hierarchy (LEACH) protocol

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Abstract--- In the wireless sensor networks (WSNs), the sensor nodes (called motes) are usually scattered in a sensor field an area in which the sensor nodes are deployed. These motes are small in size and have limited processing power, memory and battery life. The motes in these networks are coordinate to produce high quality in formation and each of these scattered motes has the capabilities to collect and routed at aback to the bases stations, which are fixed or mobile. In WSNs, conservation of energy, which is directly related to network life time, is considered relatively more important souse of energy efficient routing algorithms is one of the ways to reduce the energy conservation. In general, routing algorithms in WSNs can be divided into flat, hierarchical and location based routing. In flat, all nodes are assigned equal roles. In hierarchical, however, nodes will play different roles in the network. While in location based routing, sensor nodes are addressed by means of their locations.

The main objective of this major project is to optimize the Low Energy Adaptive Clustering Hierarchy (LEACH) protocol. There are two reasons behind the hierarchical routing be in explored. One, the sensor networks are dense and a lot of redundancy is involved in communication. Second, in order to increase the scalability of the sensor network keeping in mind the security aspects of communication. Cluster based routing holds great promise for many to one and one to many communication paradigms that are pre valentines or networks.

In this major project, the work has been carried out is implementation of flat based Flooding and Gossiping routing protocols using TinyOS Simulator (TOSSIM), implementation of LEACH routing protocol using NS2 simulator and finally some modifications in LEACH routing protocol in order to improve the performance of the LEACH protocol. The results were then analyzed based on the suggested evaluation metrics in order to verify their suitability for use in wireless sensor networks.

I. INTRODUCTION

There are lots of work has been done in the area of Wireless Sensor Network, but still a long way to go. Wireless Sensor networks consist of hundreds of thousands of low power multi-functional sensor nodes, operating in an unattended environment, with limited computation and sensing capabilities. Sensor nodes are equipped with small, often irreplaceable batteries with limited power capacities. The use of wireless sensor networks is increasing day by day and at the same time it faces the problem of energy constraints in terms of limited battery lifetime. Various approaches can be taken to save energy caused by communication in wireless sensor networks. One of them is to adopting energy efficient

routing algorithms. The routing algorithms in the sensor networks broadly classified into three categories: Flat, Hierarchical (or Cluster) and Location based routing. The cluster based routing holds great promise for many-to-one and one-to-many communication paradigms that are prevalent in sensor networks. This dissertation work includes the survey of various cluster based routing protocols and implementation of LEACH routing protocol. The idea proposed in LEACH has been an inspiration for many hierarchical routing protocols. The finally it propose some modifications to improve the performance of the LEACH routing protocol. The simulation results were then analyzed based on the suggested evaluation metrics in order to verify their suitability for use in wireless sensor networks.

II. LEACH PROTOCOL

Low-Energy Adaptive Clustering Hierarchy (LEACH)

This protocol is proposed by W. R. Heinzelman et.al [6] which minimizes energy can be conserved since cluster heads are selected for data transmission instead of other nodes. The operation of LEACH is broken up into rounds, where each round begins with a set-up phase, when the clusters are organized, followed by a steady-state phase, when data transfers to the base station occur. In order to minimize overhead, the steady-state phase is long compared to the set-up phase.

Set-up phase: During this phase, each node decides whether or not to become a cluster head (CH) for the current round. This decision is based on choosing a random number between 0 and 1 if number is less than a threshold $T(n)$, the node become cluster head for the current round. The threshold value is set as:

$$T(n) = \begin{cases} \frac{p}{1-p \cdot (r \bmod \frac{1}{p})} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases}$$

Where, P = desired percentage of cluster head, r = current round and G is the set of nodes which did not become cluster head in last 1 rounds. Once the cluster head is chosen, it will use the CSMA MAC protocol to advertise its status. Remaining nodes will take the decision about their cluster head for current round based on the received signal strength of the advertisement message. Before steady-state phase starts, certain parameters are considered, such as the network topology and the relative costs of computation versus the communication. A Time Division Multiple Access (TDMA) schedule is applied to all the members of the cluster group to send messages to the CH, and then to the cluster head towards the base station. As soon as a cluster head is selected for a region, steady-state phase

starts. Figure 1 shows the flowchart of the phase. Steady-state phase: Once the clusters are created and the TDMA schedule is fixed, data transmission can begin. Assuming nodes always have data to send, they send it during their allocated transmission time to the cluster head. This transmission uses a minimal amount of energy (chosen based on the received strength of the cluster-head advertisement). The radio of each non-cluster-head node can be turned off until the nodes allocated transmission time, thus minimizing energy dissipation in these nodes.

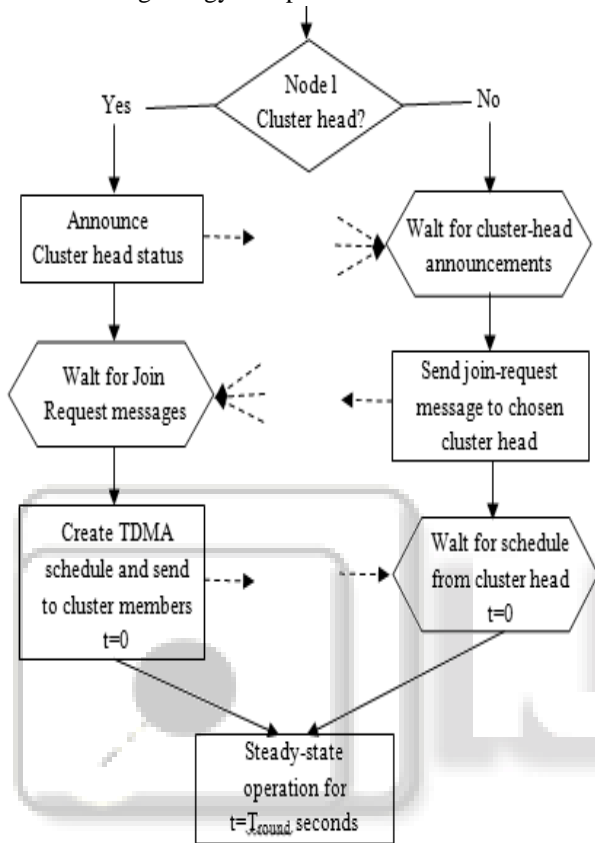


Fig. 1: Flow chart of the Set-up phase of the LEACH protocol

The cluster-head node must keep its receiver on to receive all the data from the nodes in the cluster. When all the data has been received, the cluster head node performs signal processing functions to generate the composite single signal. For example, if the data are audio or seismic signals, the cluster-head node can beam form the individual signals to generate a composite signal. This composite signal is sent to the base station. Since the base station is far away, this is a high-energy transmission. Figure 3 shows the data gathering strategy used by the LEACH protocol. Code Division Multiple Access (CDMA) is utilized between clusters to eliminate the interference from neighboring clusters.

Power-Efficient Gathering in Sensor Information Systems (PEGASIS)

Lindsey et al [7] proposed this protocol, which is an enhancement over the LEACH protocol. The main idea in PEGASIS is for each node to receive from and transmit to close neighbors and take turns being the leader for transmission to the BS. This approach distributes the energy load evenly among the sensor nodes in the network. Sensor nodes are randomly deployed in the sensor field,

and therefore, the node is at a random location. The nodes 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. For constructing the chain, it is assumed that all nodes have global knowledge of the network and employ the greedy algorithm. The greedy approach to constructing the chain works well and this is done before the first round of communication. To construct the chain, it starts with the furthest node from the BS. To begin with this node in order to make sure that nodes farther from the BS have close neighbors, as in the greedy algorithm the neighbor distances will increase gradually since nodes already on the chain cannot be revisited. Figure 2.4a shows node 0 connecting to node 3, node 3 connecting to node 1, and node 1 connecting to node 2 in that order. When a node dies, the chain is reconstructed in the same manner to bypass the dead node. The leader in each round of communication will be at a random position on the chain, which is important for nodes to die at random locations. In a given round, simple control token passing approach is initiated by the leader to start the data transmission from the ends of the chain. The cost is very less since the token size is very small. In Figure 2.4b, node c2 is the leader, and it will pass the token along the chain to node c0. Node c0 will pass its data towards node c2. After node c2 receives data from node c1, it will pass the token to node c4, and node c4 will pass its data towards node c2.

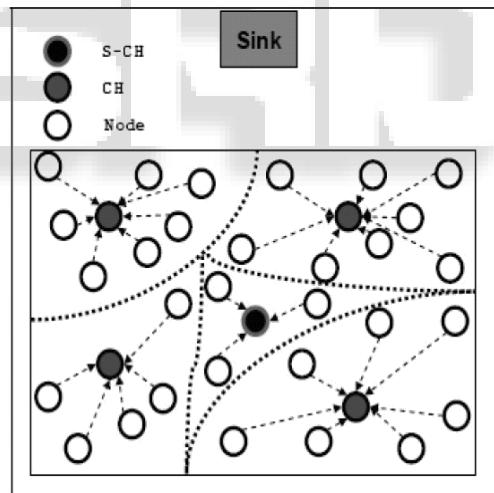


Fig. 3 Data gathering in LEACH protocol

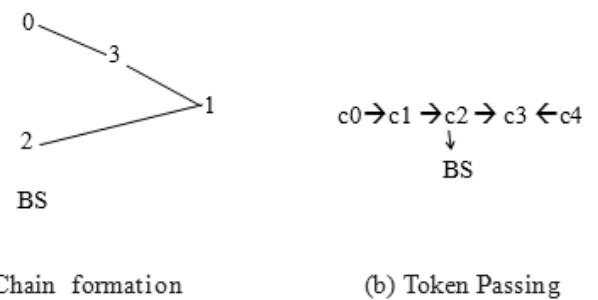


Fig. 4 PEGA SIS Protocol operations

Threshold sensitive Energy Efficient sensor Network protocol (TEEN) Manjeshwaret. al.[8] classifies sensor networks in proactive

and reactive networks. The nodes in the network periodically switch on their sensors and transmitters, sense the environment and transmit the data of interest. Thus, they provide a snapshot of the relevant parameters at regular intervals called the proactive networks. They are well suited for applications requiring periodic data monitoring. While Networks in which the nodes react immediately to sudden and drastic changes in the value of a sensed attribute, is called reactive networks. As such, they are well suited for time critical applications. In this scheme, approach is same as the LEACH but at every cluster change time, in addition to the attributes, the cluster-head (CH) broadcasts to its members,

Hard Threshold (HT): This is a threshold value for the sensed attribute. It is the absolute value of the attribute beyond which, the node sensing this value must switch on its transmitter and report to its cluster head.

Soft Threshold (ST): This is a small change in the value of the sensed attribute which triggers the node to switch on its transmitter and transmit. The nodes sense their environment continuously. The first time a parameter from the attribute set reaches its hard threshold value, the node switches on its transmitter and sends the sensed data. The sensed value is stored in an internal variable in the node, called the sensed value (SV). The nodes will next transmit data in the current cluster period, only when both the following conditions are true:

1. The current value of the sensed attribute is greater than the hard threshold.
2. The current value of the sensed attribute differs from SV by an amount equal to or greater than the soft threshold.

Whenever a node transmits data, SV is set equal to the current value of the sensed attribute. Thus, the hard threshold tries to reduce the number of transmissions by allowing the nodes to transmit only when the sensed attribute is in the range of interest. The soft threshold further reduces the number of transmissions by eliminating all the transmissions which might have otherwise occurred when there is little or no change in the sensed attribute once the hard threshold. Figure 2.5 shows the operation of the TEEN protocol.

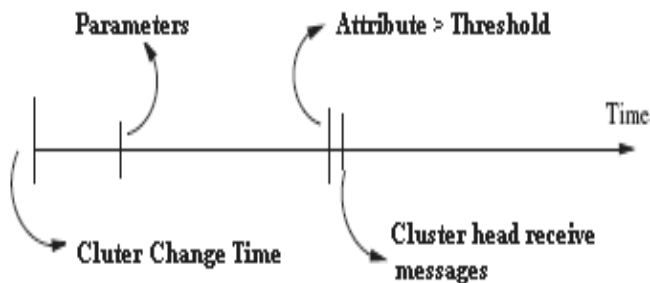


Fig. 5: Operation of TEEN protocol.

Adaptive Periodic Threshold-sensitive Energy Efficient Sensor Network (APTEEN)

Manjeshwaret. al.[9] have proposed APTEEN, which allows for comprehensive in- formation retrieval. The nodes in such a network not only react to time-critical situations, but also give an overall picture of the network at periodic

intervals in a very energy efficient manner. Such a network enables the user to request past, present and future data from the network in the form of historical, one-time and persistent queries respectively. In APTEEN once the cluster head are decided, in each cluster period, the CHs first broadcast the following parameters:

Attributes (A):

This is a set of physical parameters which the user is interested in obtaining data about.

Thresholds: This parameter consists of a hard threshold (HT) and a soft threshold (ST) which are similar to used in [8]. Thresholds are used to minimize the number of transmission in order to save the energy.

Schedule: This is a TDMA schedule similar to the one used in [6], assigning a slot to each node.

Count Time(TC): It is the maximum time period between two successive reports sent by a node. It can be a multiple of the TDMA schedule length and it accounts for the proactive component

In a sensor network, close-by nodes fall in the same cluster, sense similar data and try to send their data simultaneously, causing possible collisions. A TDMA schedule is declared such that each node in the cluster is assigned a transmission slot to avoid collisions, as shown in Figure 6.

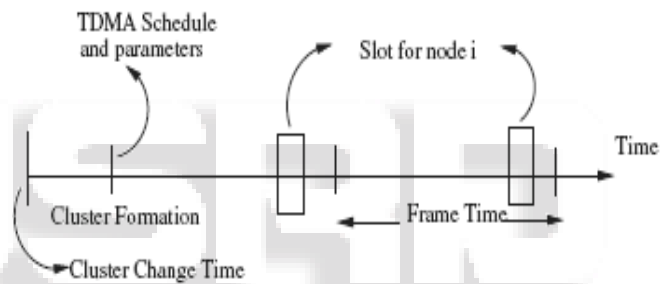


Fig. 6: A TDMA schedule

Hybrid Energy Efficient Distributed clustering (HEED)

Younis, O. et. al[10] proposed Hybrid Energy-Efficient Distributed Clustering (HEED) which is a multi-hop clustering algorithm with focus on efficient clustering by proper selection of cluster heads based on the physical distance between nodes. The most important aspect of HEED is the method of cluster head selection. Cluster heads are determined based on two important parameters:

1. The residual energy of each node is used to probabilistically choose the initial set of cluster heads. This parameter is commonly used in many other clustering schemes

2. Intra-Cluster Communication Cost is used by nodes to determine the cluster to join. This is especially useful if a given node falls within the range of more than one cluster head.

In HEED it is important to identify what the range of a node is in terms of its power levels as a given node will have multiple discrete transmission power levels. The power level used by a node for intra-cluster announcements and during clustering is referred to as cluster power level. Low cluster power levels promote an increase in spatial reuse while high cluster power levels are required for inter cluster communication as they span two or more cluster areas.

Therefore, when choosing a cluster, a node will communicate with the cluster head that yields the lowest intra-cluster communication cost. The intra-cluster communication cost is measured using the Average Minimum Reach ability Power (AMRP) measurement. The AMRP is the average of all minimum power levels required for each node within a cluster range R to communicate effectively with the cluster head i . The AMRP of a node i then becomes a measure of the expected intra-cluster communication energy if this node is elevated to cluster head. Utilizing AMRP as a second parameter in cluster head selection is more efficient than a node selecting the nearest cluster head.

E-LEACH Protocol

Energy-LEACH protocol improves the CH selection procedure. It makes residual energy of node as the main metric which decides whether the nodes turn into CH or not after the first round [12]. Same as LEACH protocol, 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.

TL-LEACH Protocol

In LEACH protocol, the CH collects and aggregates data from sensors in its own cluster and passes the information to the BS directly. CH might be located far away from the BS, so it uses most of its energy for transmitting and because it is always on it will die faster than other nodes. A new version of LEACH called Two-level Leach was proposed. In this protocol; CH collects data from other cluster members as original LEACH, but rather than transfer data to the BS directly, it uses one of the CHs that lies between the CH and the BS as a relay station [13].

M-LEACH protocol

In LEACH, Each CH directly communicates with BS no matter the distance between CH and BS. It will consume lot of its energy if the distance is far. On the other hand, Multihop LEACH protocol selects optimal path between the CH and the BS through other CHs and use these CHs as a relay station to transmit data over through them [14]. First, multi-hop communication is adopted among CHs. Then, according to the selected optimal path, these CHs transmit data to the corresponding CH which is nearest to BS. Finally, this CH sends data to BS. M-LEACH protocol is almost the same as LEACH protocol, only makes communication mode from single hop to multi-hop between CHs and BS.

LEACH-C protocol

LEACH offers no guarantee about the placement and/or number of cluster heads. In [15], an enhancement over the LEACH protocol was proposed. The protocol, called LEACH-C, uses a centralized clustering algorithm and the same steady-state phase as LEACH. LEACH-C protocol can produce better performance by dispersing the cluster heads throughout the network. During the set-up phase of LEACH-C, each node sends information about its current location (possibly determined using GPS) and residual energy level to the sink. In addition to determining good

clusters, the sink needs to ensure that the energy load is evenly distributed among all the nodes. To do this, sink computes the average node energy, and determines which nodes have energy below this average.

Once the cluster heads and associated clusters are found, the sink broadcasts a message that obtains the cluster head ID for each node. If a cluster head ID matches its own ID, the node is a cluster head; otherwise the node determines its TDMA slot for data transmission and goes sleep until it's time to transmit data. The steady-state phase of LEACH-C is identical to that of the LEACH protocol.

VLEACH protocol

In VLEACH [16] protocol, the cluster contains vice-CH, the node that will become a CH of the cluster in case of CH dies. In the original leach, the CH is always on receiving data from cluster members, aggregate these data and then send it to the BS that might be located far away from it. The CH dies earlier than the other nodes in the cluster because of its operation of receiving, sending and overhearing. When the CH dies, the cluster becomes useless because the data gathered by cluster nodes will never reach the base station. In VLEACH protocol, besides having a CH in the cluster, there is a vice-CH that takes the role of the CH when the CH dies. Because of this, cluster nodes data will always reach the BS; no need of electing a new CH each time the CH dies. This extends the overall network life time.

III. SUMMARY

In this chapter, examined the current state of clustering protocols. Despite the significant overall energy savings approaches, however, the various assumptions made by some protocols raise a number of issues. Like LEACH assumes that all nodes begin with the same amount of energy, which is however not realistic. It also assumes that all nearby nodes have correlated data which is not always true. PEGASIS assumes that the radio channel is symmetric so that the energy required to transmit a message from node i to node j is the same as energy required to transmit a message from node j to node i for a given signal to noise ratio (SNR). Protocols presented in this chapter offer a promising improvement over conventional clustering; however there is still much work to be done. Many energy improvements so far have focused with minimization of energy associated in the cluster head selection process or with generating a desirable distribution of cluster heads. Optimal clustering in terms of energy efficiency should eliminate all overhead associated not only with the cluster head selection process, but also with node association to their respective cluster heads. Sensor network reliability is currently addressed in various algorithms by utilizing re-clustering that occurs at various time intervals; however the result is often energy inefficient and limits the time available within a network for data transmission and sensing tasks. Finally E-LEACH, TL-LEACH, MLEACH, LEACH-C and VLEACH suggested the improvements in the basic LEACH protocols in order to improve the performance of the basic LEACH protocols.

IV. CONCLUSION

The core operation of a WSN is to gather and convey the

collected data to a distant BS for further processing and analysis. Gathering information from a WSN in an energy effective manner is of paramount importance in order to prolong its life span. This calls for use of an appropriate routing protocol to ensure efficient data transmission through the network. In this research project, the basic cluster based LEACH routing protocol is improved by suggesting distributed cluster formation approach. The result of simulations conducted indicates that the proposed clustering approach is more energy efficient and hence effective in prolonging the network life time compared to LEACH.

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