Performance Analysis of Deterministic Energy Efficient Clustering Protocol for WSN

P. Samundiswary, M. Raj Kumar Naik

Abstract: Recently, there has been an increase in the use of ad hoc wireless sensor networks for monitoring environmental information (temperature, sound levels, humidity etc) across an entire physical space. In sensor networks, sensor nodes are used to gather local data and communicate with other nodes. Wireless sensor network (WSN) is built of several "nodes" from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors. The main challenging task in this network is routing. There are different types of protocols in WSN used to route the packets from source to destination. They are data centric, hierarchical, location–based and QoS aware. Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol is one of the best hierarchical protocols utilizing the probabilistic model to manage the energy consumption of WSN. However LEACH offers unguaranteed election of cluster head and election is not guaranteed to be optimal. In this paper, Deterministic Energy-efficient Clustering protocol (DEC), a deterministic model is developed to analyse the network performance. A deterministic energy-efficient clustering protocol promises a better election of cluster-heads and is dynamic, distributive, self-organizing and more energy efficient than the existing conventional LEACH protocols. Then the performance parameters such as number of rounds and energy dissipation of LEACH and DEC protocols are determined and analyzed by varying coverage area, packet length and nodes. The simulation is done by using MATLAB. The simulation results shows that DEC protocol has better performance than the existing LEACH protocol.

Index Terms— Energy efficiency, DEC, LEACH, Wireless Sensor Networks.

I. INTRODUCTION

Sensor networks have also recently emerged as an important computing platform. Sensor nodes are typically less mobile and more densely deployed than Mobile Ad-hoc NETworks (MANETs). Sensor nodes must be left unattended e.g., in hostile environments, which makes it difficult or impossible to re-charge or replace their batteries (solar energy is not always an option). This necessitates devising novel energy-efficient routing protocols in sensor network. LEACH is one of such probabilistic-based model of hierarchical protocol. The lifetime of WSN is extended with the help of LEACH by managing energy consumption [1], [2]. One of the goals of this protocol is to extend the WSN lifetime by using the global information derived from the network without considering the local information i.e. the residual energy of each node.

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The downside of such protocols is that there is no guarantee that the desired number of Cluster Heads (CHs) will be elected or the elected CH will have enough energy to perform its duty as a leader. However this model suffers from similar problem of unguaranteed cluster-head election per round as with the other probabilistic-based models[3], [4], [5]. Although, LEACH uses an optimal setting that can guarantee the best performance using their stochastic model, but most of the time the result could be sub-optimal due to the uncertainties in the cluster-head election process.

In this paper, an attempt has been made to develop deterministic energy-efficient clustering protocol for various coverage area, packet length and nodes to analyse the performance of the network. The performance parameters such as number of rounds and energy dissipation are determined and analysed. The rest of the paper is organized as Section 2 deals with discussion of the WSN, and their routing protocols with a detailed discussion on the hierarchical routing protocols. It further describes about the features of LEACH protocol. In Section 3, the deterministic energy-efficient clustering protocol for wireless sensor networks is discussed and their characteristics are also explained. Section 4 describes about the simulation model of WSN using DEC Protocol and LEACH protocol. The performance parameters of both protocols are also discussed. Conclusion is drawn in Section 5.

II. WIRELESS SENSOR NETWORKS

A WSN consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature and pressure, etc. and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, also enabling control of sensor activity. The development of wireless sensor networks, [7] was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications. Routing protocols of WSN are classified as data-centric, hierarchical, location-based and QoS based routing protocols. Hierarchical protocols are one of the energy efficient routing protocols used to reduce the energy consumption in WSN.

Hierarchical Protocols

Many research projects in the last few years have explored hierarchical clustering in WSN from different perspectives. Clustering is an energy-efficient communication protocol that can be used by the sensors to report their sensed data to the sink. A sample of layered protocol is described with several different *clusters* of sensors [8]. Each cluster is managed by a special node, called *cluster head*, which is responsible for coordinating the data transmission activities of all sensors in its cluster.

As shown in figure 1, a hierarchical approach breaks the network into clustered layers .Nodes are grouped into clusters with a cluster head that has the responsibility of routing from one cluster to the other cluster heads or base stations. Data travel from a lower clustered layer to a higher one. Although, it hops from one node to another, but as it hops from one layer to another it covers larger distances. This moves the data faster to the base station. Clustering provides hierarchical-based routing protocols for WSNs. LEACH is one of the clustering hierarchical routing protocols in WSN.

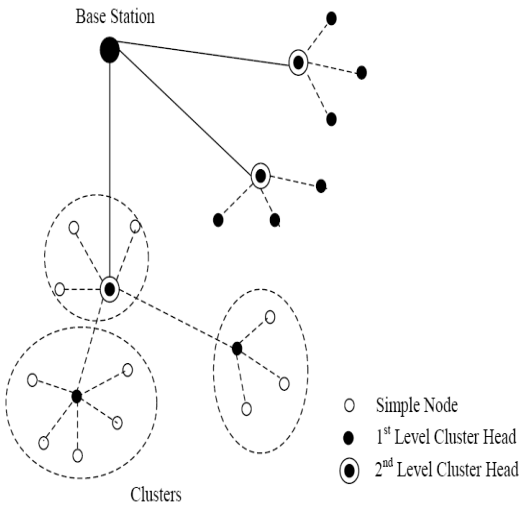

Figure 1: Cluster-Based Hierarchical Model

***Low-Energy Adaptive Clustering Hierarchy* (LEACH)**

LEACH is the first and most popular energy-efficient hierarchical clustering algorithm for WSNs [9], [10], that was proposed for reducing power consumption. In LEACH, the clustering task is rotated among the nodes, based on duration. Direct communication is used by each cluster head (CH) to forward the data to the base station (BS). It uses clusters to prolong the life of the wireless sensor network. LEACH is based on an aggregation (or fusion) technique [11] that combines or aggregates the original data into a smaller size of data that carry only meaningful information to all individual sensors. LEACH divides the network into several clusters of sensors, which are constructed by using localized **c**oordination and control not only to reduce the amount of data that are transmitted to the sink, but also to make routing and data dissemination more scalable and robust. LEACH uses a randomize rotation of high-energy CH position rather than selecting in static manner, to give a chance to all sensors to act as CHs and avoid the battery depletion of an individual sensor and dying quickly.

The operation of the clustering process [12] begins with a setup phase when all nodes use the indicator function for election as CHs. The elected CHs broadcast Advertisement message (ADV) using the non-persistent Carrier Sense Multiple Access Medium Access Control (CSMA MAC) protocol. This message contains the CH's ID and header that indicate it as an announcement message[13]. The non-elected nodes called cluster members (CMs) determine their cluster by choosing the CH with the minimum communication cost based on the received signal strength of the advertisement message. The CMs send join-request to their chosen CH using CSMA MAC protocol. This message contains the Cluster Member-ID (CM-ID), Cluster Head-ID (CHID) and the header that indicates the message as a request [14]. The CHs set up a Time Division Multiple Access (TDMA) for their intra-cluster communication, which ends the setup phase. The steady-state phase begins when sensed data are sent from CMs to CHs and from CHs to BS. The inter-cluster communication is also achieved using the Direct Sequencing Spread Spectrum (DSSS).

III. DETERMINISTIC PROTOCOL

A deterministic clustering protocol uses residual energy of each node in the cluster for election process of CH. DEC [6] seems to be similar to an ideal solution as shown in figure.2. However, the uncertainties in the cluster-head elections have been minimized in DEC. The setup phase used in LEACH is modified, but the steady-state phase is kept same as that of in LEACH protocol. Since node's energy can be determined a priori, the CH election process is reorganized by using the RE of each node. In DEC, the BS elects N_{opt} cluster-heads at round m for the network. The BS can only take part in the election of CHs if and only if m=1. The elected CHs advertise their role using CSMA MAC just as in LEACH. However, in DEC unlike in LEACH, the join-request message will contain CM-ID, CHID, CM-RE (cluster member-residual energy) and the header that indicates it as a request. This way the RE information of CMs is known to their respective CHs, thus localized and it can be utilized for CH rotation in the subsequent rounds.

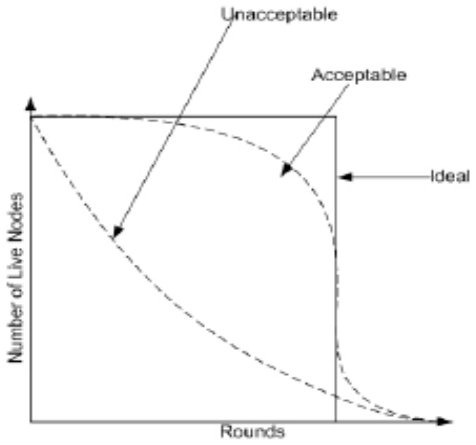

Figure 2: Behaviour of Node Energy Consumption Overtime

After the setup phase ends, the steady phase begins, but before the end of this phase, the current CHs checks the piggy-backed CM-RE's information received to decide whether they will remain as CHs or relinquish their roles by choosing any node in their clusters with the highest RE as the new CHs. After this decision is made for the new CHs and all the data from the current round is communicated to the BS, the current round (r=m) ends (a perfect synchronization is assumed, just as in LEACH). The next round r=m+1 begins; but since the new CH's are already chosen in the previous round, they broadcast their role in the new round, CMs join their cluster as already explained above. The steady phase begins again. This process continues in each round until the last node dies. With this method, the battery life of WSNs is significantly optimized.

Based on the simulation studies, the followings are observed, which makes the DEC protocol desirable:

- The CH election is locally decided based on each node's RE. And each round is independent of the subsequent round unlike in LEACH.
- DEC guarantees every node a chance of election as long as RE of each node is higher than its neighbors.
- DEC ensures a fixed N_{opt} cluster-head is chosen.
- DEC guarantees that every CH has enough energy to take up its role, until at least the end of the network lifetime, unlike in LEACH.

IV. SIMULATION RESULTS

The wireless sensor network model using DEC and LEACH protocol is simulated by using MATLAB. The performance parameters such as number of rounds and energy dissipation of deterministic energy-efficient clustering protocol and low-energy adaptive clustering hierarchy protocols are determined by varying nodes, coverage area and packet length. The parameters used for simulation is given in the Table 1.

Table 1 Simulation Parameters

Simulation Parameters	Values
No of Nodes	100,200,300
Coverage Area(m^2)	100*100,150*150,200*200,250*250, 300*300
Packet Length(bytes)	6400,8400
Initial Energy(Joules)	0.5
Rounds Max	9999

Analysis of Rounds with respect to Nodes, Coverage Area and Packet Length

The simulation process is carried out to analyze the number of rounds for various coverage area, packet length and nodes.

A) Coverage Area Vs Rounds

It is observed from the figure 3 and 4, that the number of rounds of DEC protocol is higher than LEACH protocol by varying the coverage area with constant packet length of 6400 and 8400 bytes. The reason is due to the increase in the number of alive nodes in DEC which uses residual energy for the election criteria of cluster head. Further, it is also inferred that as the coverage area increases, the number of rounds decreases. The reason is due to the involvement of the path for the data transmission is more when the coverage area is increased. Hence, the nodes die at a faster rate by reducing the number of rounds in the network.

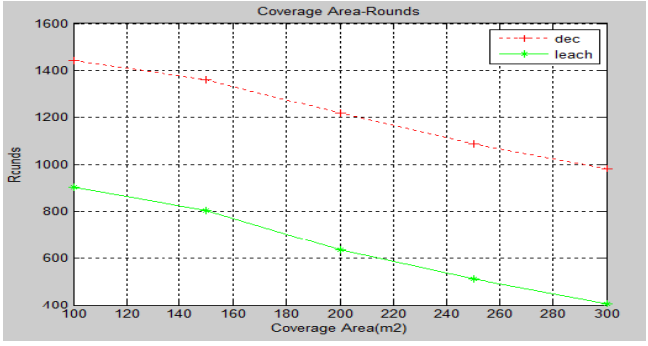

Figure 3: Coverage area with respect to number of rounds considering packet length of 6400 bytes

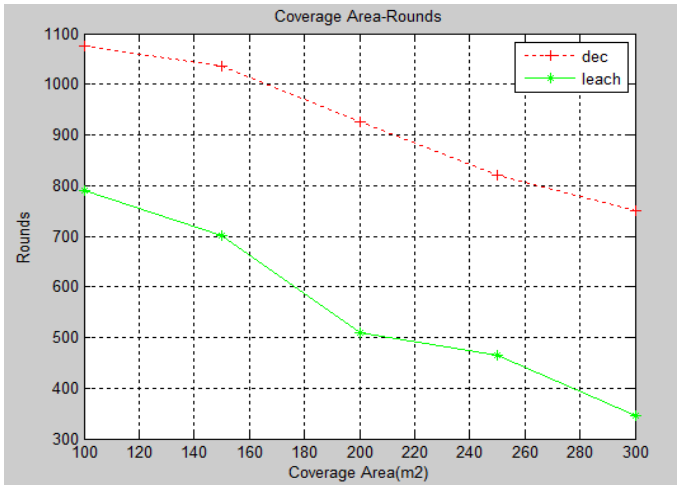

Figure 4: Coverage area with respect to number of rounds considering packet length of 8400 bytes

B)Packet Length Vs Rounds

It is observed from the figure 5 and 6, that the number of rounds of DEC protocol is higher than LEACH protocol by varying the packet length with constant number of nodes as 100 and 200. The reason is due to the decrease in the number of dead nodes in DEC which uses residual energy for the election criteria of cluster head. Further, it is also inferred that as the packet length increases the number of rounds decreases. The reason is, as the packet length increases, more number of nodes is repeatedly used for the data transmission process. Since fixed numbers of nodes are considered, the number of rounds is reduced as the nodes die at a faster rate. Therefore, the number of rounds in particular system is decreased when the packet length is increased.

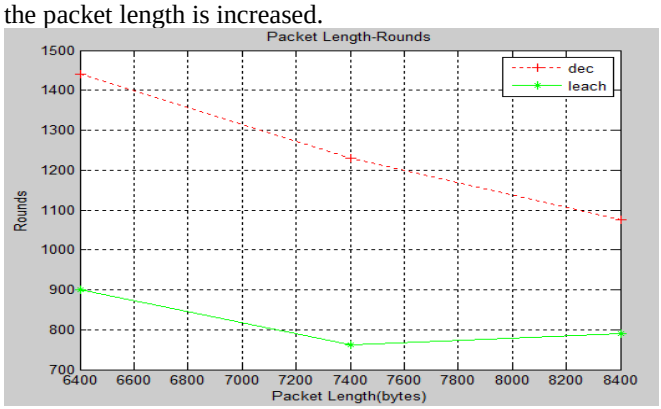

Figure 5: Packet length with respect to number of rounds considering 100 nodes

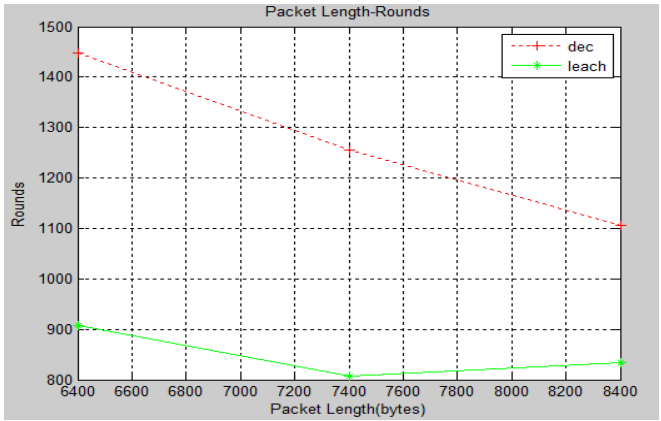

Figure 6: Packet length with respect to number of rounds considering 200 nodes

C)Nodes Vs Rounds

It is verified through the simulation result shown in figure 7 and 8, that the number of rounds of DEC protocol is higher than LEACH protocol by varying the nodes with constant packet length of 6400 and 8400 bytes. The reason is due to the increase in the number of alive nodes in DEC which uses the deterministic clustering approach. Further, it is also inferred that as the nodes increases, the number of rounds also increases. This is due to the involvement of nodes for the data transmission process is less which increases the more number of alive nodes. Hence number of the rounds in the network is increased when the nodes is increased.

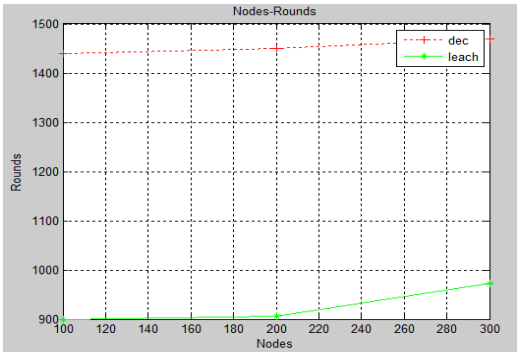

Figure 7: Nodes with respect to number of rounds considering packet length of 6400 bytes

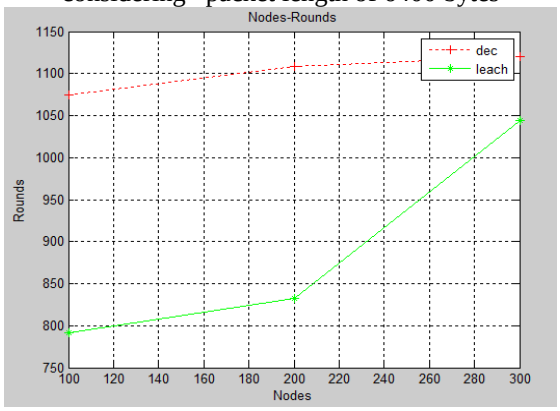

Figure 8: Nodes with respect to number of rounds considering packet length of 8400 bytes

Analysis of Energy Dissipation with respect to Nodes, Coverage Area and Packet Length

The determination and analysis of energy dissipation is done through simulation by varying coverage area, nodes and packet length.

D) Coverage Area Vs Energy Dissipation

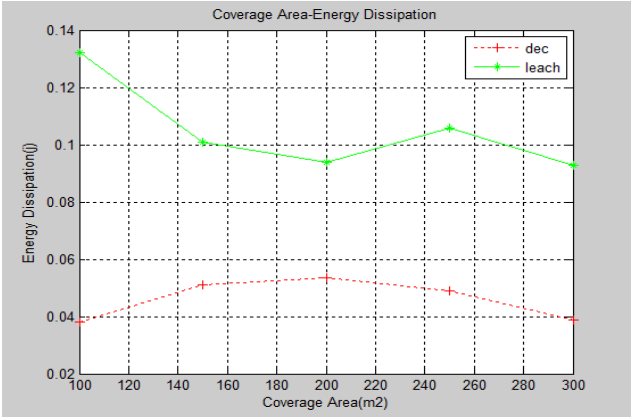

Figure 9: Coverage area with respect to Energy Dissipation

It is inferred from the figure 9, that the energy dissipation of DEC protocol is lower than LEACH protocol by varying the coverage area. The reason is due to the usage of nodes based on residual energy for routing process in DEC. Further, it is also observed that as the coverage area increases, the energy dissipation increases. This is because more number of nodes is involved for data transmission, when the coverage area is increased. Thus, as coverage area increases, energy dissipation will also increase.

E)Nodes Vs Energy Dissipation

It is verified through the simulation result shown in figure 10, that the energy dissipation of DEC protocol is lower than LEACH protocol by varying the nodes. The reason is due to the nodes involved for data transmission is less in DEC which uses the deterministic clustering approach. Further, it is also inferred that as the nodes increases the energy dissipation decreases. This is because; the data transmission process is carried out with less number of nodes.

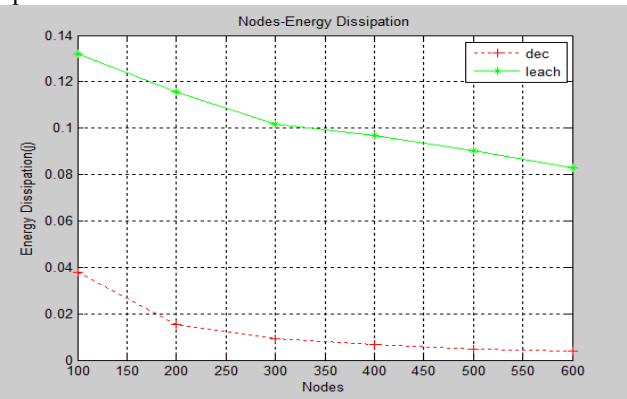

Figure 10: Nodes with respect to Energy Dissipation

F) Packet Length Vs Energy Dissipation

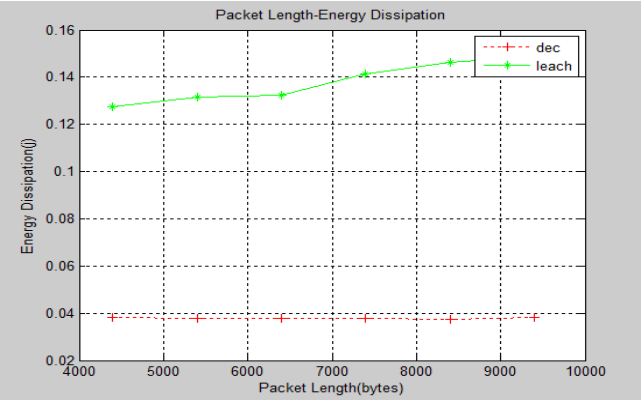

Figure 11: Packet length with respect to Energy Dissipation

It is observed from the figure 11, that the energy dissipation of DEC protocol is lower than LEACH protocol by varying the packet length. The reason is due to the path involved for data transfer operation is less in DEC which uses residual energy for the election criteria of cluster head. Further, it is also inferred that as the packet length increases, the data transmission is more which results in more energy dissipation. Therefore, the energy dissipation increases with increase in the packet length.

V. CONCLUSION

LEACH is a probabilistic-based model used to manage energy consumption in WSNs by using the global information derived from the network without considering the local information i.e. the residual energy of each node**.** DEC outperforms the probabilistic-based models by guaranteeing that a fixed number of cluster-heads are elected per round. DEC determines CH election based on the residual energy of each node. DEC proves to be more robust and stable than the probabilistic-based models. In this paper, LEACH and DEC are simulated by using MATLAB. The performance parameters of LEACH and DEC protocols (Nodes Vs Rounds; Packet Length Vs Rounds; Coverage Area Vs Rounds) are determined and analyzed. The energy dissipation of DEC and LEACH protocols has also been analyzed. From the simulation results, it is observed that DEC protocol outperforms LEACH protocol in terms of rounds as well as in energy dissipation. Hence it increases the life time of sensor network.

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