

The Effects of Spreading Factor on the Data Gathering Performance of Low Energy Adaptive Clustering Hierarchy (LEACH)

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Abstract— Low energy adaptive clustering hierarchy (LEACH) guided a considerable portion of the research, and is used as benchmark, in energy efficient data gathering schemes in wireless sensor networks. In it, the probabilistic and randomized selection strategy of clusterhead selection results in their variable number, during different rounds of data gathering. To avoid communication interference in different clusters it uses Direct Sequence Spread Spectrum (DS-SS) technique, which spreads the signal by multiplying it with a spreading signal, and thus results in increased data size. The variable number of clusterheads requires the spreading factor to be set corresponding to the probable maximum number of clusterheads, to avoid collisions. This increases the data size and correspondingly the amount of energy required to transmit it to the base station. This letter presents the effect of spreading factor on the data gathering performance of LEACH scheme with its simulation in NS-2. The obtained results show that, there is a great effect of spreading factor on data gathering rate, energy efficiency and data gathering efficiency.

Index Terms— Clustering, Data Gathering, Energy Efficiency, Network Lifetime, Wireless Sensor Network

I. INTRODUCTION

Use of clustering is widely discussed for energy efficient data gathering by wireless sensor network researchers, over last decade. A major breakthrough was provided by Low Energy Adaptive Clustering Hierarchy (LEACH), proposed in [1], with suggestion of rotation of clusterhead role among the sensor nodes for distribution of energy consumption over the network, in cluster based data gathering. Operation of LEACH is divided into rounds. During each round sensor nodes autonomously decide on their role as clusterhead or a general sensor node by evaluating a threshold function, which is dependent on the desired percentage of nodes to select as clusterhead, current round number and total number of alive nodes, and its comparison with a random number generated. Each round consists of a set-up phase followed by a steady state phase. During the set-up phase, nodes are organized into clusters with each cluster having its own clusterhead. Clusterheads then prepare the TDMA schedule and distribute it to their respective member nodes, to utilize for data gathering during steady-state phase. Member nodes transmit their data to their respective clusterhead, during designated slot, which then performing aggregation, pass it on to the base station.

Motivated from LEACH, so many clustering schemes are reported in the literature for energy efficient data gathering, which may broadly be categorized as

centralized or distributed. In centralized schemes [2] [3] [4], the base station is responsible for cluster formation utilizing the information like node location, remaining energy communicated by the sensor nodes, individually during each instance of cluster set up. However, collection of all the necessary information at the base station makes them both time and energy consuming [5]. And in distributed schemes, sensor nodes take decision about their clusterhead role autonomously, either stochastically [1] [6] [7] or in deterministic fashion [8] [9]. Among these schemes, LEACH is the most popular protocol but is reported, in the literature [2] [3] [4] [6] [7] [8] [9] [10] [11], to have many limitations and most of them may be credited to its basic clusterhead selection strategy used [11].

Previous studies [1]-[10] regarding performance evaluation of LEACH, highlighting some of its limitation(s), carry it with the effects of one or more factors among node density, base station location, network size, number of clusterheads and different probability of transmissions and evaluates the performance with the use of metrics like network lifetime, energy efficiency, number of clusterheads during different rounds, energy consumption of clusterheads, energy consumption of non clusterhead nodes etc. Many of the works report energy consumption over the network lifetime and the number of node death over simulation time and claim that the scheme improves with respect to these parameters. However, data gathering is the major operation of the sensor networks. So, number of data units received over the network lifetime and per unit of energy consumption needs to be treated as equally important parameters along with the network lifetime and energy efficiency.

Apart from the factors listed in literature, another factor affecting the energy efficiency of the clustering algorithm is the number of nodes selecting them as clusterheads. All the clustering schemes use CDMA codes in clusters to avoid interference [5]. To use the CDMA code, the signal needs to be spread and hence the number of bits required to be transmitted gets multiplied by the amount of spreading required, increasing the energy consumption. Due to the randomized approach proposed in LEACH, the number of clusterheads during different rounds is not fixed which needs the spreading factor to be set corresponding to the maximum number of clusterheads expected during some data gathering round.

So, to study the effect of spreading factor on the data gathering performance of clustering schemes, LEACH

scheme was simulated in NS-2 [12] and the results obtained highlight a need of distributed clustering scheme with exactly equal number of clusterheads during each round of data gathering.

II. SIMULATION PARAMETERS

To evaluate the performance of LEACH scheme different parameters were set for the network simulator NS-2 with incorporation of MIT uAMPS project (NS-2 Extension) sensor network framework [13]. The channel was assumed to be symmetrical. 100 immobile nodes were considered to be distributed over a network area of size 100 meter \times 100 meter in a random fashion, which are considered to be within the communication range of each other and are expected to be capable of reporting to the base station. The data packet of 500 bytes and packet header of 25 bytes were considered. Desired number of clusterheads, during each round of data gathering, was set as 5. Propagation model used was two ray ground. All nodes were assumed to have initial energy of 2 Joules. Channel bandwidth was set as 1Mbps. Base station was assumed to be located at (50, 175), at a distance of 125 meters from the network center. Radio energy model as in [7] was used for this study, which uses a 914 MHz radio. The assumed energy required for running the transmitter and receiver electronic circuitry was 50nJ/bit and for acceptable SNR required energy for transmitter amplifier for free space propagation is 100pJ/bit/m² and for two ray ground it was 0.0013pJ/bit/m⁴.

It is observed during different trial runs of simulations that the number of clusterheads varies from 0 to 10, during different rounds of data gathering and during different runs. With the setting of desired number of clusterheads as 5, the minimum spreading factor required to be set is 6 and as there can be as much as 10 nodes selecting them as clusterheads during some round, maximum spreading factor is considered to be 11. Hence, spreading factor was varied from 6 to 11, to see its effect.

III. SIMULATION RESULTS

This section presents the simulation results to show the effect of spreading factor on data gathering performance of LEACH.

A. Data Gathering Efficiency

Following Fig.1 presents the effect of spreading factor on the data gathering performance of LEACH scheme, which is a plot of average of the number of data units received at the base station (for sufficient number of simulations) with respect to different spreading factors. In the literature, 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 alive no

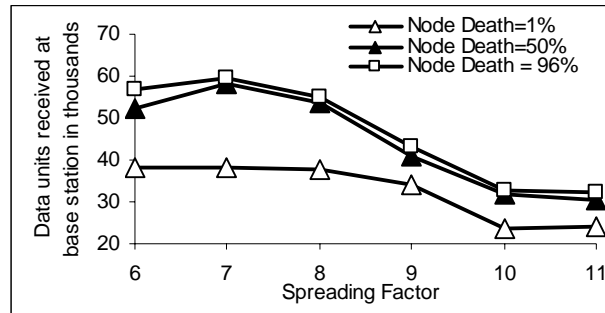


Fig.1: Data gathering efficiency for different node death scenarios

nodes reduces below optimum number of clusterheads required. It can be observed from the graph that initially with increase in spreading factor (SF) from 6 to 7, the number of data units received at the base station increases after which the received number of data units decreases, for all the node death scenarios considered.

The less number of data units received for spreading factor 6 as compared to 7 may be due to the inter cluster interference due to insufficient number of CDMA codes. This may result in receipt of lesser number of data units at the base station.

The decrease in the number of data units received, with the use of increased spreading factor, may be due to increase in the effective data size. With increase in spreading factor, the multiplicative spreading factor increases the data length and thereby the energy required to transmit it. This increased energy consumption causes the sensor nodes to die earlier, reducing the number of data received at the base station.

The careful observation shows that, for LEACH scheme, 7 is optimum number of spreading factor to make it data gathering efficient. Further it may also be observed that, after the death of 50% nodes network survives for lesser time and fewer number of data units are gathered. However, during different runs of simulations it is observed that the data gathering performance of LEACH scheme is not consistent. Fig. 2, below, presents the performance of LEACH scheme for five different runs of simulations for different spreading factors. It can be observed from the plot that for spreading factor between 6 and 8, the performance is comparable and the performance is more consistent for spreading factor of 8 and for larger spreading factors the performance is very much inconsistent. Additional reason may be the non uniform distribution of clusterheads over the network area.

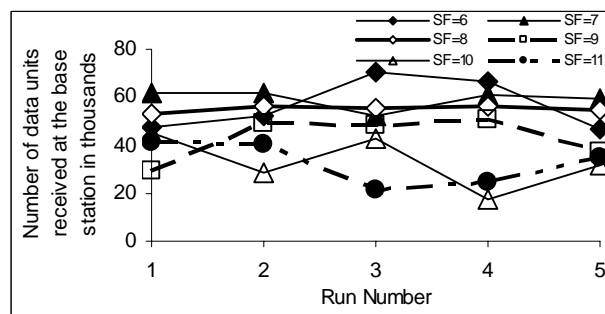


Figure 2: Data gathering efficiency during different runs of simulations

B. Energy Efficiency

Figure 3, below, shows the effect of spreading factor on the energy efficiency of LEACH scheme for three different node death scenarios. It can be observed from the plot that the spreading factor of 7 gives the better energy efficiency and with further increase in spreading factor the energy efficiency decreases sharply. It may be due to the same reasons as explained earlier with respect to data gathering efficiency. With respect to energy efficiency also, the performance of LEACH scheme is comparable for spreading factor between 6 and 8.

C. Data Gathering Rate

Number of data units received at the base station is plotted against the simulation run time for different spreading factors in Fig. 4, to follow. During different runs of simulations a large variation in the performance of LEACH scheme was observed for larger spreading factors. So to observe the capability of LEACH scheme in terms of network lifetime and its data gathering rate, the best results from the set of results obtained, from several runs of simulations, are presented in this graph. With the figure, it may be observed that the LEACH scheme has the capability to achieve network lifetime of 550 seconds in the given scenario. Further, it may also be observed that with increase in the spreading factor the number of data units received over network lifetime (considering death of 96% nodes), i.e. data gathering rate, decreases. This is obvious due to the requirement of transmission of larger number of bits per data unit.

IV. CONCLUSION AND FUTURE SCOPE

Simulation results of LEACH scheme are presented in this letter, to highlight the effect of spreading factor on its data gathering performance. In terms of data gathering and energy efficiencies spreading factor of 7 is observed to be optimum and the performance is much consistent when it was set as 8. This indicates that, while utilizing the probabilistic clusterhead selection approach, spreading factor needs to be set carefully to achieve the optimal data gathering efficiency. As a further enhancement, this demands development of a distributed clustering scheme to select exactly equal and well distributed number clusterheads, during each data gathering round.

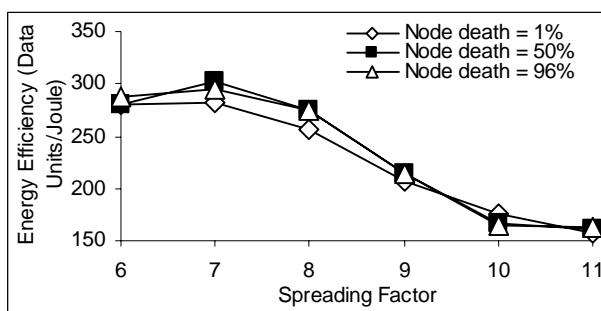


Figure 3: Effect of spreading factor on energy efficiency

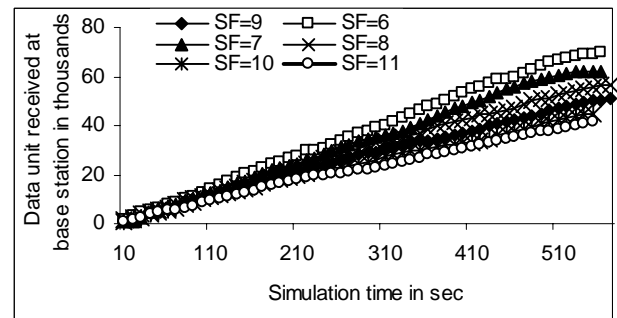


Figure 4: Data gathering rate

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