

Performance Analysis with Lifetime Optimization of LEACH Routing Protocol for Wireless Sensor Network

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Abstract - Advancement in technology like MEMS (micro electromechanical systems), wireless communication and digital electronics led the development of wireless sensor network. The distributed nature and dynamic topology of WSN (wireless sensor network) introduces very special requirement in routing protocols. Due to the dependency on the nature of application and network architecture WSN generally works on small battery cell. So there is limited energy for every sensor node which opens the door for development of energy efficient routing protocol to maximize the lifetime of the WSN. To overcome this problem, we have developed LEACH-ACH. Simulations shows that LEACH-ACH is an energy-efficient protocol than the fundamental LEACH protocol to extend system lifetime.

Keywords— Cluster head, Classical routing protocol, Network lifetime, WSN, Assistant cluster head (ACH)

I. INTRODUCTION

Wireless sensor networks (WSN) consist of a huge number of small self-contained devices with computational, sensing and wireless communication capabilities. WSN aims to apperceive in collaborative mode, gather, deal with and send information to observer in network areas. Sensor, sensing object and observer form the three factors in WSN. WSN protocol stack contains physical layer, data link layer, network layer, transport layer and application layer. According to network architecture, routing protocols are generally classified as plane routing, and level routing. Typical plane routing protocols are DD, SAR, SPIN Routing and etc; Typical level routing protocols are LEACH, PAGASIS, and TEEN etc [4].

Among the numerous routing protocols, Low-Energy Adaptive Clustering Hierarchy (LEACH) is one of the first major improvements on conventional clustering approaches in WSN[5]. Many clustering algorithms are based on the LEACH's ideology and architecture. However, the LEACH clustering strategy is mainly depends on the randomly selected cluster-heads (CHs), resulting the fluctuation of the number of cluster heads and the ignorance of the node's residual energy. In order to prolong the life span of the entire network, this paper represent a modified LEACH protocol with a second

selection of the cluster heads each round to keep the constant and near-optimal cluster heads number. As a result, the total energy dissipation of the sensors is balanced and minimized.

II. LEACH PROTOCOL

A. LEACH Algorithm

LEACH is first proposed by W.B.Heinzelman. This protocol provides a conception of round. LEACH protocol runs with many rounds. Each round contains two states: cluster setup state and steady state. In the set-up phase, each node decides whether or not become a cluster-head for current round. This decision is made by the node n choosing a random number between 0 and 1. If the number is less than a threshold $T(n)$, the node becomes a cluster-head for the current round. The threshold is set as:

$$T(n) = \begin{cases} \frac{p}{1 - p \times (r \times \text{mod } \frac{1}{p})} & n \in G \\ 0 & n \notin G \end{cases} \quad (1)$$

Where p is the desired percentage of cluster heads, r =the current round, and G is the set of nodes that have not been cluster-heads in the last $1/p$ rounds. Then, operation moves to the steady phase, the steady phase is divided into frame, where nodes send their data to the cluster head at most once per frame during their allocated transmission slot. After a period, the entire networks are renewed, preparing for the new round. The flow chart of LEACH algorithm is shown in figure 1. When one node is selected, it will inform other nodes. No cluster-head nodes will choose a cluster to join in, according to the distance between them and the cluster heads. When cluster heads have received all the messages for joining in, they will produce a time message TDMA to inform all the nodes in their clusters. When every node in the cluster received this message, they will send data in their time-slice separately. After transmitting data for a period time, cluster head collects received data, aggregates data, then sends the result to sink node.

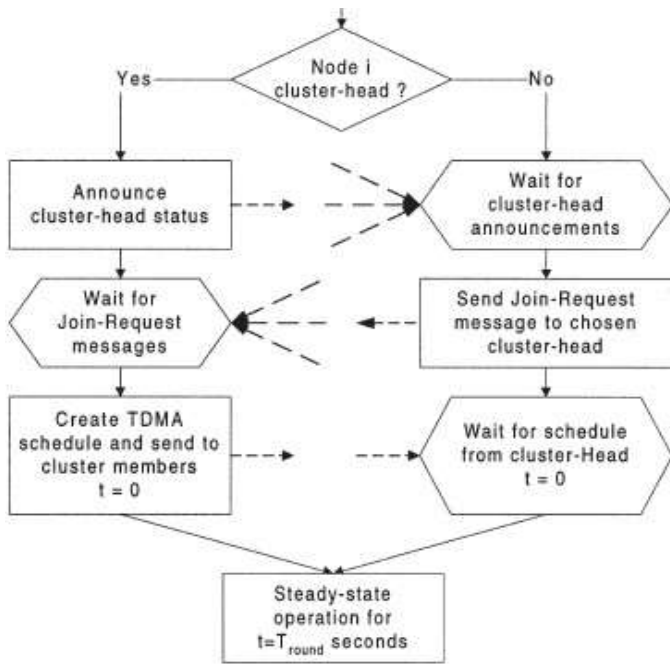


Fig. 1 Flow chart of LEACH Algorithm

B. Problems of LEACH Protocol

Cluster head selection algorithm, adopted by LEACH protocol, avoids fast energy loss of cluster heads and its data aggregation effectively reduces the amount of communication. Therefore, LEACH protocol prolongs the network life time in contrast to plane multi-hop routing and static routing. However, there are still some improvements to be done in the LEACH protocol.

Leach may be unstable during the setup phase that depends on the density of sensors. Leach is not applicable to networks that are deployed in large region. The cluster heads consume a large amount of energy if they are located farther away from the sink node. Leach does not guarantee good cluster head distribution.

III. LEACH-ACH ARCHITECTURE

In consideration of the defect of LEACH, as description prior, we put forward an improved protocol called LEACH-ACH(Assistant Cluster head). This enhanced protocol adds a second selection of cluster heads to modify the number cluster-head in the set-up phase considering the shortest distance.

A. The near optimal number of cluster heads

Experiments has proved that system is the most energy efficient when there are between 3 and 5 clusters from the total 100 nodes in the network. That means the optimal percentage of cluster heads range from 3% to 5%.In this paper, we regard 5% as the near optimal percentage.

B. Selection of the ACH

First of all, as we can see from the figure that two random numbers are selected, one if for Ch and the other is for ACH. If R1 is less than threshold value than it will go to check for R2. If R2 is also less than ach_th than for that particular round, the node which satisfies the above condition will become ACH. Here we have describe it with one example as shown below.

Suppose ach_th is the threshold value for generation of assisting cluster head. We are considering number of nodes as 100 and percentage of becoming CHs is set as 10% then 10 number of nodes will become CHs. Approximate no. of assisting cluster head is given by below Equation:

$$\begin{aligned} \text{No of assisting CHs} &= n * p * \text{ach_th} \\ &= 100 * (10/100) * 0.5 = 5 \end{aligned}$$

So according to above equation if ‘ach_th=0.5’ then approximately 5 nodes are able to become assisting cluster heads. So with the help of this equation we can approximate the number of ACH for large networks too. And eventually the idea of ACH will minimize the load of CH and make it free to improve its performance and lifetime of the entire network by saving energy.

C. Flow Chart

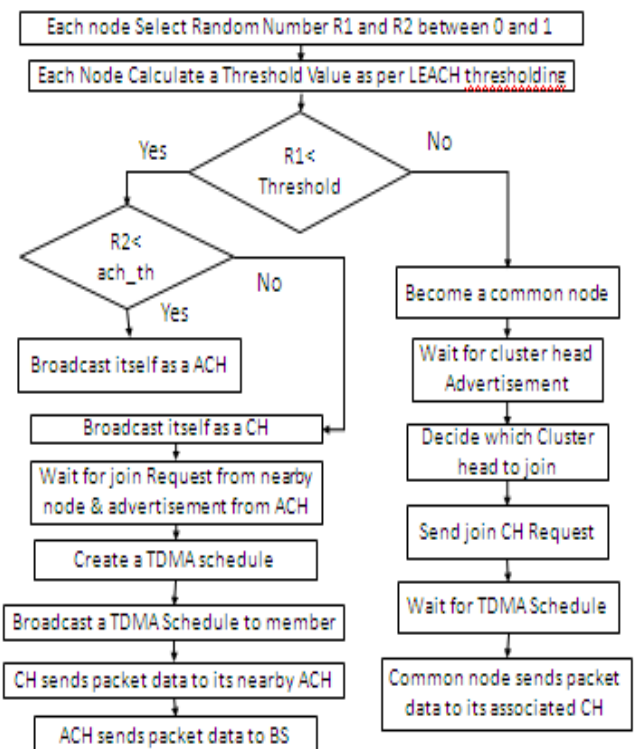


Fig. 2 Flow chart of ACH algorithm

IV. SIMULATION RESULTS AND ANALYSIS

To evaluate the performance of LEACH and LEACH-ACH, we simulated both LEACH and LEACH-ACH by Matlab.

A. Network Model

There are many possible models for sensor networks. For the development of our protocol, we make some assumptions about the network model as follows :

- 1) The base station (BS) is located far from the sensors and is immobile
- 2) All nodes in the network are homogeneous and energy constrained
- 3) All nodes are able to reach the bs
- 4) Nodes have no location information
- 5) Cluster-heads perform data compression

B. Parameters for Simulation

This paper set the following parameters for Simulation:

Table I SIMULATION PARAMETERS FOR LEACH & LEACH-ACH

Parameters	Scenario 1	Scenario 2
Area	200 * 200 (meter ²)	400 * 400 (meter ²)
No. of nodes	100	200
Base station location	(250,250) meter- from origin	(500,500) meter- from origin
Initial energy of each node	2 J	
Percentage of cluster head	8%	
Packet length of each node per round	4000 bits	
Packet generated per round by each note	1	
Ctrpacket length	100 bits	
Transmission & Receiving energy (E _{elec})	50 nJ/bit	
Free space Transmitter amplifier energy(E _{fs})	10 PJ/bit/m ²	
Multipath fading Transmitter amplifier energy(E _{mp})	0.0013 PJ/bit/m ⁴	
Data aggregation energy (E _{da})	5 nJ	
Type of Distribution	Random	

C. Figures and Analysis

In Figure 3, the distribution of sensor nodes for LEACH protocol is shown. The blue bubble represents the nodes deployed in the given area and blue bubble at (x, y) = (250,250) shows the location of base station. The green lines indicate the connection between the normal node and its associated cluster head. The red lines indicate the connection

between cluster head to base station. In leach protocol each cluster head sends data direct to the base station.

In Figure 4, the distribution of sensor nodes for LEACH-ACH protocol is shown. All the details are same as LEACH protocol, only the difference is that red line shows the connection between CH(cluster heads) to ACH(assistant cluster heads) and blue lines shows connection between ACH to BS(base station).

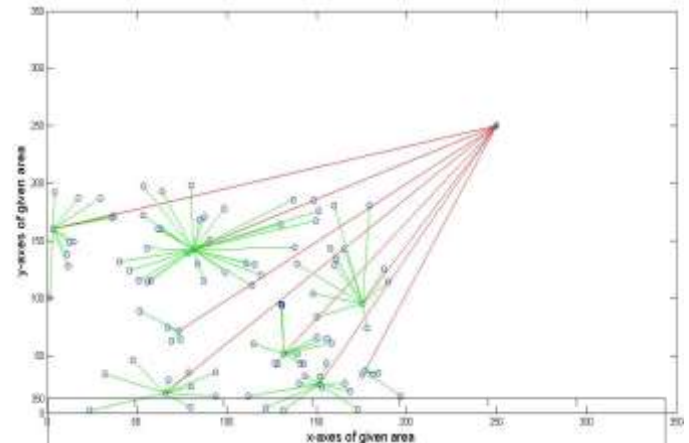


Fig. 3 Distribution of LEACH

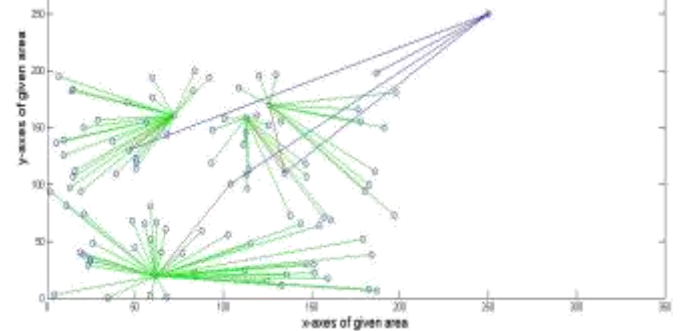


Fig. 4 Distribution of LEACH-ACH

In Figure 5 and Figure 6, it shows the network lifetime for scenario 1 and scenario 2 respectively as shown in table 1. We can clearly see that LEACH-ACH can perform for more number of rounds which increase the lifetime and entire network working.

As shown in fig. 5.6 is the comparison of Leach and Leach-ACH for the data packets sent to the base station v/s number of rounds. The blue line shows the variations for Leach protocol and red line shows the variation of dead nodes for Leach-ACH. From the analysis, we can say that Leach-ACH has completed more number of rounds compare to Leach. It means the data packet sent from the nodes to base station is more in Leach-ACH than Leach which again shows the energy efficiency and cost reduction for sensor nodes of Leach-ACH.

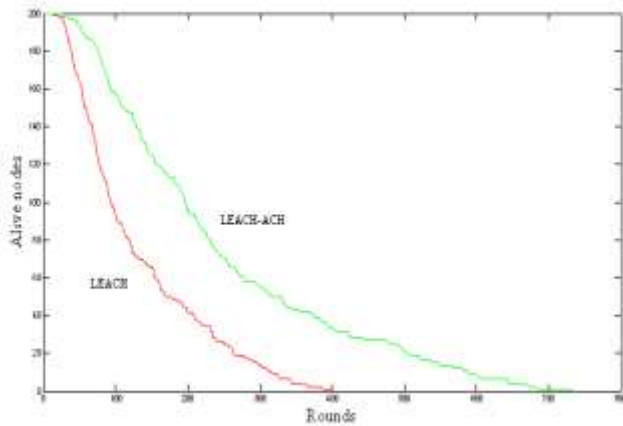


Fig. 5 System Lifetime of LEACH and LEACH-ACH for scenario 1

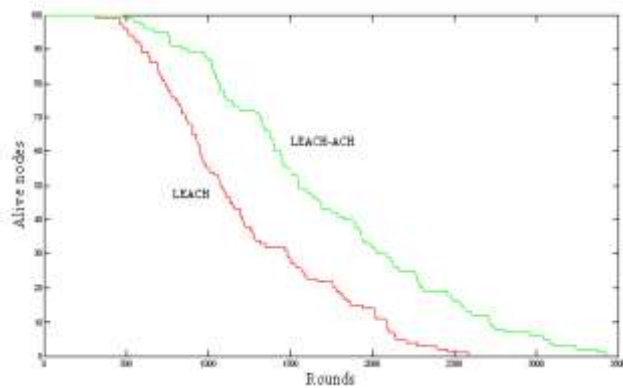


Fig.6 System Lifetime of LEACH and LEACH-ACH for scenario 2

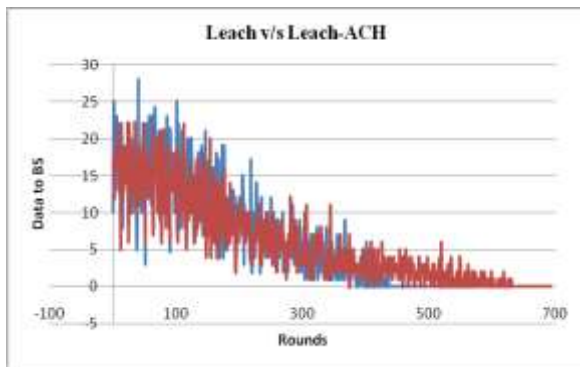


Fig.7 Data received at Base station for LEACH & LEACH-ACH

V. CONCLUSION

In this paper we have proposed the routing protocol leach-ACH. Simulation results shows that proposed algorithm improves lifetime of network by 40% to 70% by proper adjustment of network parameters. Future scope is there in the selection area of assistant cluster heads with more sophisticate rule in the proposed algorithms for better routing protocol design.

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