International Journal of Scientific Engineering and Applied Science (IJSEAS) – Volume-2, Issue-7,July 2016
ISSN: 2395-3470
www.ijseas.com

Performance evaluation of routing protocols for wireless sensor networks

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Abstract- in this work, performance evaluation of LEACH and LEACH-C protocols based on NS2 is depicted, which helps to understand the regularity how performances of these two routing protocols change with the sink locations. To compare the two protocols we use the different sink locations and going to conclude the performance based on different sink locations. Simulation results show that a distance threshold area, which is a key factor for choosing between LEACH and LEACH-C protocols, can be achieved. Routing issues are very critical due to severe resource constraints like efficient energy utilization, lifetime of network, and drastic environmental conditions in WSNs. In this regard, many routing protocols have been proposed to optimize the efficiency of WSNs amongst above mentioned severe resource constraints. Out of these, clustering algorithms have gained more importance, in increasing the life time of the WSN, because of their approach in cluster head selection and data aggregation.

Keywords— Routing protocols, wireless sensor network, LEACH protocol, LEACH-C protocol, Network lifetime.

I. INTRODUCTION

Hop-by-hop mode of communication increases overhead on routing table management in all sensor nodes and quickly brings down lifetime of those nodes which are very near to Gateway since they will be extensively used as relay nodes. This makes network to be virtually non-existent. Many routing protocols have been proposed to solve such routing issues. Out of these, clustering algorithms have been of much interest as they well balance several key factors of WSN operation simultaneously. Choosing one arbitrary node to act as servicing node for several sensor nodes than each trying to reach Gateway node can extend network lifetime and bring down energy utilization considerably [1]. This process of choosing one node to act as servicing node for several neighbour nodes is known as 'clustering'. The concept of hierarchical clustering comes when levels of hierarchy are increased. The level of hierarchy can be increased to some extent to attain the maximum lifetime of the network based on the requirement of application of WSN. For example, if the application consists of thousands of nodes, then it may be desirable to prefer two level hierarchies or three level hierarchies [2]. Micro-sensors with sensing, computing, storing and communicating capabilities are increasingly applied in the military, meteorological, agricultural, industrial and aerospace areas [3].

II. INTRODUCTION ABOUT HIERARCHICAL ROUTING PROTOCOL

Routing in wireless sensor networks differs from conventional routing in fixed networks in various ways. There is no infrastructure, wireless links are unreliable, sensor nodes may fail, and routing protocols have to meet strict energy saving requirements. Many routing algorithms were developed for wireless networks in general. 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. In this section, we describe a sample of layered protocols in which a network is composed of several clusters of sensors. 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. 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 inherent optimization capabilities at the cluster heads.

A. *LEACH:*

LEACH is the first and most popular energy-efficient hierarchical clustering algorithm for WSNs 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 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 a network into several clusters of sensors, which are constructed by using localized coordination 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 dyeing quickly. The operation of LEACH is divided into rounds having two phases each namely:

1. A setup phase to organize the network into clusters, CH advertisement, and transmission schedule creation and
2. A steady-state phase for data aggregation, compression, and transmission to the sink.

LEACH is completely distributed and requires no global knowledge of network. It reduces energy consumption by (a) minimizing the communication cost between sensors and their cluster heads and (b) turning off non-CH nodes as much as possible. 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 rings extra overhead, e.g. head changes, advertisements etc., which may diminish the gain in energy consumption. While LEACH helps the sensors within their cluster dissipate their energy slowly, the CHs consume a larger amount of energy when they are located farther away from the sink. Also, LEACH clustering terminates in a finite number of iterations, but does not guarantee good CH distribution and assumes uniform energy consumption for CHs.

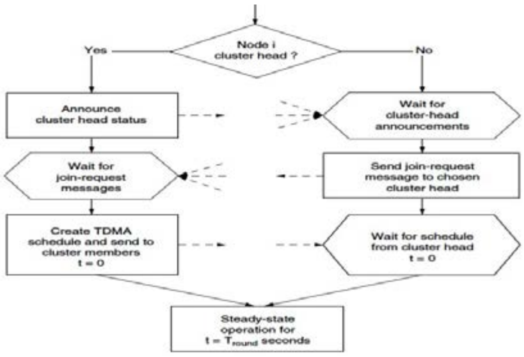

Fig.1 Flowchart of cluster head election in LEACH protocol

The method of LEACH cluster head selecting can be expressed as follows: each node selects a number between 0 and 1 randomly. If the value is less than the threshold value T (n), the node becomes the cluster head. T (n) is shown as equation below

$$T(n) = \begin{cases} \dfrac{p}{1 - P\left[r \bmod \left(1/P\right)\right]}, & n \in G \\ 0, & otherwise \end{cases}$$

Where P is the percentage of cluster heads to all nodes, and r is the selected rounds number, r mod (1 / P) stands for the number of selected cluster head nodes before this round, and G is the group of nodes which have not been elected as cluster head nodes previously. When r = 0, the possibility of each node becoming the cluster head is P. If it becomes the cluster head node in the first r rounds, it can be no longer re-elected in the future (1/P-r) round which enhances the possibility of other nodes to become a cluster head. After 1 / P rounds, all nodes have a possibility of P to be a cluster head once again, over and over again [4].

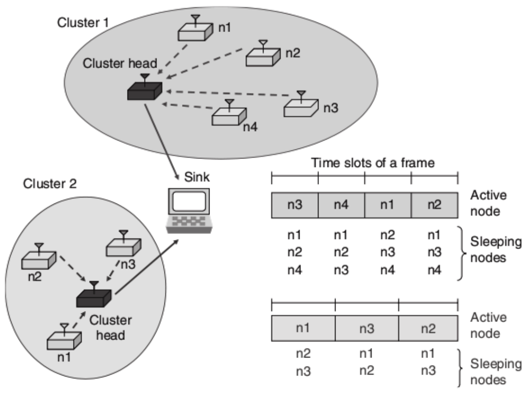

Fig.2 TDMA schedule of LEACH protocol

B. *LEACH-C*

It is a change of the traditional LEACH protocol. First of all, in any round of the cluster head selection stage, the base station must know the remaining energy of all nodes as well as the location information. Based on this information, the base station uses a specific method to select the cluster head and divides all nodes to these clusters, which can easily figures out the better segmentation approach of the clusters [5]. Thus we can enhance the performance of the LEACH protocol by solving those limitations which the LEACH protocol has. We do not believe that the LEACH-C protocol is necessarily superior to the LEACH protocol. It is more expense based on the central base station's control. Each node transmits its information to the respective base station, and the sink will make the choice of selecting the cluster head and how to divide clusters. Then the cluster head sends this information to each node. All these need extra energy cost which will affect the performance of the protocol.

III SIMULATION EXPERIMENTS AND RESULT ANALYSIS:

A. *Simulation platform:*

The experimental platform in this paper is NS2. The NS2 network simulator is installed on the fedora 10 operating system. Considering that NS2 cannot achieve the LEACH protocol and LEACH-C protocol, another extension achievement or installing simulation package (software modules) of these two protocols is needed. The main focus of this research is to compare the changes of the LEACH protocol and the LEACH-C protocol performance while the base station locations change, and find out the rules inside. Hence we make direct use of the protocol simulation package (http://www.internetworkflow.com / downloads / ns2leach/mit.tar.gz), and download mit.tar.gz and decompress it. In order to make them available, we modify the relevant files (make file, test, leach test, leach-c_test, etc.) and configure the environment variables (.Bashrc).To simplify the simulation of these protocols few assumptions are made [9]. Those are as follows:

1. Initial energy of nodes is same.
2. Nodes are static
3. Nodes assumed to have sufficient transmission range to reach other nodes
4. Homogeneous distribution of nodes.
5. Nodes always have to send the data.

Details of the simulation environment are mentioned in Table given below:

Simulation area	100*100
Simulation time	500
Initial energy of node	2J
Channel Type	wireless Channel
Radio Propagation Model	Two ray ground
Antenna Model	Antenna/Omni antenna
Energy Model	Battery
Communication Channel	Bi direction

We use the same simulation parameters for the LEACH protocol and the LEACH-C protocol. We just change the base station location at each time. Simulation parameters are in the range of (100,100), distributing 100 sensor nodes randomly and the file recording spread of nodes is 100nodes.txt (it is used as a working standard in simulating the protocols.) About the network lifetime, there are following regulations: without considering other unpredictable factors, when a node's energy value is less than 0, we think that it's dead; when surviving nodes within the network are less than 20%, i.e. 4 / 5 of all nodes are dead, we consider that the network is out of work [6] [7].

In order to explain the performance relationship between the base station location of the LEACH protocol and the LEACH-C protocol scientifically, we introduce the concept of the centre of gravity of distribution nodes so as to calculate the distance between base station location and the centre of gravity of distribution nodes. The distribution nodes file, 100nodes.txt, takes record of the coordinates (x, y) of 100 nodes which is randomly distributed. The centre of the gravity of distribution nodes is not the centre of the area covered with the nodes necessarily; it will be off the centre with the changing of node distribution. The distance between the base station and the centre of gravity decreases as the distance between the base station and the closed node decreases. The average distance is smaller in general, and the power consumption is less, which can extend the network lifetime. We propose the function of centre of gravity of the discrete planar distribution targets. Taking a weighted average centre of discrete targets, which is the balance point of the discrete targets. The equation is as follows:

$$X_G = \frac{\sum W_i X_i}{\sum W_i} \qquad Y_G = \frac{\sum W_i Y_i}{\sum W_i}$$

Where i is the node serial number (1-100); W_i is target node weight, whose value is taken as 2, i.e. the energy value of node; (X_i , Y_i) is the coordinate of the node i ; (X_G, Y_G) is the coordinate of the centre of gravity. Using the same computer program, we calculate the centre of gravity is (49.34, 47.33) according to node distribution file 100nodes.txt.

B. *Simulation:*

We simulate a large number of protocols by changing the location of base station constantly, and analyse comparatively simulation curves of the parameters. Due to the length limitations, we select three simulation curves of the parameters to elaborate on our analysis in this paper. The LEACH protocol and LEACH-C protocol performance parameters curves are shown in Figure 3 and Figure 4 represent the network base station location at A (49,175), B (49,225) (with other simulation parameters unchanged) respectively. There are two contrast curves in each figure. The 'a' curve describes the number of successful transmission packet data. The 'b' curve describes energy consumption.

When the location of the BS gradually moves from the gravity of distribution area to coordinate (49,215), the network lifetime is almost as long as the LEACH-C's. When the BS keeps moving away from the centre of gravity, the difference becomes larger. When the coordinate of the BS changes from (175, 47) to (275, 47), the life length of LEACH gets shorter while LEACH-C's gets longer. After a large number of simulative comparative analyses, we have the following conclusions, the distance between the location of base station and the centre of gravity of distribution area of sensor nodes will affect the performance of routing protocols—the performance of the protocol affected by the distance is the closer, and the better. When the distance is greater than a certain threshold area, LEACH-C protocol's performance will be superior to LEACH protocol and the threshold area between 160 to 170.

C. *Analysing Results:*

It is observed from the graph in Fig. 3 that as the time increases, no of data signals received at BS through LEACH-C linearly increase compared to that of LEACH and able to deliver more number of data signals compared to that of LEACH because, in LEACH-C, BS knows the network topology and hence it can form good clusters compared to that of LEACH. From Fig. 4 it can

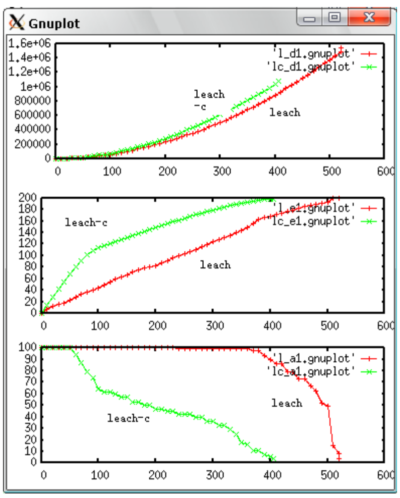

Fig. 3 Simulation Curves with Sink Coordinate (49, 175)

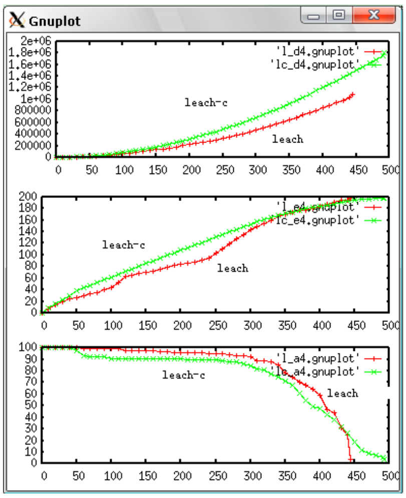

fig. 4 Simulation Curves with Sink Coordinate (49, 225)

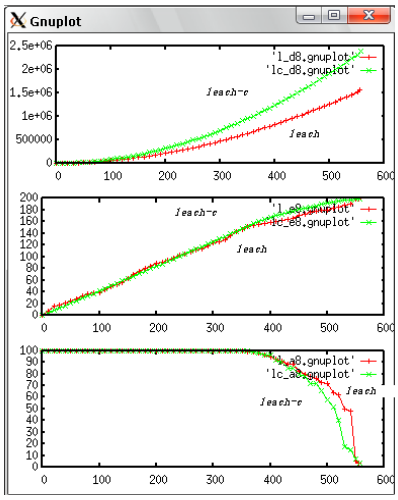

fig. 5 Simulation Curves with Sink Coordinate (215, 47)

be observed that start up energy dissipation is constant and more compared to that of LEACH, because of overhead in cluster set up formation in LEACH-C. It can be concluded that LEACH and LEACH-C both performs well when number of cluster heads, and number of nodes in the network are chosen appropriately depending upon nature & application of WSN.

LEACH is distributed, random and probabilistic algorithm bringing no overhead for BS in making clustering decisions. It performs well giving more network life time than LEACH-C only when uniformly distributed clustered network is formed and it does not assure about desired number of cluster heads and consideration of overall network parameters like residual energy of every sensor node in the network etc., while making decisions about clustering. LEACH-C, on the other hand, can be chosen when centralized and deterministic approach for clustering is required. Also, LEACH-C covers entire network, in terms of residual energy of each sensor node in network, before deciding clusters. This may bring in more uniform distribution of clusters than in case of LEACH. But, disadvantage of LEACH-C is that it increases overhead on BS since it is involved in each & every aspect of clustering process.

Wireless Sensor Networks, which may be spread over vast geographical area, are finding applications in many areas. In this context, there is need of approaches which can manage these WSNs in better way. In this regard, this paper, presented need for clustering to overcome several limitations of WSNs. Detailed discussion about existing work is provided. Brief working of chosen clustering protocols, namely LEACH & LEACH-C, is presented. We also presented the simulation results and analyses of these protocols. As a conclusion of observation from results, it can be mentioned that LEACH can be preferred if localized coordination of nodes in clustering without involving BS is of high priority than other factors like assurance over desired number of clusters etc.; and LEACH-C can be chosen when centralized and deterministic approach covering entire network is expected still bringing in increased network lifetime and desired number of clusters. There exists a work [8][9] comparing LEACH and LEACH-C protocols

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