

Performance Analysis of LEACH Protocol

Jose Anand

Research Scholar, Anna University
Chennai, & Associate Professor/ECE,
KCG College of Technology
Email: joseanandme@yahoo.co.in

B. Thyala

Assistant Professor/ECE,
KCG College of Technology, Chennai,
Tamil Nadu, India – 600 097

S. Abida Begum

Assistant Professor/ECE,
KCG College of Technology, Chennai,
Tamil Nadu, India – 600 097

Abstract – Wireless Sensor Networks (WSN) the availability of cheap, low power, and miniature embedded processors, radios, sensors, and actuators, often integrated on a single chip, is leading to the use of wireless communications and computing for interacting with the physical world in applications such as security and surveillance applications, smart classroom, monitoring of natural habitats and ecosystems, medical monitoring etc. The resulting systems, often called WSNs, differ considerably from current network and embedded systems. A wireless sensor network with a large number of sensor nodes can be used as an effective tool for gathering data in various situations. One of the major issues in wireless sensor networks is developing an energy-efficient routing protocol which has a significant impact on the overall lifetime of the sensor network. In this paper the energy analysis of LEACH (Low Energy Adaptive Clustering Hierarchy) protocol is carried out using the NS-2 simulator. In this paper the energy and throughput of LEACH protocol is analyzed. The simulation is carried out in a scenario of 100 nodes and an initial energy of 10 Joules is considered.

Keywords – LEACH, WSN, Energy, Routing Protocol.

I. INTRODUCTION

In recent years, the use of wired sensor networks is being advocated for a number of applications. Some examples include distribution of thousands of sensors and wires over strategic locations in a structure such as an airplane, so that conditions can be constantly monitored both from the inside and the outside and a real-time warning can be issued when the monitored structure is about to fail. Sensor networks are usually unattended and need to be fault-tolerant so that the need for maintenance is minimized. This is especially desirable in those applications where the sensors may be embedded in the structure or are in inhospitable terrain and are inaccessible for any service. The advancement in technology has made it possible to have extremely small, low powered devices equipped with programmable computing, multiple parameter sensing and wireless communication capability. Also, the low cost of sensors makes it possible to have a network of hundreds or thousands of these wireless sensors, thereby enhancing the reliability and accuracy of data and the area coverage as well. Also, it is necessary that the sensors be easy to deploy (i.e., require no installation cost etc). Protocols for these networks must be designed in such a way that the limited power in the sensor nodes is efficiently used. In addition, environments in which these nodes operate and respond are very dynamic, with fast changing physical parameters. The following are some of the parameters which might change dynamically depending on the application:

- Power availability
- Position (if the nodes are mobile)
- Reachability
- Type of task (i.e. node attributes to operate on)

So, the routing protocol should be fault-tolerant in such a dynamic environment. The traditional routing protocols defined for wireless ad hoc networks are not well suited due to the following reasons:

1. Sensor networks are “data centric” i.e., unlike traditional networks where data is requested from a specific node, data is requested based on certain attributes such as, which area has temperature $<50^{\circ}\text{F}$?
2. The requirements of the network change with the application and so, it is application-specific. For example, in some applications the sensor nodes are fixed and not mobile, while others need data based only on one attribute (i.e., attribute is fixed in this network).
3. Adjacent nodes may have similar data. So, rather than sending data separately from each node to the requesting node, it is desirable to aggregate similar data and send it.
4. In traditional wired and wireless networks, each node is given a unique id, used for routing. This cannot be effectively used in sensor networks. This is because, these networks being data centric, routing to and from specific nodes is not required. Also, the large number of nodes in the network implies large ids, which might be substantially larger than the actual data being transmitted. Thus, sensor networks need protocols which are application specific, data centric, capable of aggregating data and optimizing energy consumption. An ideal sensor network should have the following additional features:

Attribute based addressing is typically employed in sensor networks. The attribute based addresses are composed of a series of attribute-value pairs which specify certain physical parameters to be sensed.

Location awareness is another important issue. Since most data collection is based on location, it is desirable that the nodes know their position whenever needed.

II. CLUSTERING

In order to support data aggregation through efficient network organization, nodes can be partitioned into a number of small groups called *clusters*. Each cluster has a coordinator, referred to as a *cluster head*, and a number of *member* nodes. Clustering results in a two-tier hierarchy in which cluster heads (CHs) form the higher tier while member nodes form the lower tier.

Figure 1 illustrates the clustering process of various nodes. The member nodes report their data to the respective CHs. The CHs aggregate the data and send

them to the central base through other CHs. Because CHs often transmit data over longer distances, they lose more energy compared to member nodes. The network may be re-clustered periodically in order to select energy-abundant nodes to serve as CHs, thus distributing the load uniformly on all the nodes. Besides achieving energy efficiency, clustering reduces channel contention and packet collisions, resulting in better network throughput under high load.

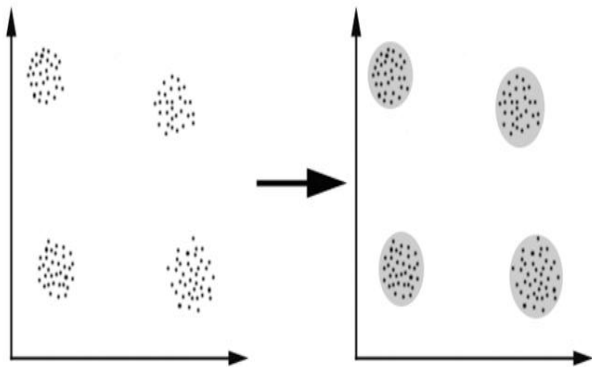


Fig.1. Clustering of Nodes

Clustering has been shown to improve network lifetime, a primary metric for evaluating the performance of a sensor network. Although there is no unified definition of “network lifetime,” as this concept depends on the objective of an application, common definitions include the time until the first/last node in the network depletes its energy and the time until a node is disconnected from the base station. In studies where clustering techniques were primarily proposed for energy efficiency purposes, the network lifetime was significantly prolonged.

Clustering has been extensively studied in the data processing and wired network literatures. The clustering approaches developed in these areas cannot be applied directly to WSNs due to the unique deployment and operational characteristics of these networks. Specifically, WSNs are deployed in an ad hoc manner and have a large number of nodes. The nodes are typically unaware of their locations. Hence, distributed clustering protocols that rely only on neighborhood information are preferred for WSNs (however, most studies in this area still assume that the network topology is known to a centralized controller). Furthermore, nodes in WSNs operate on battery power with limited energy. Hence, the employed clustering approach must have low message overhead.

Finally, harsh environmental conditions result in unexpected failures of nodes. Hence, periodic re-clustering is necessary in order to heal disconnected regions and distribute energy consumption across all nodes. Periodic re-clustering is also necessary, as the parameters used for clustering (e.g., the remaining energy, node degree, etc.) are *dynamic*. The clustering techniques proposed for data processing typically consider *static* parameters, such as the distance between the nodes, and assume that nodes are more reliable.

A. Classification of Clustering Techniques in WSNs

Clustering in WSNs involves grouping nodes into clusters and electing a CH such that: The members of a

cluster can communicate with their CH directly. A CH can forward the aggregated data to the central base station through other CHs. Thus, the collection of CHs in the network forms a connected dominating set. Research on clustering in WSNs has focused on developing centralized and distributed algorithms to compute connected dominating sets. We focus on distributed approaches since they are more practical for large-scale deployment scenarios. Since obtaining an optimal dominating set is an NP-complete problem, the proposed algorithms are heuristic in nature. We classify the clustering techniques based on two criteria: First is using the parameter(s) used for electing CHs. Secondly, the execution nature of a clustering algorithm (probabilistic or iterative)

B. Election of Cluster Heads

One class of clustering techniques uses the node identifier to elect CHs. The success of this approach depends on two assumptions, every node has a unique identifier and these identifiers are uniformly assigned throughout the field.

The execution of a clustering algorithm can be carried out at a centralized authority (e.g., a base station) or in a distributed way at local nodes. Centralized approaches require global information about the network topology. Probabilistic Clustering Techniques — the probabilistic (or randomized) approach for node clustering ensures rapid convergence while achieving some favorable properties, such as balanced cluster sizes. It enables every node to independently decide on its role in the clustered network while keeping the message overhead low. Clustering has numerous advantages. Some of these are:

1. Clustering reduces the size of the routing table stored at the individual nodes by localizing the route set up within the cluster.
2. Clustering can conserve communication bandwidth since it limits the scope of intercluster interactions to CHs and avoids redundant exchange of messages among sensor nodes.
3. The CH can prolong the battery life of the individual sensors and the network lifetime as well by implementing optimized management strategies.
4. Clustering cuts on topology maintenance overhead. Sensors would care only for connecting with their CHs.
5. A CH can perform data aggregation in its cluster and decrease the number of redundant packets.
6. A CH can reduce the rate of energy consumption by scheduling activities in the cluster.

III. LEACH

Low Energy Adaptive Clustering Hierarchy (LEACH) is the first hierarchical cluster-based routing protocol for wireless sensor network which partitions the nodes into clusters, in each cluster a dedicated node with extra privileges called Cluster Head (CH) is responsible for creating and manipulating a TDMA (Time division multiple access) schedule and sending aggregated data from nodes to the BS where these data is needed using CDMA (Code division multiple access). Remaining nodes are cluster members.

This protocol is divided into rounds; each round consists of two phases:

A. Set-up Phase

Each node decides independent of other nodes if it will become a CH or not. This decision takes into account when the node served as a CH for the last time (the node that hasn't been a CH for long time is more likely to elect itself than nodes that have been a CH recently). In the following advertisement phase, the CHs inform their neighborhood with an advertisement packet that they become CHs. Non-CH nodes pick the advertisement packet with the strongest received signal strength.

In the next cluster setup phase, the member nodes inform the CH that they become a member to that cluster with "join packet" contains their IDs using CSMA. After the cluster-setup sub phase, the CH knows the number of member nodes and their IDs. Based on all messages received within the cluster, the CH creates a TDMA schedule, pick a CSMA code randomly, and broadcast the TDMA table to cluster members. After that steady-state phase begins.

B. Steady-State Phase

Data transmission begins; Nodes send their data during their allocated TDMA slot to the CH. This transmission uses a minimal amount of energy (chosen based on the received strength of the CH advertisement). The radio of each non-CH node can be turned off until the nodes allocated TDMA slot, thus minimizing energy dissipation in these nodes. When all the data has been received, the CH aggregate these data and send it to the BS. LEACH is able to perform local aggregation of data in each cluster to reduce the amount of data that transmitted to the base station.

Although LEACH protocol acts in a good manner, it suffers from many drawbacks like: CH selection is randomly, that does not take into account energy consumption. It can't cover a large area. CHs are not uniformly distributed; where CHs can be located at the edges of the cluster. Since LEACH has many drawbacks, there is a requirement to make this protocol perform better.

V. RESULTS AND SIMULATIONS

For experimentation the NS-2 simulator is used. The parameters of the experiment are as follows: the initial position of the sink node is (0,0), the area of the network is 100m×100m , the number of the nodes is 100, the initial energy of each node is 0.5J, the size of common data packet is 8192 bits, the size of control information packet is 64 bits, the number of the optimal cluster heads is 5, the maximum number of iterations is 1000.

The LEACH protocol uses the Random Inertia Weight (RIW) strategy. In this the nodes are selected as cluster heads randomly and in this process the low energy nodes are also selected as cluster heads. Hence the network performance gets affected as the low energy cluster heads die soon in the system.

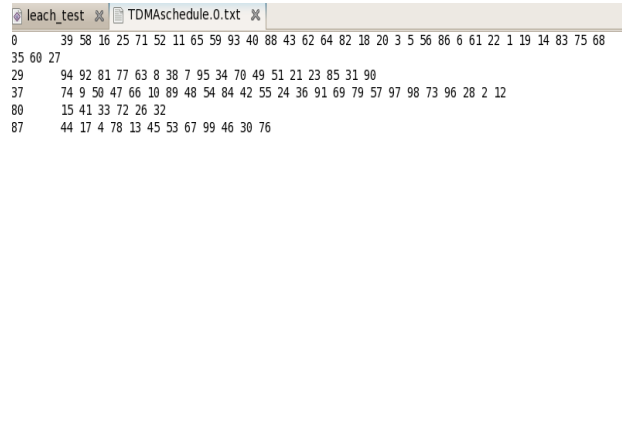


Fig.2. Random Inertia Weight Strategy

In figure 2, it shows how the cluster heads are selected using the RIW strategy. The cluster heads are selected in a random manner in each round. Hence in this process the low energy nodes are selected as cluster heads.

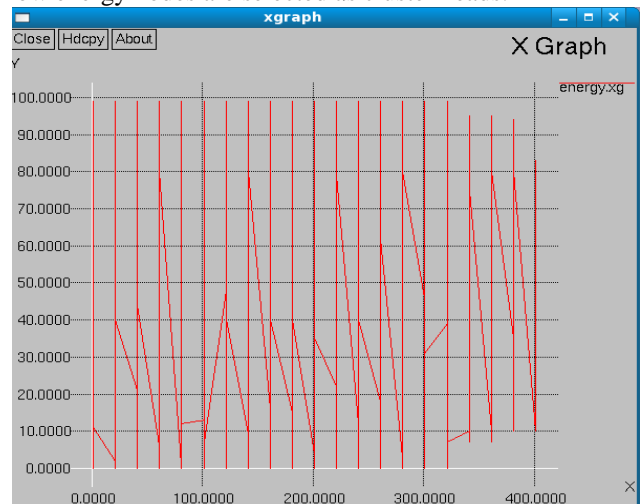


Fig.3. Energy analysis of LEACH protocol

In fig 3 the energy of the nodes in different rounds and time are plotted. In LEACH the energy of the nodes are not constant throughout the lifetime of the network. The low energy nodes are also selected as cluster heads in the RIW strategy. The graph is plotted with time in milliseconds in X-axis and Energy in Joules in Y-axis.

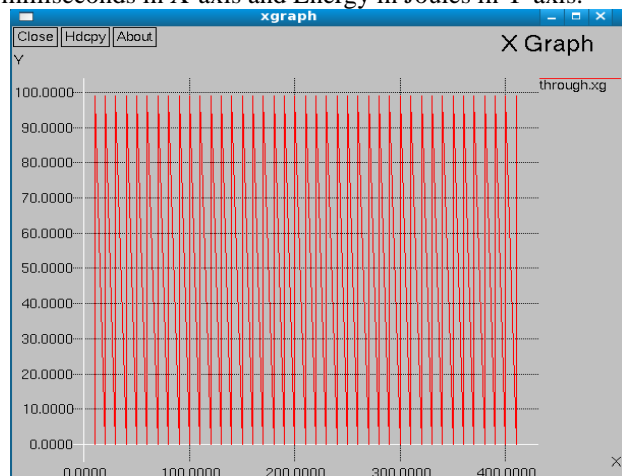


Fig.4. Throughput Analysis of LEACH Protocol

In figure 4, the throughput of LEACH protocol is analyzed and plotted with time in milliseconds in X-axis and throughput percentage in Y-axis. Hundred percentage throughput is attained in the LEACH protocol.

VI. CONCLUSION

In this paper we considered a well-known protocol for wireless sensor networks called LEACH protocol which is the first and the most important protocol in WSN which uses cluster based broadcasting technique. The energy analysis shows that the energy is not constant throughout the lifetime of the network and this is due to the RIW strategy. This drawback can be avoided by using a protocol which selects the cluster head in a Decreasing Inertia Weight Strategy where the cluster heads are selected in a decreasing priority.

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