Advanced Low Energy Adaptive Clustering Hierarchy

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***Abstract*—The use of Wireless Sensor Networks (WSNs) is anticipated to bring enormous changes in data gathering, processing and dissemination for different environments and applications. However, a WSN is a power constrained system, since nodes run on limited power batteries which shorten its lifespan. Prolonging the network lifetime depends on efficient management of sensing node energy resource. Hierarchical routing protocols are best known in regard to energy efficiency. By using a clustering technique hierarchical routing protocols greatly minimize energy consumed in collecting and disseminating data. Low Energy Adaptive Clustering Hierarchy (LEACH) is one of the fundamental protocols in this class. In this paper we propose Advanced LEACH (A-LEACH), a heterogeneous-energy protocol to decrease probability of failure nodes and to prolong the time interval before the death of the first node (we refer to as stability period) and increasing the lifetime in heterogeneous WSNs, which is crucial for many applications.**

Keywords- Network Clustering, Nodes failure, routing protocol,

Wireless Sensor Networks, heterogeneous-energy, LEACH

I. Introduction

Wireless Sensor Networks (WSNs) are a special kind of Ad hoc networks that became one of the most interesting areas for researchers. Routing techniques are the most important issue for networks where resources are limited. WSNs technology's growth in the computation capacity requires these sensor nodes to be increasingly equipped to handle more complex functions. Each sensor is mostly limited in their energy level, processing power and sensing ability. Thus, a network of these sensors gives rise to a more robust, reliable and accurate network. Lots of studies on WSNs have been carried out showing that this technology is continuously finding new application in various areas[5,6,7], like remote and hostile regions as seen in the military for battle field surveillance, monitoring the enemy territory, detection of attacks and security etiquette. Other applications of these sensors are in the health sectors where patients can wear small sensors for physiological data and in deployment in disaster prone areas for environmental monitoring. It is noted that, to maintain a reliable information delivery, data aggregation and information fusion that is necessary for efficient and effective communication between these sensor nodes. Only processed and concise information should be delivered to the sinks to reduce communications energy, prolonging the effective network life-time with optimal data delivery.

An inefficient use of the available energy leads to poor performance and short life cycle of the network. To this end, energy in these sensors is a scarce resource and must be managed in an efficient manner. We present a new protocol which is an extension of the LEACH [2], to properly distribute energy and ensure maximum network life time. Our simulation result shows an improvement in effective network life time and increased robustness of performance in the presence of energy heterogeneity.

The remaining part of this paper is organized as follows. We briefly review related work in section 2. Section 3 summarizes Energy Analysis of Routing protocols. In section 4, we present our A-LEACH protocol. Our simulation results is presented in section 5. Finally, in section 6, we conclude the paper and highlights future directions for other aspects of improvement in WSN.

II. RELATED WORKS

Similar to other communication networks, scalability is one of the major design attributes of sensor networks. A single-tier network can cause the gateway to overload with the increase in sensor density. Such overload might cause latency in communication and in adequate tracking of events.

In addition, the single-gateway architecture is not-scalable for a larger set of sensors covering a wider area of interest since the sensors are typically not capable of long-haul communication. To allow the system to cope with additional load and to be able to cover a large area of interest without degrading the service, networking clustering has been pursued in some routing approaches.

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. LEACH [2] is one of the first hierarchical routing approaches for sensors networks. The idea proposed in LEACH has been an inspiration for many hierarchical routing protocols [3, 9, 10, 11, 12, 13].We explore hierarchical routing protocols LEACH and SEP in this section

A. Leach protocol

Low-energy adaptive clustering hierarchy (LEACH) [2] is one of the most popular hierarchical routing algorithms for sensor networks. The idea is to form clusters of the sensor nodes based on the received signal strength and use local cluster heads as routers to the sink. This will save energy since the transmissions will only be done by such cluster heads rather than all sensor nodes.

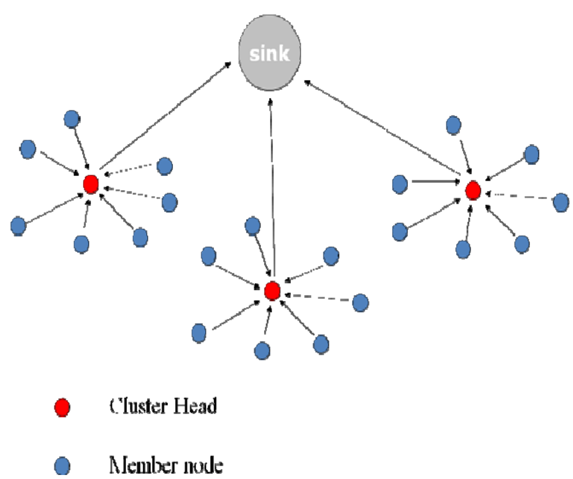

Figure 1: Network style with clustering

The template is used to format your paper and style the text. All the data processing such as data fusion and aggregation are local to the cluster. Cluster heads change randomly over time in order to balance the energy dissipation of nodes. This decision is made by the node choosing a random number between 0 and 1. The node becomes a cluster head for the current Round if the number is less than the following threshold:

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

- r = Current Round
- G = Set of nodes which have not been cluster heads

in 1/P rounds (1)

LEACH achieves over a factor of 7 reduction in energy dissipation compared to direct communication and a factor of 4–8 compared to the minimum transmission energy routing protocol[7]. The nodes die randomly and dynamic clustering increases lifetime of the system. LEACH is completely distributed and requires no global knowledge of network. However, LEACH uses single-hop routing where each node can transmit directly to the cluster-head and the sink. Therefore, it is not applicable to networks deployed in large regions. Furthermore, the idea of dynamic clustering brings extra overhead, e.g. Head changes, advertisements etc., which may diminish the gain in energy consumption.

B. SEP protocol

SEP (A Stable Election Protocol) protocol [1] was improved of LEACH protocol. Main aim of it was used heterogeneous sensor in wireless sensor networks. This protocol have operation like LEACH but with this difference that, in SEP protocol sensors have two different level of energy. SEP based on weighted election probabilities of each node to become cluster head according to their respective energy. This approach ensures that the cluster head election is randomly selected and distributed based on the fraction of energy of each node assuring a uniform use of the nodes energy. In the SEP, two types of nodes (two tier in-clustering) and two level hierarchies were considered.

III. ENERGY ANALYSIS OF PROTOCOLS

For this project, three routing protocols, namely LEACH and SEP and our protocol A-LEACH (Advanced LEACH) had been analyzed based on according to the radio energy dissipation model illustrated in Figure 1, in order to achieve an acceptable Signal-to-Noise Ratio (SNR) in transmitting a K bit message over a distance d.

The Radio Energy Dissipation Model is illustrated in Figure 1 and the characteristics are summarized in Table 1[1].

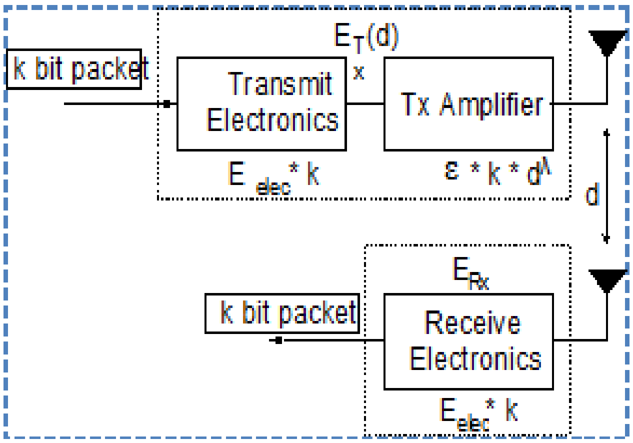

Figure 2: Radio Energy Dissipation Model.

The energy expended by the radio is given by:

$$E_{Tx}(k,d) = \begin{cases} (E_{elec} * k) + (\varepsilon_{fs} * k * d^2) & \text{if } d \le do \\ (E_{elec} * k) + (\varepsilon_{mp} * k * d^4) & \text{if } d \ge do \end{cases} \quad (2)$$

Where E_{elec} is the energy dissipated per bit to run the transmitter or the receiver circuit, ε_{fs} and ε_{mp} depend on the transmitter amplifier model we use, and d is the distance between the sender and the receiver. By equating the two expressions at $d=do$, we have

$do = (\varepsilon_{fs} / \varepsilon_{mp})^{1/2}$. To receive a k bit message the radio expends $E_{Rx}(k) = E_{elec} * k$.

IV. ADVANCED LEACH PROTOCOL(A-LEACH)

In this section we describe A-LEACH which is an extension of the LEACH, which improves the stable region of the clustering hierarchy and decrease probability of failure nodes using the characteristic parameters of heterogeneity.

Routing in A-LEACH works in rounds and each round is divided into two phases, the Setup phase and the Steady State; each sensor knows when each round starts using a synchronized clock. Let us assume the case where a percentage of the population of sensor nodes is equipped with more energy resources than the rest of the nodes. Let m be the fraction of the total number of nodes n which are equipped with a times more energy than the others. We refer to these powerful nodes as CAG nodes (nodes selected as cluster heads or gateways), and the rest $(1-m) \times n$ as normal nodes. We assume that all nodes are distributed uniformly over the sensor field.

Initially, each sensor of n nodes decides if it will be a CH (Cluster Head) or not based on the desired percentage of the CHs for the network, and the number of times the sensor has been a CH (to control the energy consumption), this decision is made by the sensor (s) choosing a random number between Zero and One. Then it calculates the threshold for (s) T(s), then it compares the random number with resulting T(s); if the number is less than T(s), (s) becomes a CH for the current round. Note that all the nodes called CAG nodes become gateways except CAG nodes chosen as cluster head for the current round.

Setup phase includes three steps. Step1 is the advertisement step, where each sensor decides its probability to become a CH, based on the desired percentage of CHs. For the current round sensor who decides to become a CH broadcasts an advertising message to

$(1-m) \times n$ other nodes that it is ready to become a CH. Carrier sense multiple access protocol is used to avoid the collision. Clustering joining step is the second step, where the remaining sensors pick a cluster to join according to the highest signal received; then they send request messages to the desired CHs. Step three starts after the CHs receive all requests from other sensors, where CHs broadcast confirmation messages to their cluster members; these messages include the time slot schedule to be used during the steady state phase. The Steady State phase then starts. It consists of two steps; in the first step each nodes starts by send its sensor report to its CH based on the time provided by the time slot schedule. When CH receives all the reports, it aggregates them in one report and it sends this report to the base station according to the nature of CH:

- If CH is a normal node seeks a node chosen as nearest CAG node selected as gateway that will route the data to the base station.

- If CH is a *CAG* node selected as cluster head data are sent directly to the base station.

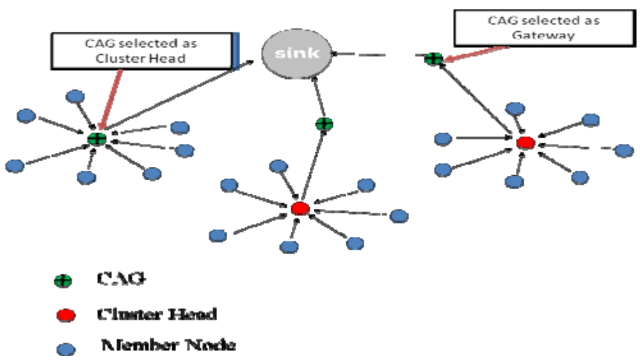

Figure 3 The A-LEACH Network model

A-LEACH protocol has the following advantages:

- Self-configuration of clusters is independent of the base station (distributed algorithm).
- The data are merged to reduce the amount of information transmitted to the base station.
- The Gateways reduces energy consumption and extends the lifetime of the cluster head in network.
- The Gateway decrease probability of failure nodes and prolong the time interval before the death of the first node and increasing the lifetime in heterogeneous WSNs
- The use of techniques TDMA / CDMA allows a hierarchy and makes clustering on several levels. They can save more energy.
- when all normal nodes death the CAG nodes continues to send data to the sink

V. SIMULATION

Parameter	**E_{elect}**	**E_{DA}**	**Efs**	**εmp**	**Eo**	**K**	**Popt**	**n**	**a**
Value	50 nJ/bit	5 nJ/bit/ message	10 pJ/bit/m2	0.0013 pJ/bit/m4	0.5 J	4000 Bit	0.1	100	1

Table 1 parameter settings

A. *Simulation settings*

We use a 100m×100m region of 100 sensor nodes scattered randomly. MATLAB is used to implement the simulation. To make a fair comparison, we introduce advanced energy levels to LEACH and SEP nodes with same settings as in our A-LEACH protocol, so as to assess the performance of these protocols in the presence of heterogeneity. Specifically, we have the parameter settings:

Performance metrics used in the simulation study are:

i. Stability period, the period from the start of the network operation and the first dead node. We also refer to this period as “stable region.”

ii. Instability period, the period between the first dead node and last dead node.

iii. Number of alive and dead nodes per round.

iv. Length of stable region for different values of heterogeneity.

v. Sensitivity to degree of heterogeneity in large-scale networks.

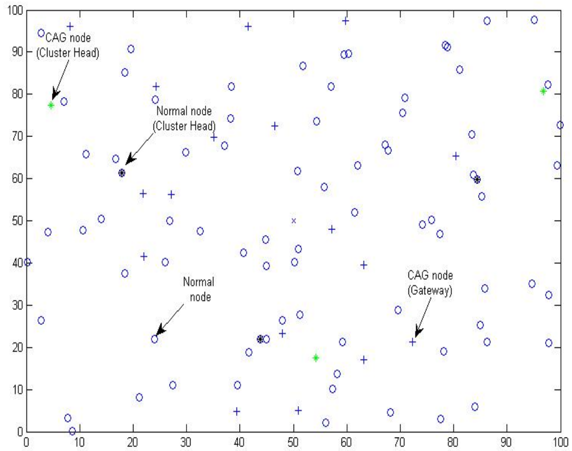

Figure4: A wireless sensor network with A-LEACH Model

B. Simulation results

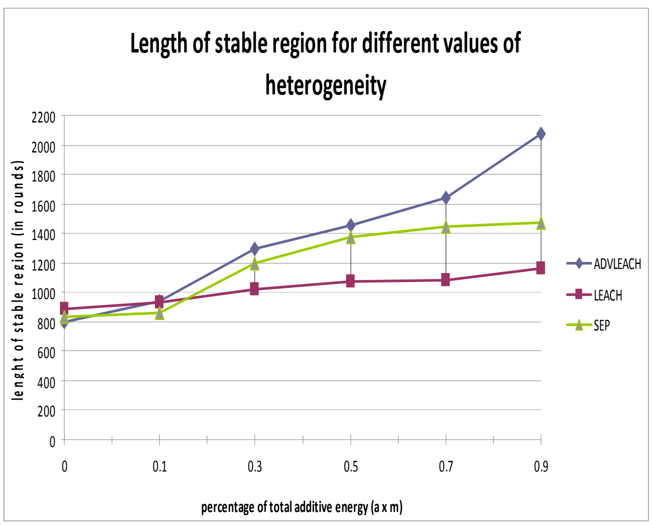

Figure 5 Length of stable region for different values of heterogeneity

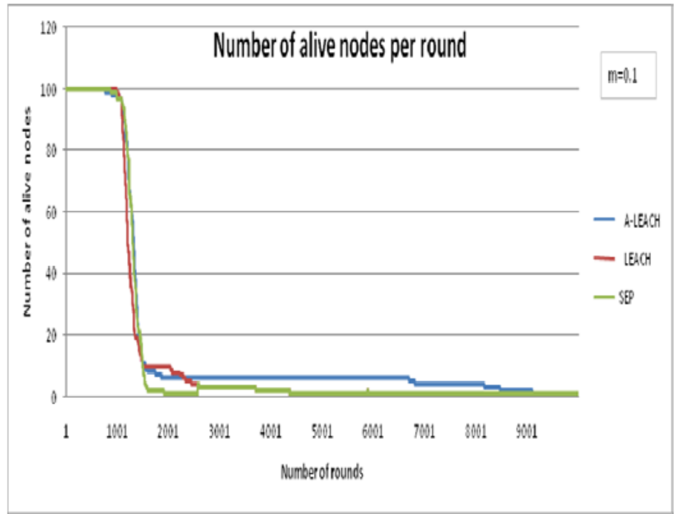

Figure 6 Number of alive nodes per round with m=0.1 and a=1

(100m×100m)

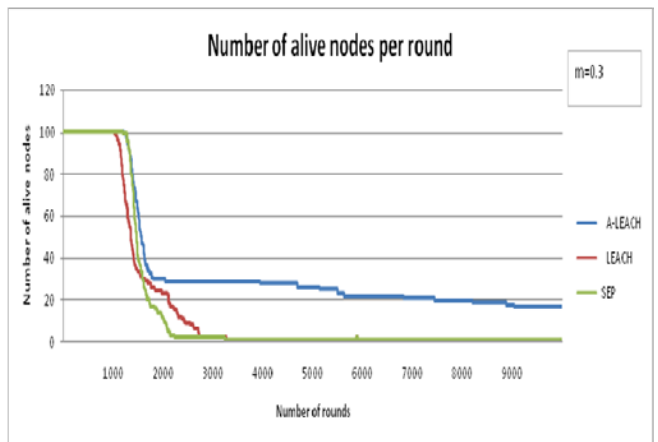

Figure 7 Number of alive nodes per round with m=0.3 and a=1

(100m×100m)

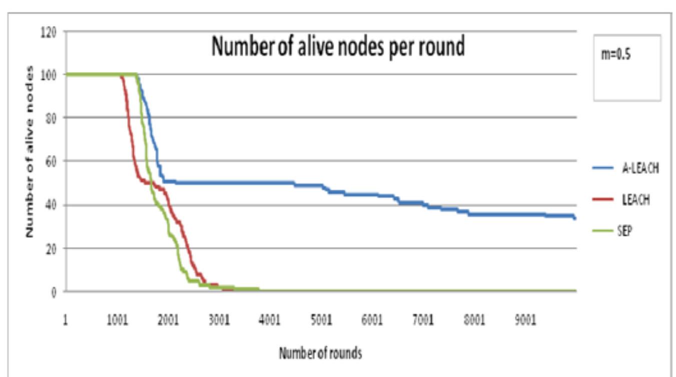

Figure 8 Number of alive nodes per round with m=0.5 and a=1

(100m×100m)

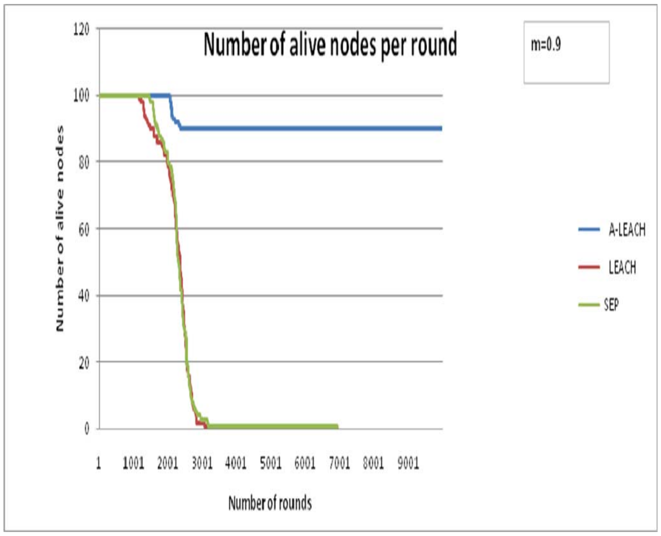

Figure 9 Number of alive nodes per round with m=0.9 and a=1

(100m×100m)

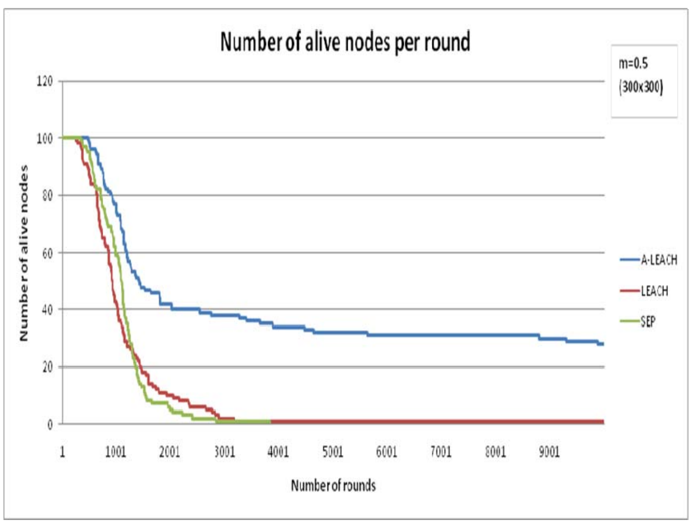

Figure 10 Sensitivity of A-LEACH, LEACH and SEP to degree of

heterogeneity in large-scale networks (300m×300m)

LEACH in comparison with LEACH and SEP acts better and also increases the networks lifetime and a stability period. We test this protocol and LEACH and SEP with different heterogeneity parameters (m=0.1 to m=0.9 and a=1) .the results show that A-LEACH is better than LEACH and SEP. And the lifetime of the network is more than the same lifetime in LEACH and SEP. Both LEACH and SEP die with 100 sensors when they see the first sensor and live for few hundred rounds. While in the proposed protocol after observing the first died sensor and then lives for another few thousand rounds.

VI . CONCLUSION AND FUTURE WORKS

A-LEACH is an extension of the LEACH, which improves the stable region of the clustering hierarchy and decrease probability of failure nodes using the characteristic parameters of heterogeneity in networks. In these networks some high-energy nodes called CAG nodes become cluster head to aggregate the data of their cluster members and transmit it to the sink or Gateways to reduce the energy consumption of cluster head because is used to route information from cluster head to the sink which allow decrease the failure probability of clusters head and this increase the lifetime of the network. Ultimately after simulating we found out that proposed protocol plays an indispensable role in increasing network lifetime and stability period in comparison with SEP and LEACH.

In this article it is supposed that nodes called CAG nodes are distributed randomly. On the other program we will research to predict the choice of CAG nodes to becoming cluster head or gateway that will depend on the density of nodes in an area.

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