Performance Evaluation of LECH and HEED Clustering Protocols in Wireless Sensor Networks

Narmada[1], Sunil Kumar[2] and Sudesh Kumar[3]

[1]M.Tech Scholar, BRCM CET BAHAL,Bhiwani(Haryana)

[2]Assistant Professor, BRCM CET BAHAL,Bhiwani(Haryana)

[3]Associate Professor, BRCM CET BAHAL,Bhiwani(Haryana)

Abstract: ***Research on wireless sensor networks has recently received much attention as they offer an advantage of monitoring various kinds of environment by sensing physical phenomenon. Prolonged network lifetime, scalability, and load balancing are important requirement for many sensor network applications. Clustering sensor nodes is an effective technique for achieving these goals. In this paper, we evaluate and compare state-of-the-art clustering protocols, i.e., LEACH ,LEACH C and HEED. Finally, these clustering approaches were compared based on a few metrics such as convergence rate, cluster stability, cluster overlapping, location-awareness and support for node mobility. Finally, we summarize and conclude the paper with some future directions***

Keywords: HEED, LEACH , WSN, Routing Protocols.

1. INTRODUCTION

WSN is a very large array of diverse sensor nodes that are interconnected by a communication network. The wireless sensor network has many sensor nodes; these nodes can forward the information and cooperate with each other to accomplish some specific tasks through the application of communication for wireless self organization [1].The elementary components of a sensor node are sensing unit, a processing unit, a transceiver unit and a power unit. The sensor node senses the physical quantity being measured and coverts it into an electrical signal. Then, the signal is fed to an A/D converter and is ready to be used by the processor[3]. The processor will convert the signal into data depending on how it is programmed and it sends the information to the network by using a transceiver. The sensing data are shared between the sensor nodes and are used as input for a distributed estimation system[4][5]. The fundamental objectives for WSN are reliability, accuracy, flexibility, cost effectiveness, and ease of deployment. WSN is made up of individual multifunctional sensor nodes [4]. As we know that wireless sensor network mainly consists of tiny sensor node which is equipped with a limited power source. The lifespan of an energy-constrained sensor is determined by how fast the sensor consumes energy. A node in the network is no longer useful when its battery dies. Researchers are now developing new routing mechanisms for sensor networks to save energy and pro-long the sensor lifespan. The dynamic clustering protocol allows us to space out the lifespan of the nodes, allowing it to do only the minimum work it needs to transmit data[2]. The WSN can be applied to a wide range of applications, such as environment management, environmental monitoring, industrial sensing, infrastructure protection, battlefield awareness and temperature sensing. So, it is essential to improve the energy efficiency to enhance the quality of application service [2] [7].

2. LEACH [LOW-ENERGY ADAPTIVE CLUSTERING HIERARCHY]

LEACH is hierarchical routing approach for sensors networks. The idea proposed in LEACH has been an inspiration for many hierarchical routing protocols, although some protocols have been independently developed. We explore hierarchical routing protocols in following figure.

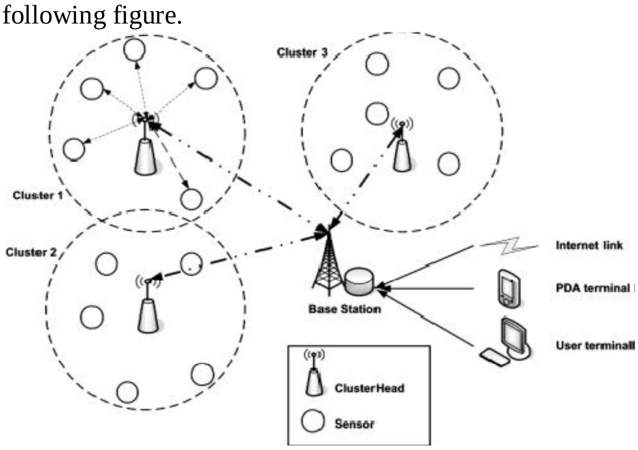

Figure 1 Hierarchical or cluster-based routing

The main aim of hierarchical routing is to efficiently maintain the energy consumption of sensor nodes by involving them in multi-hop communication within a particular cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the sink. Cluster formation is typically based on the energy reserve of sensors and sensor's proximity to the cluster head. Hierarchical or cluster-based routing, originally proposed in wire line networks, are well-known techniques with special advantages related to scalability and efficient communication.

As such, the concept of hierarchical routing is also utilized to perform energy-efficient routing in WSNs. In a hierarchical architecture, higher energy nodes can be used to process and send the information while low energy nodes can be used to perform the sensing in the proximity of the target. This means that creation of clusters and assigning special tasks to cluster heads can greatly contribute to overall system scalability, lifetime, and energy efficiency. Hierarchical routing is an efficient way to lower energy consumption within a cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the BS. Hierarchical routing is mainly two-layer routing where one layer is used to select cluster heads and the other layer is used for routing. LEACH randomly selects a few sensor nodes as cluster heads (CHs) and rotates this role to evenly distribute the energy load among the sensors in the network In LEACH, the cluster head (CH) nodes compress data arriving from nodes that belong to the respective cluster, and send an aggregated packet to the base station in order to reduce the amount of information that must be transmitted to the base station. LEACH uses a TDMA/CDMA MAC to reduce inter-cluster and intra-cluster collisions. However, data collection is centralized and is performed periodically. Therefore, this protocol is most appropriate when there is a need for constant monitoring by the sensor network. A user may not need all the data immediately.

Hence, periodic data transmissions are unnecessary which may drain the limited energy of the sensor nodes. After a given interval of time, a randomized rotation of the role of the CH is conducted so that uniform energy dissipation in the sensor network is obtained. The operation of LEACH is separated into two phases (figure 2.2), the setup phase and the steady state phase.

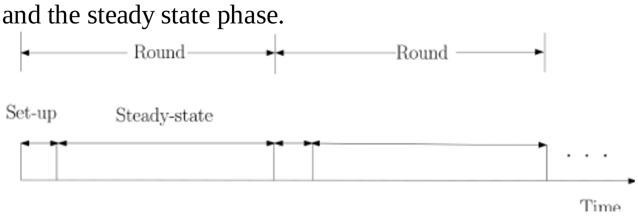

Figure 2 LEACH operations

In the setup phase, the clusters are organized and CHs are selected.

In the steady state phase, the actual data transfer to the base station takes place. The duration of the steady state phase is longer than the duration of the setup phase in order to minimize overhead.

During the setup phase, a predetermined fraction of nodes, p, elect themselves as CHs as follows. A sensor node chooses a random number, r, between 0 and 1. If this random number is less than a threshold value, T(n), the node becomes a cluster head for the current round. The threshold value is calculated based on an equation that incorporates the desired percentage to become a cluster-head, the current round, and the set of nodes that have not been selected as a cluster-head in the last (1/P) rounds, denoted by G. It is given by:-

Where G is the set of nodes that are involved in the CH election. Each elected CH broadcast an advertisement message to the rest of the nodes in the network that they are the new cluster-heads. All the non-cluster head nodes, after receiving this advertisement, decide on the cluster to which they want to belong to. This decision is based on the signal strength of the advertisement. The non cluster-head nodes inform the appropriate cluster-heads that they will be a member of the cluster. After receiving all the messages from the nodes that would like to be included in the cluster and based on the number of nodes in the cluster, the cluster-head node creates a TDMA schedule and assigns each node a time slot when it can transmit. This schedule is broadcast to all the nodes in the cluster. During the steady state phase, the sensor nodes can begin sensing and transmitting data to the cluster-heads. The cluster head node, after receiving all the data aggregates it before sending it to the base-station. After a certain time, which is determined a priori, the network goes back into the setup phase again and enters another round of selecting new CH. Each cluster communicates using different CDMA codes to reduce interference from nodes belonging to other clusters.

Pros [5] are

1. The coordination and control in the cluster is localized in the set up phase.
2. The role of the CH is rotated and randomized to distribute the energy requirements among the nodes of the network.
3. To reduce the total amount of data transmission, local compression techniques are used in the CH.
4. LEACH is suitable for homogeneous networks.

Cons [6] are:

1. LEACH does not provide clarity about position of sensor nodes and the number of cluster heads in the network.
2. Each Cluster-Head directly communicates with BS no matter the distance between CH and BS. It will consume lot of its energy if the distance is far.
3. The CH uses most of its energy for transmitting and collecting data, because, it will die faster than other nodes.
4. The CH is always on and when the CH die, the cluster will become useless because the data gathered by cluster nodes will never reach the base station.

3. LEACH-C PROTOCOL

LEACH offers no guarantee about the placement and/or number of cluster heads. 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 its time to transmit data. The steady-state phase of LEACH-C is identical to that of the LEACH protocol.

4. HYBRID, ENERGY-EFFICIENT DISTRIBUTED CLUSTERING (HEED) PROTOCOL

HEED [11] excellent cluster-based protocol it elect CHs based on residual energy and node degree or density of nodes as a metric for cluster selection to achieve power balancing, which is a rational improvement compared with LEACH. In HEED, the proposed algorithm periodically selects CHs according to a combination of two clustering parameters. The primary parameter is their residual energy of each sensor node and the secondary parameter is the intra-cluster communication cost as a function of cluster density. The primary parameter depends on the residual energy of the node, is used to probabilistically select an initial set of CHs while the secondary parameter is used for breaking ties, is considering the cost of communications within the intra-cluster. HEED was proposed with four primary goals namely,

(i) Prolonging network lifetime by distributing energy consumption,

(ii) Terminating the clustering process within a constant number of iterations,

(iii) Minimizing control overhead,

(iv) Producing well-distributed CHs and compact clusters.

Hybrid Energy Efficient Distributed clustering (HEED) [8] is a multi-hop wireless sensor network clustering algorithm that brings an energy-efficient clustering routing with explicit consideration of energy.

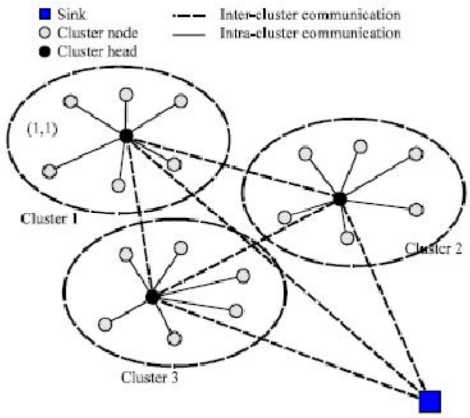

Figure 3 HEED operations

A node considers itself covered if it has heard from either a tentative_ CH or a final _CH. If a node completes HEED execution without selecting a cluster head that is final _CH, it considers itself uncovered, and announces itself to be a cluster head with state final_ CH. A tentative _CH node can become a regular node at a later iteration if it finds a lower cost cluster head. HEED protocol depend on residual energy, and communication cost to select cluster head.

The communication cost is the minimum power levels required by all nodes within the cluster range to reach the cluster head. The communication cost uses to allow a node that belong to several CHS choose the best one. In HEED protocol each node can join only to one cluster head with one hop only. After a cluster formation, each node can be either elected to become a CH due to a probability or join a cluster according to CH messages.

The advantages of the HEED protocol are as follows:

(1) It is a fully distributed clustering method that benefits from the use of the two important parameters for CH election

(2) Low power levels of clusters promote an increase in spatial reuse while high power levels of clusters are required inter-cluster communication. This provides uniform CH distribution across the network and load balancing.

(3) Communications in a multi-hop fashion between CHs and the BS promote more energy conservation and scalability in contrast with the single-hop fashion, i.e., long-range communications directly from CHs to the sink, in the LEACH protocol.

However, there are some limitations with HEED as follows:

(1) The uses of tentative CHs that do not become final CHs leave some uncovered nodes. As per HEED implementation, these nodes are forced to become a CH and these forced CHs may be in range of other CHs or may not have any member associated with them. As a result, more CHs are generated than the expected number and this also accounts for unbalanced energy consumption in the network.

(2) Similar to LEACH, performing of clustering in each round imposes significant overhead in the network. This overhead causes noticeable energy dissipation which results in decreasing the network lifetime.

(3) HEED suffers from a consequent overhead since it needs several iterations to form clusters. At each iteration, a lot of packets are broadcast.

(4) Some CHs, especially near the sink, may die earlier because these CHs have more work load, and the hot spot will come into being in the network.

5. IMPLEMENTATION

a) Protocols implemented

After having finished a survey of the state-of-the-art it was necessary to select the protocols that would be implemented. Firstly, LEACH, i.e. LEACH-distributed, was selected due to the fact that is the first well known clustering-based routing protocol and all the subsequent clustering-based protocols are based on it or are referred to it somehow. Therefore, it was a good first step to start with. Other interesting protocols that were selected to be implemented were LEACH-C, i.e. LEACH-centralized, created by the same authors of LEACH and also the solar-

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aware extensions of both, which were found in with the original paper.

Finally, a more complex protocol, which is called HEED, was chosen since it is currently one of the most well known and mentioned routing protocols. Moreover, some published surveys as show its suitable features and good results.

The implementation of HEED is based on the pseudo-code that is provided in the original paper.

Therefore, different protocols were selected for their implementation and simulation. These protocols differ in their complexity, the strength and number of assumptions they make and the goals they have. Once the programming of all these protocols was finished it was necessary to create and implement one basic protocol to compare the rest of them with it. The simplest approach for routing protocols is the One-hop that has been implemented for this work since it is a good simulation to see whether the compared protocols are energy-efficient or not and how much they elongate the batteries lifetime.

Therefore, in this work is presented a comparison among four protocols, i.e. One-hop, LEACH, LEACH-C and HEED, and two solar-aware extensions, i.e. Solar-aware LEACH and Solar-aware LEACH-C.

One-hop

This protocol is the easiest and simplest routing approach and has been implemented to establish a reference for the comparison among the different protocols. It is based on the assumption that every node is able to reach the base station, otherwise it would be impossible the communication between every node and the base station. The operation of this protocol is quite simple. In ‘every round the base station receives a status message from all nodes, which points out to the base station the position and parameters of the node. Once the base station has received all the messages it creates a TDMA schedule telling each node when it can transmit the data and how many times this process is repeated. Once all nodes have sent all the data packets regarding to the current round, they send another status message in order to start the next round.

Implementation Result

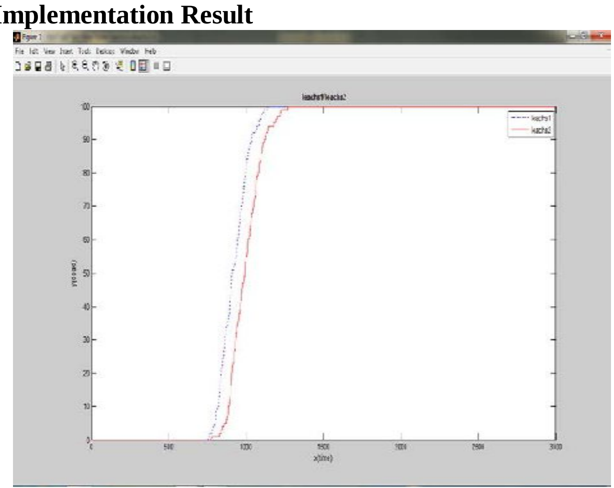

Figure 4 LEACH1 Vs LEACH2

This graph shows the LEECH protocols comparison in terms of dead node and time.

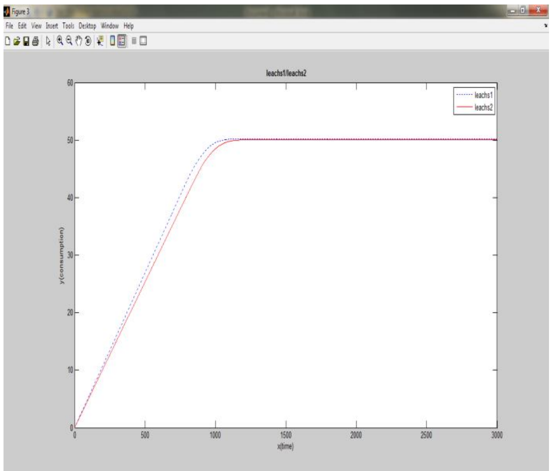

Figure 5 LEACH1 Vs LEACH2 (Consumption, Time)

This graph shows the LEACH protocols comparison in terms of consumption and time, with different variations.

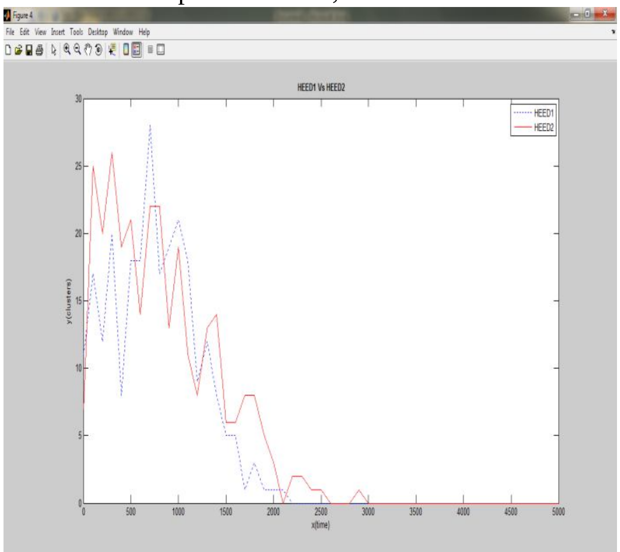

Figure 6 HEED1 Vs HEED2 (Cluster, Time)

This graph shows the HEED protocol in terms of number of clusters and time, with different variations.

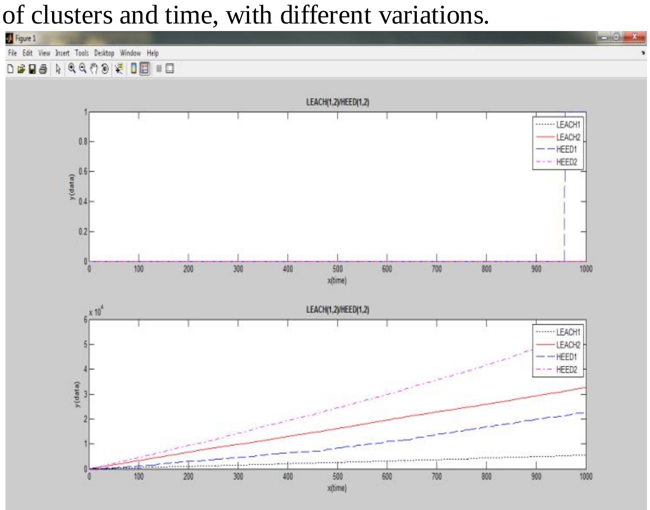

Figure 7 LEACH Vs HEED

This graph shows the comparison between the two protocols in terms of data and time, which states the energy conservation by these protocols.

6. CONCLUSION AND FUTURE SCOPE:

Finally it is concluded from the survey that, still it is needed to find more scalable, energy efficient and stable clustering scheme, for data gathering in wireless sensor networks. . The result of our experimental study shows after the comparing that the HEED routing protocol is more energy efficient routing protocol for wireless sensor network as comparisons to LEACH protocol in the form of energy consumption and cost of sensor nodes.
Simulations have been carried out in MATLAB that helped us to exploit the benefits of the propagation channels for longevity of the energy constrained network. Further in future we use the movable nodes to compare and analyzed these protocols and the evaluation of usability of the API to develop new protocols.

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