



Analysis of LEACH Protocol in Wireless Sensor Networks

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Abstract— *Wireless Sensor Network is a network of sensor nodes without having any central controller. Its growth is expeditiously increasing and that's why there is an immense field for research in this area. Sensors depend entirely on the trust of their battery for power, which cannot be revitalized or substituted. So the design of energy aware protocol is essential in respect to enhance the network lifetime. LEACH is energy-efficient hierarchical based protocol that balances the energy expense, saves the node energy and hence prolongs the lifetime of the network. So this paper presents a detailed review and analysis of LEACH protocol. Comparison of various network parameters is done in the form of tables and graphs. The simulation work has been carried out by using own set of parameters and in the last of the paper conclusions is drawn.*

Keywords— *Routing, LEACH, Energy efficiency, Energy level, Number of Cluster head NCH, network lifetime.*

I. INTRODUCTION

WSN is a very large array of diverse sensor nodes that are interconnected by a communication network. 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 converts 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].

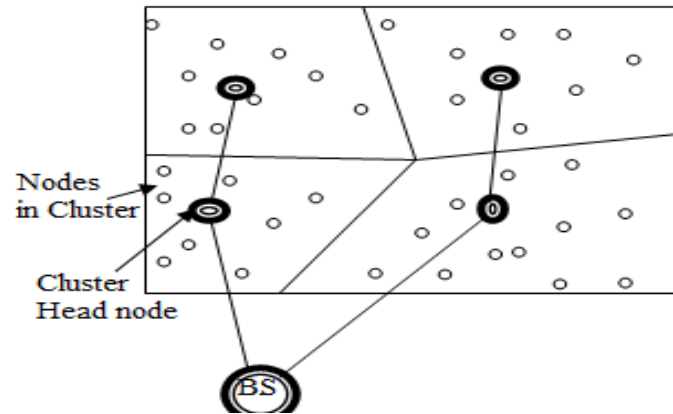
II. LOW ENERGY ADAPTIVE CLUSTERING HIERARCHY(LEACH)

As we all know that all the networks have a certain lifetime during which nodes have limited energy by using that, the nodes gather, process, and transmit information. This means that all aspects of the node, from the sensor module to the hardware and protocols, must be designed to be extremely energy-efficient. Decreasing energy usage by a factor of two can double system lifetime, resulting in a large increase in the overall usefulness of the system. In addition, to reduce energy dissipation, protocols should be robust to node failures, fault-tolerant and scalable in order to maximize system lifetime[1].

LEACH is the first network protocol that uses hierarchical routing for wireless sensor networks to increase the life time of network. All the nodes in a network organize themselves into local clusters, with one node acting as the cluster-head. All non-cluster-head nodes transmit their data to the cluster-head, while the cluster-head node receive data from all the cluster members, perform signal processing functions on the data (e.g., data aggregation), and transmit data to the remote base station. Therefore, being a cluster-head node is much more energy-intensive than being a non-cluster-head node. Thus, when a cluster-head node dies all the nodes that belong to the cluster lose communication ability [6][8].

LEACH incorporates randomized rotation of the high-energy cluster-head position such that it rotates among the sensors in order to avoid draining the battery of any one sensor in the network[5]. In this way, the energy load associated with being a cluster-head is evenly distributed among the nodes. Since the cluster-head node knows all the cluster members, it can create a TDMA schedule that tells each node exactly when to transmit its data. In addition, using a TDMA schedule for data transfer prevents intra-cluster collisions. The operation of LEACH is divided into

rounds. Each round begins with a set-up phase when the clusters are organized, followed by a steady-state phase where several frames of data are transferred from the nodes to the cluster-head and onto the base station [9].



II(a). Set-up phase

In LEACH, nodes take autonomous decisions to form clusters by using a distributed algorithm without any centralized control. Here no long-distance communication with the base station is required and distributed cluster formation can be done without knowing the exact location of any of the nodes in the network. In addition, no global communication is needed to set up the clusters. The cluster formation algorithm should be designed such that nodes are cluster-heads approximately the same number of times, assuming all the nodes start with the same amount of energy [8]. Finally, the cluster-head nodes should be spread throughout the network, as this will minimize the distance the non-cluster-head nodes need to send their data. A sensor node chooses a random number, r , between 0 and 1. Let a threshold value be $T(n)$:

$$T(n) = p / (1 - p \times (r \bmod p^{-1})).$$

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 the above given 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, p is cluster head probability.

After the nodes have elected themselves to be cluster-heads, it broadcasts an advertisement message (ADV). This message is a small message containing the node's ID and a header that distinguishes this message as an announcement message. Each non-cluster-head node determines to which cluster it belongs by choosing the cluster-head that requires the minimum communication energy, based on the received signal strength of the advertisement from each cluster-head. After each node has decided to which cluster it belongs, it must inform the cluster-head node that it will be a member of the cluster. Each node transmits a join-request message (Join-REQ) back to the chosen cluster-head. The cluster-heads in LEACH act as local control centers to co-ordinate the data transmissions in their cluster [9]. The cluster-head node sets up a TDMA schedule and transmits this schedule to the nodes in the cluster. This ensures that there are no collisions among data messages and also allows the radio components of each non-cluster-head node to be turned off at all times except during their transmit time, thus minimizing the energy dissipated by the individual [8][10].

II(b). Steady-State Phase

The steady-state operation is broken into frames where nodes send their data to the cluster-head at most once per frame during their allocated transmission slot. The set-up phase does not guarantee that nodes are evenly distributed among the cluster

head nodes. Therefore, the number of nodes per cluster is highly variable in LEACH, and the amount of data each node can send to the cluster-head varies depending on the number of nodes in the cluster. To reduce energy dissipation, each non-cluster-head node uses power control to set the amount of transmits power based on the received strength of the cluster-head advertisement. The radio of each non-cluster-head node is turned off until its allocated transmission time. Since all the nodes have data to send to the cluster-head and the total bandwidth is fixed, using a TDMA schedule is efficient use of bandwidth and represents a low latency approach, in addition to being energy-efficient [5][9]. The cluster-head must keep its receiver on to receive all the data from the nodes in the cluster. Once the cluster-head receives all the data, it can operate on the data and then the resultant data are sent from the cluster-head to the base station.

III. Performance of LEACH Protocol

To evaluate the performance of LEACH, we consider a 100 X 100 network configuration with 101 nodes, where each sensor node is assigned an initial energy of 2.0 J, the amount of transmission energy is 50 nJ/bit, transmit amplifier energy (E_{amp}) is 100 pJ/bit. The criteria for performance evaluation are the network lifetime, the energy consumption

and data aggregated at BS and no. of nodes alive. Each performance criteria is evaluated by varying the number of cluster-heads from 1 to 8. To determining quality of data we need to measure the amount of data (number of data signals represented by an aggregate signal) received at the base station. We tracked the rate at which the data are transferred to the base station and the amount of energy required to get the data to the base station.

The comparison of performance for the number of cluster heads is shown in the following graphs:

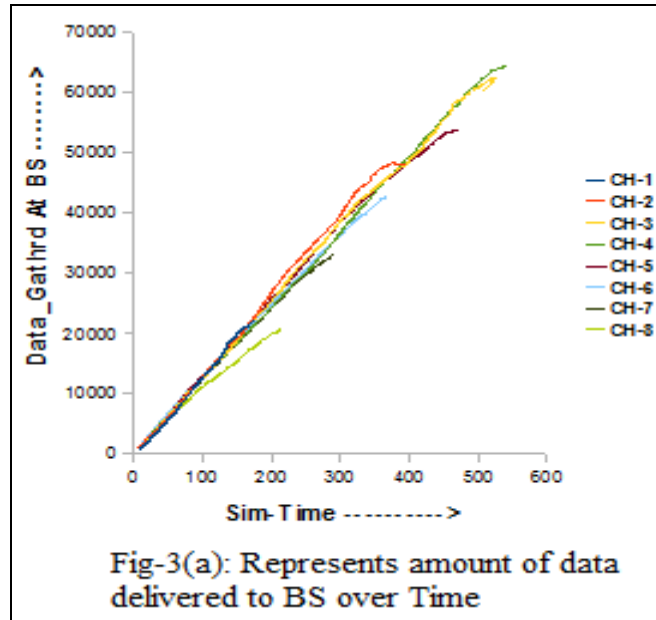
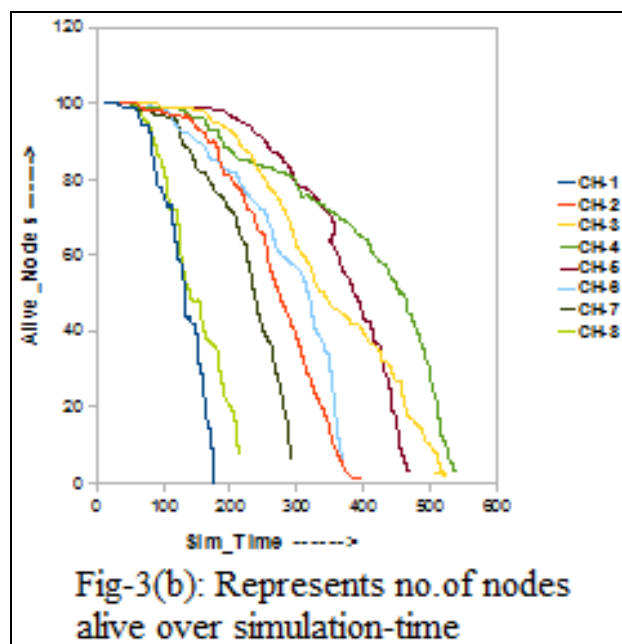
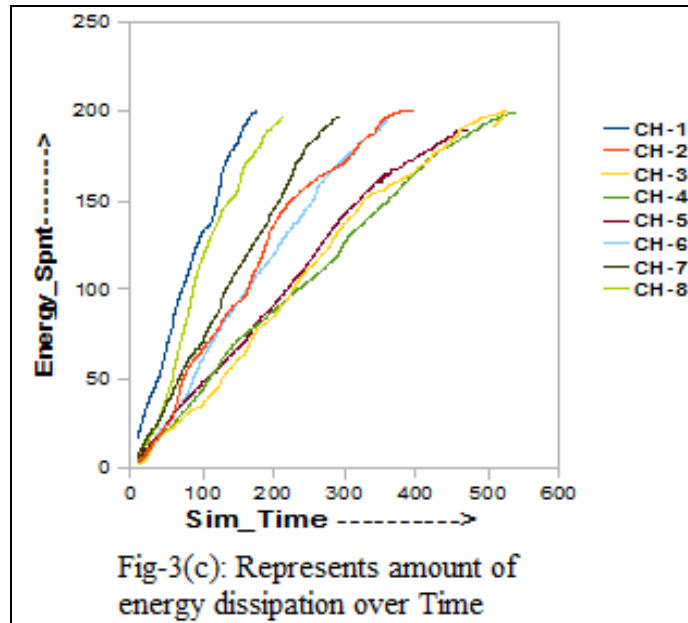


Figure3(a) shows amount of data delivered to BS over the time. Here maximum data is sent to BS when NCH=3 and 4 (NCH implies here the no. of cluster-heads) because both of these deliver almost same amount of data to the BS. At time 525 seconds NCH=3 delivered 62332 data signals and at time 541 seconds NCH=4 delivered 64246 data signals to BS. For NCH=5 amount of data delivered is significant but less comparatively. For NCH=8 and 1 very less amount of data is delivered that is (176, 21933) and (212, 20563) respectively.



In figure 3(b) for NCH=3 or 4 more number of nodes are alive over the simulation time as compared to other cases. The most inefficient results takes place for NCH=1 are (176,0) that means after only 176 seconds all nodes dies, because as soon as the head node dies communication to other nodes has been stopped. In NCH=3, some nodes are alive till 525 seconds after start of simulation and in NCH=4, they are alive for 541 seconds and for NCH=1 and 8 almost all nodes dies very quickly.



In Figure 3(c) it is found that the life time of network is improved only for NCH= 3 and 4, they are using same amount of energy over simulation time. They are using full energy till 525 seconds and 541 seconds after starting simulation. For NCH=1 and 8 the battery exhaust only after 176 seconds and 212 seconds respectively. For NCH=5 efficiency is at a good mark, it is slightly less comparatively.

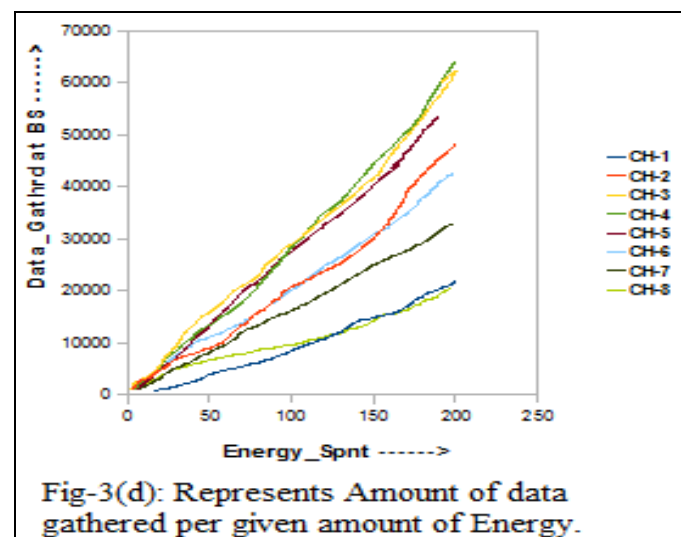


Figure 3(d) explains better results for NCH=3 and 4, by showing consumption of full energy at the cost of delivering 62332 and 64246 data signals to the BS respectively. When NCH= 1 and 8 very less amount of data signals (approx only 21900) has been delivered at the cost of consuming full energy, reason is being because for NCH=1, it behaves like static-clustering algorithm. For NCH=8 , here no. of clusters are more covering overlapping areas and when data is sent to BS duplicated data arrives resulting in loss of energy

So we test the network performance for number of cluster head from one to eight. When the no. of cluster-heads are only one or two then all the non-cluster-head nodes have to transmit data very far to the cluster-head node, thus resulting into energy draining very soon. When the no. of cluster-heads is more than 5 then local data aggregation is very less so are not much effective. But when the no. of cluster-heads are 3 and 4 then it provide full network coverage efficiently with less distance for non-cluster-head nodes to transmit. This results into more system life-time, more data delivered to BS, and using the limited power of battery for a long time comparatively with other situation. For no. of cluster-head is 5, it provides significant results but less than 3 or 4. So we analyzed the LEACH protocol by taking our interested set of parameters.

3.2 Disadvantages of LEACH[6]

- LEACH does not provide clarity about position of sensor nodes and the number of cluster heads in the network.
- 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.
- The CH uses most of its energy for transmitting and collecting data, because, it will die faster than other nodes.
- 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.

IV. Conclusion and Future Work

The main concern of this work is to examine the energy efficiency and performance of LEACH protocol using own set of parameters. We compare the lifetime and data delivery characteristics with the help of analytical comparison and also from our simulation results. From this work we find that LEACH provides better results for number of cluster heads as 3 and 4. This paper has covered performance of LEACH protocol only, we can also compare this protocol with other routing protocols that may or may not be hierarchical in nature. The process of data aggregation and fusion among clusters is also one of an interesting problem to explore. It is needed to satisfy the constraints introduced by factors such as fault tolerance, topology change, cost, environment, scalability, and power consumption for realization of sensor networks. Since these constraints are highly specific and stringent for sensor networks, new wireless ad-hoc networking techniques will have to be explored further.

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