Analyzing the Effect of Cluster Head in Low Energy Adaptive Clustering Hierarchical in Wireless Sensor Network

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ABSTRACT

The wireless sensor networks consist of hundreds of inexpensive wireless nodes, each with some computational power and sensing capability, operational power and sensing capability, operating in an unattended mode. Clustering is an efficient approach to capitalize the energy of energy constraint sensor nodes in wireless sensor networks (WSNs). Low Energy Adaptive Clustering Hierarchy (LEACH) is a major breakthrough for clustering technique by forming and rotating cluster head among nodes randomly. In present work the cluster heads are formed, number of cluster heads was fixed to 8 and LEACH scheme was simulated in NS-2 to study the performance in terms of network lifetime and energy consumption rate for each cluster head. The most significant performance was found in the cluster head having optimum load balancing factor and moderate distance from base station.

Keywords: LEACH Protocol, Wireless Sensor Network, Energy Efficiency, Cluster Algorithm.

1. INTRODUCTION

A wireless sensor network (WSN) [1] [2] consists of spatially distributed autonomous sensor to monitor physical or environmental conditions [3], such as, temperature, sound, vibration, pressure motion or pollutants and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, enabling also to control the activity of the sensors. The development of wireless sensor networks was motivated by military applications [2] [3] such as battlefield surveillance; today such networks are used in many industrial and consumer application, such as industrial process monitoring and control, machine health monitoring.

A sensor network [3] [4] [7] is designed to detect events or phenomena, collect and process data, and transmit sensed information to interested users. Low Energy Adaptive Cluster Hierarchy (LEACH) [7] suggested that the rotation of role of cluster head among nodes randomly and it was vary at every simulation. A node will be a cluster head for a round and after which re-clustering is done with a new cluster head for each cluster. Every node has the possibility of being a cluster head and the cluster head heaving the more energy than the other node. To distribute the energy consumption among all sensor nodes, the role of cluster head was proposed to be rotated among them after specific time, called round, in LEACH [5]. However, the stochastic approach used for cluster head selection during each round is highlighted to be responsible for many of its limitations [8] and motivated from which so many clustering schemes [6] [8] [9] are reported in the literature. Those schemes may be classified as centralized or distributed. In centralized schemes [7] [10], base station is responsible for cluster formation utilizing the information like node location, remaining energy and data gathering rate at the different time periods etc., communicated by the sensor nodes, individually, during each instance of cluster set up. And in distributed schemes, sensor nodes take decision about their cluster head role autonomously, either with a probabilistic approach [5] or with a deterministic approach.

So, to study the effect of cluster head (CH) on network lifetime and energy consumption rate of LEACH scheme, simulations were carried out in NS-2 [18]. The results obtained show that there is a great effect on network lifetime as well as energy consumption rate and CH four results gives the optimum value, to achieve the desired goals, in the scenario simulated.

Rest of the paper is organized as follows. Overview of LEACH scheme is presented in section II. The radio energy model used is described, in brief, in section II. Simulation setup and the performance metric used are described in section III. Simulation results are presented in section IV and finally, with conclusion of the study carried out and describing prospective scope for continuation of this work, section V concludes the paper.

2. RELATED WORK

LEACH [7] protocol was a major breakthrough in clustering scheme. Now most of the clustering schemes proposed use LEACH as backbone. This section narrates LEACH protocol and the radio energy model [7] of LEACH protocol.

A. LEACH Overview

LEACH [7], [16] is a distributed clustering protocol proposed for even distribution of energy consumption among sensor nodes in the network. Operation of LEACH [5] is divided into rounds. Each round is of fixed time duration. During each round, sensor nodes were autonomously decide on their role as cluster head or a general sensor node by evaluating a threshold function, which is dependent on the desired percentage of nodes to select as cluster head (P), current round number (r) and total number of nodes alive (N) and its comparison with a random number generated. The sensor nodes once selected to perform the role of cluster head are not allowed to compete for the role for next 1/P rounds. Each round consists of a set-up phase followed by a steady state phase. During the set-up phase [7], a sensor node chooses a random number between 0 and 1. Nodes are organized into clusters with each cluster having its own cluster head. Cluster heads [7] then prepares the TDMA schedule and distributes it to their respective member nodes, to utilize for data transmission during steady-state phase. If this random number is less than the threshold T (n), the sensor node is a cluster-head. T (n) is calculated as in equation (1)

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

During the steady phase [5], the sensor nodes transmit data to their respective cluster head. Cluster head aggregates data and sends to the base station. After a certain period of time spent on the steady phase, re-clustering is done. Member nodes transmit their data to their respective cluster head which then performing aggregation, to eliminate the redundancy, pass it on to the base station. Thus, the nodes become cluster head for few rounds and perform the task of data reception, their aggregation and then its transmission to the base station and non cluster head for remaining rounds in which they send the sensed data to their respective cluster heads.

B. Energy Mode

In this section the radio energy model was described and described the energy equation consumed in transmission. Radio energy model [7] used for this study uses a 914 MHz radio. The node radio energy consumed in transmission is as in equation (2).

$$E_{Tx}(m,d) = \begin{cases} m \times E(elec) + (m \times E_{fs} \times d^2) \;\; d < d_0 \\ m \times E(elec) + (m \times E_{amp} \times d^4) \; d \geq d_0 \end{cases} \quad (2)$$

Where, m is the number of bits transmitted, d is the distance between transmitter and receiver and d0 is the distance constant referred as crossover distance. And for receiving the m bit message the node radio consumed in equation (3).

$$E_{Rx}(m) = M \times E(elec) \quad (3)$$

As communication cost is considered to be much larger than computational cost, the contribution of computations to the energy consumption is considered to be negligible in this analysis. The assumed energy required for running the transmitter and receiver electronic circuitry E(elec) is 50nJ/bit and for acceptable SNR required energy for transmitter amplifier for free space propagation Efs is 100pJ/bit/m2 and for two ray ground Emp is 0.0013pJ/bit/m4. The crossover distance d0 is assumed to be 87m.

3. SIMULATION SETUP

To evaluate the performance of LEACH clustering algorithm, different parameters were set in the network simulator NS-2 with incorporation of MIT uAMPS project (NS-2 Extension) sensor network framework [18]. It has the capability to simulate both wired and wireless environment.

A. Simulation Assumptions

LEACH algorithm was simulated with node structure as in MIT framework, with following common assumptions [18]:

- The channel was assumed to be symmetrical and to have only system losses and not the propagation loss.
- All nodes were assumed to be equipped with similar facilities.
- The nodes were considered to be deployed in a random fashion across the network and once deployed were assumed to be static.
- The nodes were considered to die only when their energy is exhausted. Sudden failure of nodes was not considered.
- The sink node or the base station was assumed to be located outside the network and is considered to be constraint free.
- 6. The nodes were assumed to have sufficient range to reach each other.
- The nodes were assumed to have the capacity to eliminate data redundancy and to reduce the communication load through data aggregation.
- The nodes were assumed to be equipped with CDMA facilities**.**

B. Simulation Parameters

In simulations parameters, 100 nodes were considered to be distributed over 100 meter × 100 meter area. The data packet size was set as 500 bytes and packet header size as 25 bytes. Desired number of nodes to be selected as cluster heads during each round of data gathering was set to 5. Propagation model used was two ray ground. The cluster head change time was set to 10 seconds. Initial energy was set as 2 Joules and thus, the network was considered to have 200 Joules of energy. Channel bandwidth was set as 1Mbps. Base station was assumed to be located at (50, 175), at a distance of 75, 100, 125 meters from the network center at the different run.

4. SIMULATION RESULTS

Following performance metrics were targeted in the simulation results:

A. Network Lifetime

The network lifetime [10] depends on the application and is given by different ways. The proposals consider the time of death of first node or the death of 50% nodes of the total nodes or when number of alive nodes is less than the desired number of cluster head, at any round (death of 96%). In this paper, the results are presented for all three scenarios.

B. Energy Consumption Rate

It is defined as the amount of energy consumed [7] [10] per unit time. This is also an important parameter as it gives the estimate about the duration over which the network may continue to work, with available energy, and may be seen as another measure for network lifetime.

C. Data gathering Rate

LEACH was the data centric continuous scheme. It is defined as the amount of data send per unit time. It's also an important parameter as it gives the knowledge to know how much data send at a specific time.

5. RESULTS

This section presents simulation results with respect to different parameters, to show the effect of cluster heads on the performance of LEACH.

In the literature [10], network lifetime is defined in different ways. It is considered as time of first node death or time of death of 50% of nodes or when the number of nodes alive reduces below the desired number of cluster heads it means 96% node death. Therefore the results are resented. Fig.1 presents the effect of cluster head formation on the network

lifetime of LEACH scheme, which is a plot of average of network lifetime observed over different runs of simulations. With increase in round number, there is probability of more than desired number of nodes selecting them as cluster heads which results in repetition of CDMA codes in some clusters thereby causing inter cluster interference and thus the loss of data and consequently, the increased energy consumption. This results in reduction of network lifetime.

The decrease in network lifetime with the use of increased spreading factor may be due to increase in the effective data size. To use DS-SS the data signal needs to be multiplied by a spreading signal. With increased spreading factor this multiplicative factor increases the data length and thereby the energy required to transmit it. This increased energy consumption causes the sensor nodes to die earlier. Thus, a reduction is observed in network lifetime of LEACH.

In addition to selection of variable number of cluster heads during different rounds, their non uniform distribution over the network may also be the reason for this inconsistency. In general, use of randomized approach for cluster head selection in clustering schemes for data centric wireless sensor networks requires optimization of number of spreading codes to be used, to achieve the desired goal of prolonged network lifetime. Fig.2 shows the result of energy consumption Vs time simulation. For different cluster heads formation, CH4 having the optimal results at the various distance and the energy consumption rate

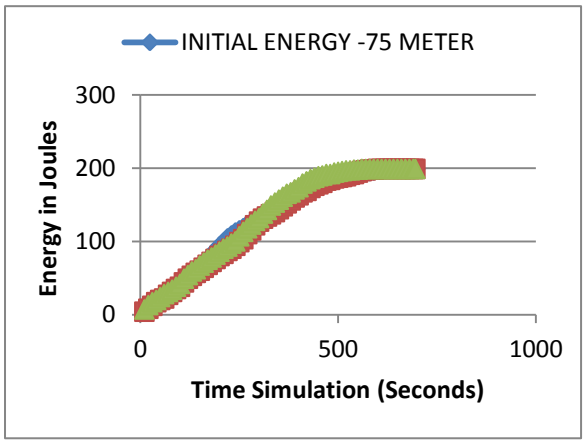

Fig.1. Time simulation Vs node death scenario

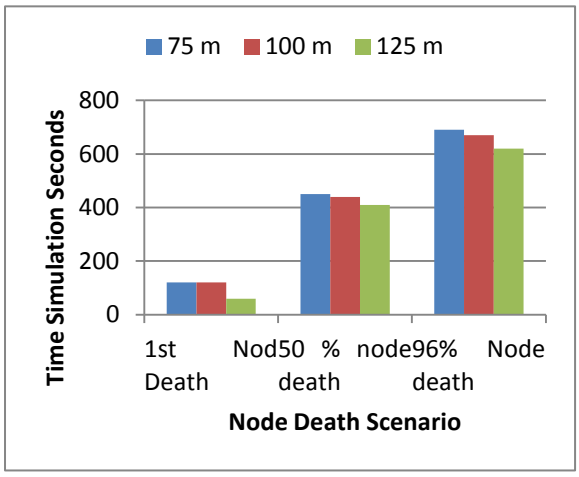

Fig. 2 Energy in joules/ Vs. time simulation (Sec.)

minimized at the distance of 75 m. Results presented are for the case with network lifetime observed when 96% of total nodes die. It may easily be concluded from this figure that, the amount of energy consumed over network lifetime (96% node death) is minimum with cluster head 4.

Fig.3 shows the difference between numbers of node in different cluster is large, nodes in the clusters with lesser number of nodes are observed to report their data at a faster rate and hence, the number of data units transmitted by such nodes is larger as compared to their counterparts in other clusters. The cluster head also is observed to transmit the aggregated cluster data at a faster rate. Thus, the uneven distribution of nodes causes the nodes in the clusters with their less number to consume their energy at a faster rate.

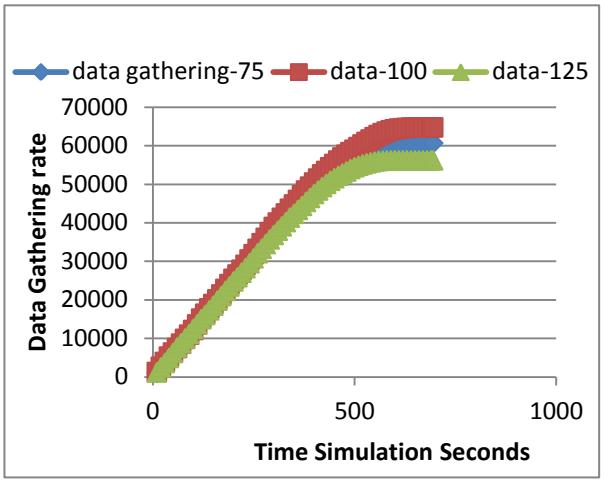

Fig. 3 Date gathering rate Vs. time simulation (Sec.)

6. CONCLUSION

In this paper the effect of cluster head formation simulated in LEACH scheme. The clustering algorithm leach does not guarantee equal number of node. In terms of network lifetime, energy consumption rate and data gathering rate the performance has been found maximum in case of CHs 3, 4 and 5 and the most optimal performance was found in CH 4. When CH 4 simulated at various distances, best performance can be achieved with distance 75 m.

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