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Performance Analysis of LEACH routing Protocol for Wireless Sensor Network

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ABSTRACT— Wireless sensor networks comprise of sensors, limited battery-operated device with restrained energy capacities. Once the energy of sensors exhausted, they stop communication. Hence, energy efficiency is an important design issue to achieve long lifespan of the network. LEACH is a power efficient clustering based on hierarchical routing protocol employed for controls the limited energy of nodes in Sensor Network. The LEACH divides the network into a cluster and assigns a head to each cluster. Each node in the network has equal chance to become a cluster head for maintaining balanced energy unitization of a node. This paper provides a comparative study of LEACH protocol with other existing protocols and simulation result shows the energy efficiency of LEACH over other existing routing protocols using NS2.

Keywords- LEACH protocol; energy; cluster head; Wireless sensor networks

I. INTRODUCTION

Wireless Sensor Network (WSN) has been extensively used in the operations of research and development in defense industries and environment protection [1]. The wireless sensor networks can be equipped in a broad geographical area to detect physical sensation with acceptable precision and efficiency. The sensors can detect various parameters including human presence, temperature, obstacles, pressure, humidity and motion. Sensor nodes may impulsively form network, set up the network themselves, animatedly familiarize to device let-down and deprivation, control operation of sensor nodes, and answer to fluctuations in activity and network requirements. Every individual sensor comprises both handling and transmission components and is designed to examine the surroundings for events selected by the operator of the network. That's why Sensor networks have a broad range of applications and systems with massively unpredictable requirements and features. The sensor networks can be employed in Military situation, Disaster management, Habitat observing, Pharmaceutical and health care, Industrial fields, Home networks, Spotting chemical, Biological, and Explosive material etc. Placement of a sensor network in these applications can be set up manually. Interfacing these sensors can assist rescue activities by tracing survivors, recognizing dangerous operations, and establishing the rescue team more sensible of the comprehensive condition in the emergency area [2].

The underlying concept of clustering routing [3] is to help the information aggregation procedure in the cluster head to scale down the amount of data transmission and hence minimizes the energy wastage in transmission and in turn bring about the purpose of preserving energy of the sensor nodes. In the clustering routing algorithms for wireless networks, LEACH (low-energy adaptive clustering hierarchy [1][4] is well-know because it is simple and efficient. LEACH divides the whole network into several clusters, and the run time of network is broken into many rounds. In each round, the nodes in a cluster contend to be cluster head corresponding to a predefined criterion. In LEACH protocol, all the sensor nodes have the same possibility to be a cluster head, which makes the nodes in the network consume energy in a relatively balanced manner so as to prolong network life.

II. LITERATURE REVIEW

A. Classification of Routing Protocols

On the principle of Network Structure routing protocols in WSNs can be subdivided into location-based routing, hierarchical-based routing and flat-based routing. In location-based routing, sensor nodes' positions are exploited to route data in the network. In hierarchical-based routing, nodes will perform diverse tasks in the network. In flat-based, all nodes are given identical tasks. Moreover, protocols are divided on the basis of operation into negotiation-based, multipath-based, query based and QoS-based routing protocol. The categorization of protocols of WSNs is depicted in Fig.1.

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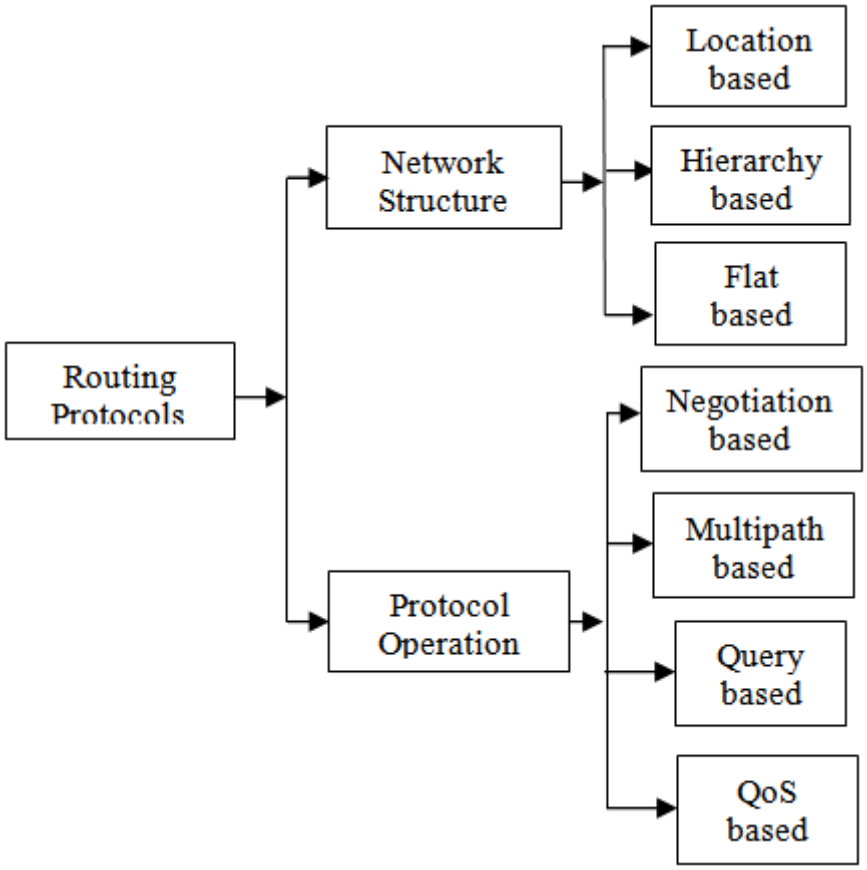

Fig. 1 Categorization of routing protocols in WSN

B. LEACH protocol

We know LEACH, a low-energy adaptive clustering protocol which supports static and dynamic assignment of cluster-head (CH). Implementing LEACH comprises two-phase: the set-up phase and the steady data transmission phase [1]. Generation of clusters in the network takes place in the first phase. The random assignment of cluster head in each cluster takes place in the second phase. In second phase, cluster's elements give data to the respective cluster head to forward the compressed data to the respected destination node. The LEACH protocol determines the CH from each cluster at occurring intervals and re-creates the clusters corresponding to a round time, to protect energy wastage of each node in the sensor network. The CH choice method in LEACH is: the sensor nodes in the network choose an arbitrary number between 0~1, and if less than a threshold T(n), the sensor node will send a message to alert others, it is a new cluster head. In each round, node continuously becomes a CH then T(n) sets to zero to decline its participation in the cluster head election. The threshold T(n) expresses as:

$$T_n = \begin{cases} \frac{T}{1-p(r \bmod \frac{1}{p})} & if \quad n \in G \\ 0 & Otherwise \end{cases} \quad \ldots\ldots\ldots\ldots (1)$$

Where, r starts from 0, which represents current round; p is the chosen percentage of cluster heads in the network, G is the group of nodes other than cluster-heads in the last 1/p rounds. Using this threshold, each node will be a cluster-head at some point within 1/p rounds. Nodes which earlier are the CH, cannot get chance of becoming CH second time in p round. After p-round, every node has a 1/p chance of selection as a cluster head to transmit data. The cluster heads merge and compress the data before transferring it to the base station, and hence extends the lifetime of most of the nodes.

In LEACH algorithm, the energy of the sensor nodes utilizes uniformly with the non-head nodes become idle for most of time. This helps in utilization of energy in efficient way in the network. All nodes in LEACH are assumed to be in range of the base station for wireless transmission, which may not be the case in every sensor network.

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III. ANALYSIS OF THE LEACH PROTOCOL

We have performed the simulation of LEACH protocol for the cluster size of 4, 16, 36, 64 and 100 sensor nodes in the network simulator NetSim. In the simulation setup, the parameters used in simulation are stated in table 1.

Table 1: Simulation Parameters

Parameter	Value
Routing Protocol	LEACH, AODV, DSR
Simulation Time	100 s
Network Size	500 * 500 m^2
Propagation Range	250 m
Number of Nodes	4, 16, 36, 64, 100
Application Type	Constant Bit Rate (CBR)
Packet Size (byte)	512
Mobility Model	Random way point
Velocity	10 m/s
Pause Time	1 s

From the simulation results, we have observed that LEACH algorithm effectively save energy of the most of the sensor nodes in the cluster and communicate with destination without data loss. However, source takes more time to transmit data to destination as compare to other routing algorithm like DSR and AODV. Fig. 2 shows the average energy consumption of LEACH, AODV and DSR. The average energy consumption in LEACH is better than existing routing protocols because of equal distribution of load on each element of cluster, which is not the case of DSR and AODV. The proper utilization of energy consumption prolongs the network lifespan and boost the communication.

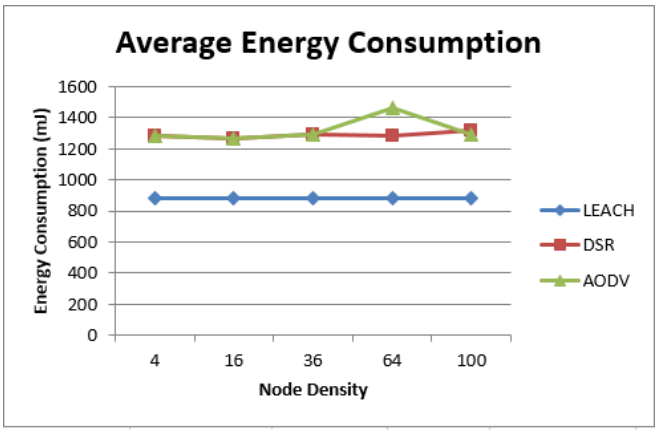

Fig. 2 Average Energy Consumption of routing protocols in WSN

Fig. 3 shows the total end-to-end delay in transmission of data from source to destination for simulation time t. As discussed earlier, the time taken for transmission of data from one particular source to the respective destination, time required in LEACH is more as compared to AODV and DSR as shown in fig. 3. This issue arises due to formation of cluster and delay in assignment of cluster head.

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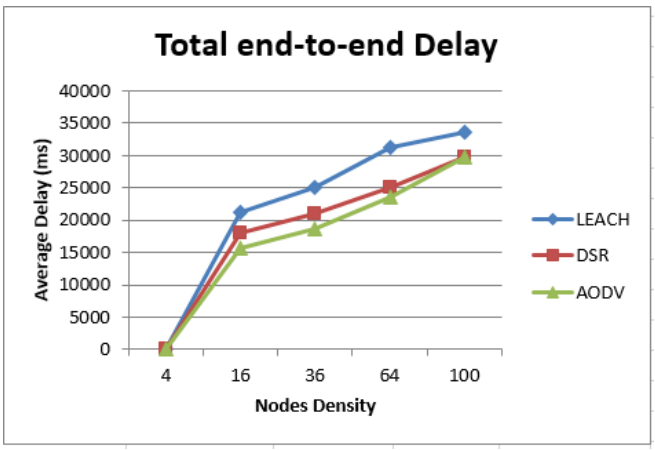

Fig. 3 Average Throughput of routing protocols in WSN

Fig. 4 shows the packet delivery capacity of LEACH, AODV and DSR. For the low-density network, the PDR is good in case of all routing protocol. But as the sensor nodes increase in the same network size, the loss of packets occurs which reduces the packet delivery capacity of routing protocols. This is because of congestion, as no routing protocol has congestion control mechanism for congested network.

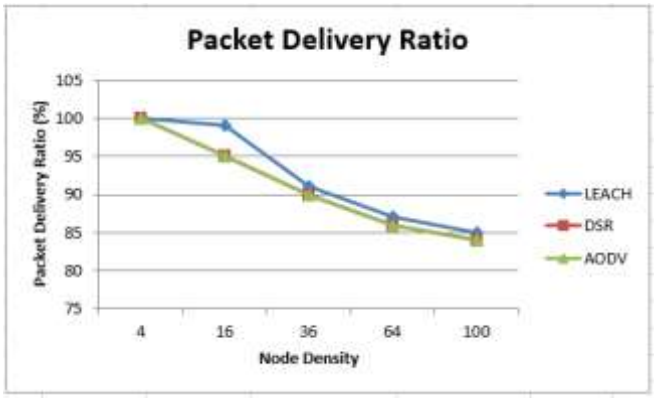

Fig. 4 Packet Delivery Ratio of routing protocols in WSN

IV. LIMITATION AND ENCHANCEMENT OF LEACH

A. Limitation of LEACH

LEACH uses clustering method to reduce energy consumption and avoid overheads. LEACH is very simple to understand and easy to implement than any other clustering based hierarchical protocol for WSN. LEACH divides the network into clusters of same size and uses static or dynamic assignment of cluster head to communicate with other elements of respective cluster. This saves energy of nodes to a great extent, which helps in prolonging network lifespan. But there are some limitations or drawbacks of LEACH; which are required to overcome for enhancement of sensor network performance. Some of the limitations of LEACH are discussed below:

- Most of the routing protocols show outstanding performance for low density networks but they are unable to provide same results for congested or dense network. Same issue arises with LEACH protocols. LEACH gives better results in small size network as it involves communication between every node to reach destination nodes. The involvement of each nodes for communication in the large network is not possible for the hunt of destination. It may cause unnecessary delay in communication and energy consumption of nodes [7][9].
- Random selection of CH in LEACH at the starting of each round; without checking of node's energy level may arise the issue of instability of route. Due to low energy, CHs are not able to provide long lasting and stable

communication after few rounds and may leave the network. It is essential to consider the residual energy of CH node before assigning it as CH. The workload in dense network is high and adequate residual energy is required for transmission and compression for data packets.

- In LEACH, each cluster head can communicate BS irrespective of their distance from BS. In dense network, communication between BS and CH consumes more energy because of long distance and large network size. This causes quick drain of limited external battery and shorten the network life. As the distance and involvement of intermediate sensor nodes increase, energy consumption of each also increase. If any of cluster head goes down during communication, BS cannot receive the data packets initiated for it.

B. Enhancement of LEACH

1) Election of Cluster Head (CH)

During formation of cluster in the sensor network, in order to establish a stable and long-lasting route avoids a node of low residual energy. It is crucial to consider a residual energy while calculation of T(n) for best and stable route.

After formation of clusters, selection of CH is done by analyzing the residual energy of each node in a cluster. A node with maximum residual energy is elected as cluster head for stable and long-lasting communication. This is called dynamic assignment of cluster head. In this type of assignment, each node is analyzed for election of cluster head. This helps in distribution of load among the nodes and save energy of each nodes. The cluster head in this case, communications with the elements of its cluster rather than BS as in case of LEACH. This will improve the energy efficiency of LEACH, as distance between source and destination reduces and also energy consumption.

2) Data transmission phase

In LEACH, data transmission is carried out by the TDMA schedule. The nodes in cluster communicates with cluster head and cluster head communicates with destination node irrespective of distance. As the distance increases there may be a high of data drop or loss during transmission. There are two types of data transmission between cluster head and BS station: One-hop transmission as in tradition LEACH and multi-hop transmission in advanced LEACH. In one-hop communication, cluster head directly communicates with BS, whereas in multi-hop communication, cluster head takes help of intermediate nodes to communicate with BS.

The ultimate aim is to reduce or minimize the data loss during the transmission. The data loss and minimum energy consumption can be achieved by communicating the cluster head of one cluster to cluster head of another cluster. One cluster head send the aggregated data to the cluster head which is near to BS. The received data are transmitted to BS via multi-hop communication. One cluster head must be able to communicate cluster head of each cluster in order to perform efficient and smooth communication.

The cluster head selects the cluster head of another cluster as the next-hop node and avoids the direct transmission of data to BS must fulfill the following conditions:

a) For the long distnace communication between one clsuter head and BS, there must be another cluster head between them with enough residual energy to participate in communication for a long time.

b) It is important for the one cluster head to communicate with anaother cluster head, if sink node is not in its range or far away from it. If cluster head transmit or receive data within its cluster, which may exhaut the limited energy and down the communication.

V. CONCLUSION

The performance analysis of LEACH protocol is presented in this paper with lamination and future enhancement in LEACH to improve routing in wireless sensor network. Elections of cluster head and proper utilization of residual energy is crucial for better performance of WSN in dense network as well. Various multi-hop algorithms are proposed to enhance the performance of LEACH routing protocols. But, still there is a lot of possible gap needs to fulfil to overcome the issue of LEACH algorithm for multi-hop communication. Simulation results for 4, 16, 36, 64 and 100 sensor nodes using NetSim show energy efficient feature of LEACH as compare to DSR and AODV, but selection of cluster head causes delay in LEACH protocol.

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