PERFORMANCE EVALUATION OF ENERGY EFFICIENT CLUSTER-BASED ROUTING PROTOCOL IN WIRELESS SENSOR NETWORKS

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ABSTRACT

Energy efficient is the most important issue that must be solved in designing a qualified routing protocol for wireless sensor networks (WSNs) is how to save sensor node energy while meeting the needs of applications/users as the sensor nodes are battery limited. . There are number of various routing protocols have been proposed to optimize the efficiency of WSNs. From these protocols, cluster based routing algorithms have achieved more significant and increasing the life time of the WSN even the nodes are in mobile state. In this paper, we introduce an energy efficient clustering algorithm for sensor networks based on the LEACH protocol. LEACH (Low Energy Adaptive Clustering Hierarchy) is one of popular cluster-based structures, which has been widely proposed in wireless sensor networks. LEACH uses a TDMA based MAC protocol, and in order to maintain balanced energy consumption. This paper mainly compares the clustering protocols, namely LEACH, LEACH-C, MTE and Stats-Clustering using NS2 tool for analyze the performance of the simulation results with different metrics like Network Life time, received packet and Energy Consumption.

KEYWORDS

LEACH, Wireless Sensor Network, Cluster-Based Protocol, Energy, NS2

1. INTRODUCTION

A wireless sensor network consists of light-weight, low power, small size of sensor nodes. The areas of applications of sensor networks vary from military, civil, healthcare, and environmental to commercial. Examples of application include forest fire detection, inventory control, energy management, surveillance and reconnaissance and so on. One important characteristic of the WSNs is that a group of sensors with limited resources and functions can achieve some large sensing task and cooperation [1]. The small size of the sensors has limitations in its energy because they have non-rechargeable batteries. Due to this constraint, a more number of works has been conducted to manage energy consumption in order to extend the lifetime of the whole network.

Energy efficiency has been known as the most important issue in research of wireless sensor networks (WSNs). So it is of great importance to design an energy efficient routing protocol for WSN. In terms of routing protocol, there are two different solutions from existing works. One is flat routing, each sensor node plays the same role and sends their data to sink node directly which always results in excessive data redundancy and faster energy consumption. The other is hierarchical routing. In hierarchical routing, the entire network is divided into several clusters. Each cluster consists of some source nodes and a cluster head. Sensor nodes, referred as source nodes, can gather information from the monitoring region and send the sensing information to their corresponding cluster head [2]. The cluster head is elected from all the sensor nodes in a cluster according to some criteria, and is responsible for collecting sensing data from source nods. After receiving data from source nodes, the cluster head also performs data aggregation to reduce the data size before sending data to the sink, which further reduces the power expended for data transfer [3]. Clustering-based routing algorithms are more appropriate and efficient than flat routing algorithms in WSN.

In this paper, a performance study of different four routing protocols in different metrics focusing on their energy consumption performance is evaluated. Experiments are preformed through simulations. The purpose is to identifies the different metrics impose an energy conservation in wireless sensor networks. The Metrics used are Network life time, Throughput, and Energy consumption. The results confirm that the energy consumption of wireless sensor network routing protocols varies significantly with node mobility pattern. It is also shown that node energy and network traffic considerably influence the network performance.

2. CLUSTER-BASED ROUTING PROTOCOL

Clustering is the procedure, in this the sensor nodes are ordered in a set about the Cluster Head by the task of an observance position and also inter cluster comparison occupied in the data processing. In hierarchical (cluster-based) routing protocols, these sensor nodes are categorized into a practical hierarchy method to structure a many-hops communication representation. The main objective to use this particular method is to decrease the power utilization which will be used to transmit the data to the sink or Base Station (BS), and it will be achieve through decreasing the different number of messages sent to the Base Station (BS) during data aggregation and also synthesis.

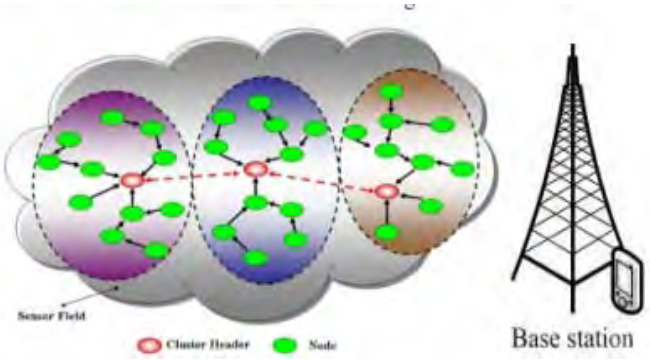

Figure 1. Cluster-Based Routing Protocol Architecture

2.1. Low Energy Adaptive Clustering Hierarchy (LEACH) Protocol

The nodes are organized themselves into local clusters. Each node has the same initial energy because of homogeneous networks. The operation is divided into rounds. In the set-up phase, the CH is selected from the organized clusters if a random number between 0 and 1 chosen by CH is less than threshold value. In the steady-state phase each non CH node sends data and the time slot allocated to CH .The CH aggregates the data and sends to the BS. But the cluster formation is initiated in each round is not energy efficient and also it does not support mobility.

2.2. Centralized–Low Energy Adaptive Clustering Hierarchy (LEACH-C) Protocol

LEACH-centralized (LEACH-C) [4] is similar to LEACH in operation except cluster formation. In LEACH-C, the cluster head selection is carried out at BS. During the setup phase, BS receives from other nodes information about their current locations and remaining energy levels. BS uses the remaining energy level to determine the candidate set for cluster head node. The average node energy is computed and the node has remaining energy falling below this value will be removed from the candidate set. Using the candidate set, BS finds clusters using the simulated annealing algorithm [5] to solve the NP-hard problem of finding k optimal clusters [6]. This algorithm attempts to minimize the total energy that non-cluster head nodes use to transmit their data to cluster head nodes by minimizing the total sum of squared distance between nodes and their cluster head nodes. Once the cluster head nodes are determined, BS broadcast to all nodes the information including cluster head nodes, clusters member node and transmission schedule for each cluster. Nodes use this information to determine its TDMA slot for data transmission.

2.3. Minimum Transmission Energy Protocol

It is clear that in MTE routing, the nodes closest to the base station will be used to route a large number of data messages to the base station. Thus these nodes will die out quickly, causing the energy required to get the remaining data to the base station to increase and more nodes to die. This will create a cascading effect that will shorten system lifetime. In addition, as nodes close to the base station die that area of the environment is no longer being monitored.

2.4. Static-Clustering Protocol

A final conventional protocol for wireless networks is clustering, where nodes are organized into clusters that communicate with a local base station, and these local base stations transmit the data to the global base station, where it is accessed by the end-user. This greatly reduces the distance nodes need to transmit their data, as typically the local base station is close to all the nodes in the cluster.

Thus, clustering appears to be an energy-efficient communication protocol. However, the local base station is assumed to be a high-energy node; if the base station is an energy-constrained node, it would die quickly, as it is being heavily utilized.

3. NETWORK MODEL

Our assumptions for sensor network are such that, sensor nodes are randomly distributed over an area of 1000 x 1000 meters with following network properties.

1. Network is static and nodes are distributed in random format.
2. There exists only one base station, which is deployed at a fixed place outside A.
3. The energy of sensor nodes cannot be recharged.
4. All the nodes of the sensor network are equipped with same amount of energy level in the beginning.
5. The radio power can be controlled, i.e., a node can vary its transmission power.

Above all assumption is on wide scope, assumption no. 5, is becoming the cause of energy saving, as nodes will be aware about their location and sink too, hence the amount of energy which normally network always use to find out the initial location will be saved. This amount will be very considerable as a whole for small and large sensor network and become reason for enhancing its energy level.

4. ENERGY MODEL

In this simulation model, we use a first order radio model is used for energy dissipation in communication, where radio dissipates E_{elec}= 50 nano Joule / bit to drive the transmitter and the transmit-amplifier dissipates ε_{elec}=100 pico Joule/ bit/m2. Fig 2 shows that the radio energy model for transmit and receive the packets. To save energy, when required the radio can be turned on or off. Also the radio spends the minimum energy required to reach the destination. The energy consumed for data transmission of k bits packet is calculated from the Eq. (1)

$$E_{Tx}(k,d)=E_{elec}*k+\varepsilon_{elec}*k*d^2 \quad (1)$$

and to receive this message, the radio expends energy is shown in Eq. (2):

$$E_{Rx}(k)=E_{RX\text{-}elec}(k) \quad (2)$$

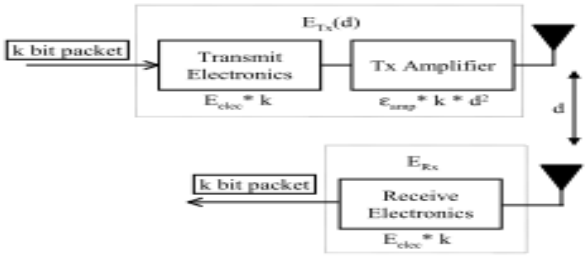

Figure 2. Radio Model

5. PERFORMANCE ANALYSIS

An extensive simulation model having scenario of n mobile nodes and n UDP/TCP connections is used to study inter-layer interactions and their performance implications. For the simulation experiment, following parameter was used:

Table 1. Simulation Parameters

Parameters	Value
Network Area	(1000,1000)
Number of Nodes	50,100,150,200
Initial Energy	2 J
E_{elec}	50 nJ/bits
E_{fs}	10nJ/bits/m^2
E_{amp}	0.0013pj/bits/m^4
Simulation time	500s
Data Packet size	4000 bits

Network simulator NS2 is used for the simulation of the scenario. The numbers of nodes chosen are 50, 100, 150 and 200 nodes are used in the simulation and they are placed in the area of 1000X1000. Wireless channel is used in the simulation process. Drop Tail queue is used. Mac/802.11 is used and omni directional antenna is used. Signal propagation uses Two Ray Ground model. UDP is used as transport agent. CBR is used for traffic generation with rate of 1024 bytes per second. The performance is analyzed over the wireless sensor network using received packets, network lifetime and energy consumption.

6. PERFORMANCE EVALUATION

In this section, the performance of the LEACH, LEACH-C, MTE and Static-Clustering protocols are evaluated on basis of scalability of the nodes. The protocols are evaluated using NS2 Simulator. The four metrics like Network life time, Received Packets and Energy Consumption are evaluated for categorize the performance of the protocols.

7. SIMULATION RESULTS

The results of simulation are shown in the Table 2, which shows the lifetime, Energy and received packets of the different number of sensor nodes. Figure shows the simulation graphs for the different number of sensor nodes versus lifetime, energy consumption and received packets respectively.

Table 2. Simulation Results

Metrics	LEACH	LEACH-C	MTE	Static-Clustering
Received packets	98%	90%	75%	65%
Lifetime(s)	85%	97%	70%	75%
Energy Consumption(J)	78%	72%	96%	76%

7.1. Energy Consumption

From the result of all the simulations, LEACH-C is found to be most energy consuming among the four tested protocols. From the graph, it can be observed that the average energy consumption per packet for the cluster head selection using LEACH-C, and Static-Clustering is less than LEACH and MTE. The reason is that in LEACH algorithm the cluster head must change in each round and it does not consider the remaining energy of a node and also it does not have the concept of sleep mode here. In LEACH-C it starts with the lower energy consumption but due to the transmission overhead it requires high energy consumptions.

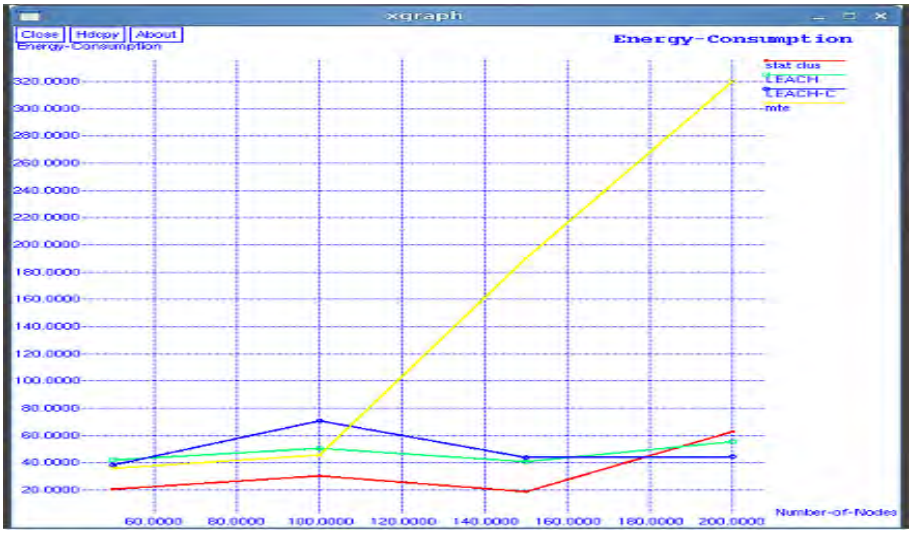

Figure 3. Energy Consumption under different number of nodes

7.2. Network Lifetime

In Figure 4, the Number of Nodes as plotted as x-axis and Network lifetime is plotted as y-axis. From the graph, it shows that the LEACH-C gives the better network lifetime when compared to MTE, LEACH and Static-Clustering.

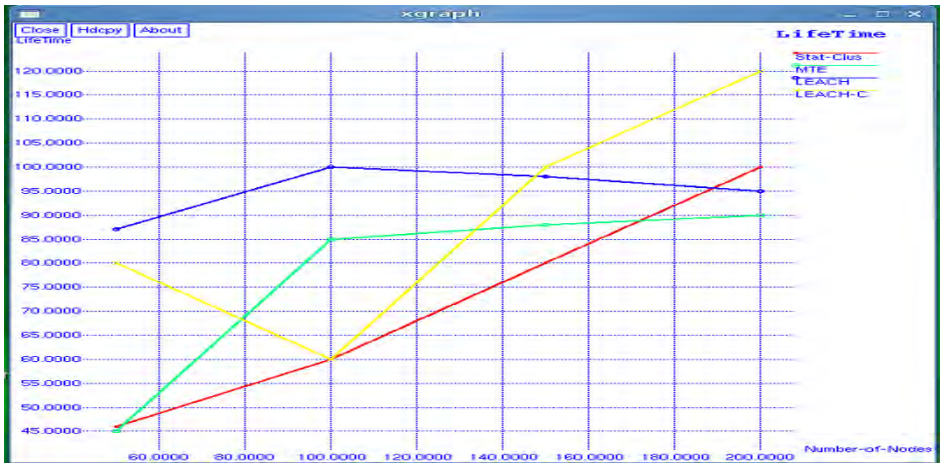

Figure 4. Network Lifetime under different number of nodes

7.3. Received Packets

In Figure 5, the numbers of nodes are x-axis and received packets as y-axis. Received packets is calculate from the total rate of data sent over the network, the rate of data sent from cluster heads to the base station as well as the rate of data sent from the nodes to their cluster heads. In Figure 5 shows the graphical representation of Throughput with respect to number of nodes. From the graph, it can be observed that the received packet is high in LEACH-C, LEACH when compared to the MTE and Static-Clustering.

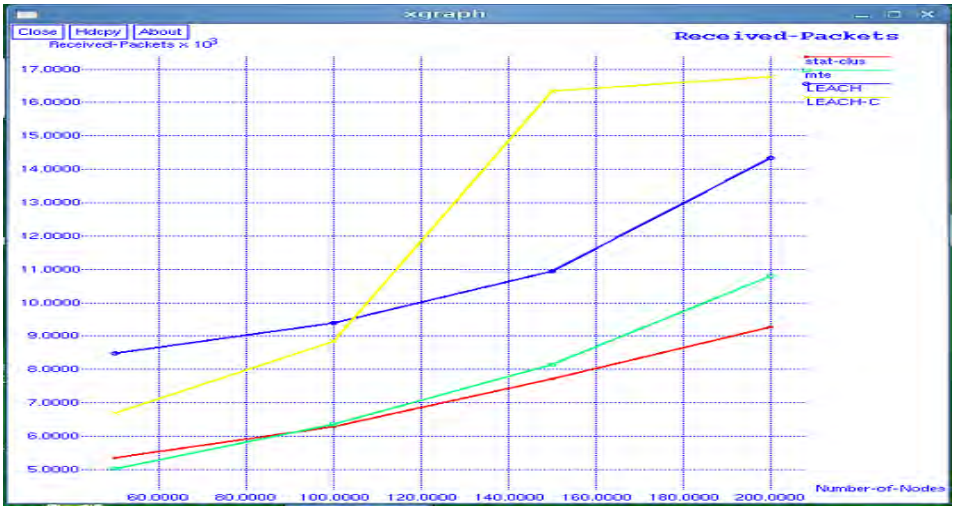

Figure 5. Received Packets under different number of nodes

8. Conclusions And Future Work

In this paper, performance of the Cluster based energy efficient routing protocols LEACH, LEACH-C, MTE and Static-Clustering are evaluated using the different metrics like Network life time, Throughput, Energy consumption and Delay. NS2 simulator is used to compare the performance of the four routing protocols. The simulation results show that LEACH-C can greatly prolong sensor network's lifetime and the lowest energy consumption as evaluate to other protocols. The throughput is high in LEACH-C and LEACH protocols than other two protocols. In future, the plan is to expand the simulation by taking into consider more challenging situations like fault tolerance, Node Balancing, mobility Model and data security etc.

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References

[1] Wenbin Jiang,Hai Jin,Chen Yu, Chao Liu Introduction and Overview of Wireless Sensor Networks DOI: 10.4018/978-1-61520-701-5.ch001

[2] J. Ibriq , I. Mahgoub, "Cluster-based routing in wireless sensor networks: issues and challenges," Proceedings of the 2004 Symposium on Performance, 2004.

[3] H. Chen, M. Hiroshi, M. Tadanori, "Adaptive data aggregation scheme in clustered wireless sensor networks," Computer communication, vol. 3, pp. 3579-3585, September 2008.

[4] W. Heinzelman, A. Chandrakasan and H. Balakrishnan, "Energy-efficient communication protocols for wireless microsensor networks" Proceedings of the Hawaii International Conference on Systems Sciences, Jan. 2000.

[5] T. Murata and H. Ishibuchi, "Performance evaluation of genetic algorithms for flow shop scheduling problems" Proc.1 st IEEE Conf. Evolutionary Computation, June 1994.

[6] P. Agarwal and C. Procopiuc, "Exact and approximation algorithms for clustering," in Proc. 9 th Annual. ACM-SIAM Symp. Discrete Algorithms, Baltimore, MD, Jan. 1999.

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