Performance Analysis of Energy Consumption Rate Based Multi-Hop Routing Protocol

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Abstract— In Wireless Sensor Network (WSN), Hierarchical clustered based routing protocol is one the most significant routing protocol. In Hierarchical Cluster protocol, network field is separated into clusters with each cluster having a Cluster Head (CH). In proposed protocol, on the basis of the location of sensor nodes, the sensor network field is separated into four logical regions. If sensor node's distance is less than the predefined distance then the data is directly transmitted through nodes. Otherwise the regions are separated into clusters with each cluster having a cluster head for aggregating and transmitting the data to gateway which further transmits the data to the base station. Cluster head election in each region is based on the Energy Consumption Rate (ECR) of each node in the previous round. Simulation results show that ECR based multihop routing protocol which provides efficient usage of node's available energy thus increases the scalability compared with existing protocols.

Index Terms— Wireless Sensor Network, Clustering, Election, Energy Consumption Rate, Gateway, LEACH, M-GEAR.

1 INTRODUCTION

In recent years, WSN has fascinated a lot of scrutiny from the researches in both academic and industrial communities [1]. WSN is contemplated as one of the most important developed technology due to gradual development of Micro-Electro-Mechanical Systems (MEMS) and highly integrated digital electronics. WSN consists of small and low cost sensor nodes which monitor the physical and environmental conditions. These sensor nodes are integrated with signal processing, sensing and communication capability. These sensor nodes communicate with each other to gather the information about the sensed area and transmit information through wireless links to the base station [2].

Due to small size of these sensor nodes, nodes have limited processing, limited storage, limited battery and limited communication capability. Energy supply and bandwidth are two constraints that put limit on available data rate and transmission range. To increase the transmission range and to improve the energy efficiency, a number of innovative ideas are required for the prolonged lifetime of the network [3]. There are many ways to transmit data from source to destination. Many routing techniques are established to route the data and to increase the energy efficiency, coverage area, reduce collision of data packets, latency, and overhead [4].

2 RELATED WORK

W. Heinzelman et al., [5] introduced the first hierarchical clustering based protocol known as Low Energy Adaptive Clustering Hierarchy protocol (LEACH) which is self organized and adaptive in nature. To divide the load among various nodes in the network Cluster heads are dynamically elected based on the predefined probability in each round. LEACH operation is divided into rounds. Each round is further divided into two phases. First phase is setup phase in which cluster heads (CHs) are formed. Cluster Heads are elected based on the threshold value.The decision is based on choosing the random number between 0 and 1 by each node. If the random number is less than threshold value $T(n)$ then the node become cluster head followed by Cluster Heads sending advertisement message to all the nodes. After receiving advertisement message, each node joins the Cluster Head based on strongest received signal strength. Second phase is steady state phase in which each node informs its Cluster Head to join their cluster by transmitting the information back to Cluster Head using Carrier Sense Multiple Access (CSMA) protocol. After receiving the information message by CHs, CH creates Time Division Multiple Access (TDMA) scheduling for transmission time of each node. After that data transmission takes place. Each node sends data to their respective Cluster Head. After receiving data, Cluster Heads aggregate the redundant data and transmit aggregated data to the Base Station.

G. Smaragdakis et al, [6] introduced as Stable Election Protocol (SEP) which uses the concept of heterogeneous nodes in the

network. In SEP two different levels of energy heterogeneity have been used. Addition of high energy nodes provides the stability in the network. In SEP the probability of CH elected based on the initial energy of each node. The performance of SEP is poor in multi level heterogeneous networks.

O. Rehman *et al*., [7] proposed a protocol Energy Consumption Rate Stable Election Protocol (ECRSEP) in which cluster head selection is based on ECR of each node. In the next round CH selection is based on the ECR calculated in the previous round. A node which has less ECR in the previous round is selected as CH in the current round. A cluster head in the previous round is not selected as CH in the next round. Because it's ECR is very high as compared to Non Cluster Head (NCH) nodes in the network.

Said Ben Alla et al, [8] proposed a robust and desirable Hierarchical Adaptive Balanced Energy Efficient Routing Protocol (HABRP). In this protocol, a gateway is used to transmit data from CHs after the aggregation of data send by the normal nodes to the cluster head in a cluster. In this each round consists of three steps. In first step gateway is selected among the high energy nodes. In second step, CH is being selected on the random probability of each node. In third step, clusters are formed in the network.

Q.Nameed et al., [9] in 2013 proposed an idea of gateway based energy-efficient multi hop routing based protocol (M-GEAR) in WSN. A rechargeable gateway is used at the center of the network field to increase the stability of the network. CHs are elected based on the random probability. BS is placed far away from the network field.

3 Radio Model

For radio hardware, energy dissipation takes place at transmitter consisting of transmitter radio electronics and transmit amplifier. The receiver energy dissipation takes place at receiver radio electronics. Depending upon the distance between the transmitter and the receiver both the free space and multipath fading channel models are used [9].

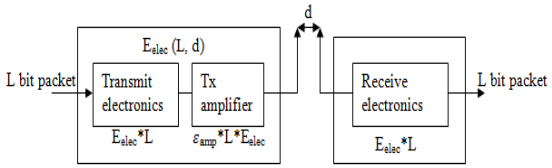

Fig. 1. Model for energy dissipation

If the distance between the transmitter and the receiver is less than threshold value then the free space model is used. If the distance between the transmitter and receiver is greater than threshold value then multipath fading model is used. In transmitter amplifier, for free space channel model, the value of α=2 is used. whereas in case of for multipath fading model α=4 is used. Energy required for transmitting L bits at a distance d with threshold d_0 is given by:

$$E_{Tx}(L,d) = E_{elec} * L + E_{amp}(L,d) \quad (1)$$

where, E_{amp} is the amplifier energy consumption and can be expressed in terms of ε_{fs} or ε_{mp}. Energy required for transmitting L bits at a distance d with threshold d_0 is given by:

$$E_{Tx}(L,d) = \begin{cases} E_{elec} * L + L * d^2 * \varepsilon_{fs}, & d < d_0 \\ E_{elec} * L + L * d^4 * \varepsilon_{mp}, & d > d_0 \end{cases} \quad (2)$$

$$d_o = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \quad (3)$$

To receive L messages bits, radio energy expenditure is given by:

$$E_{Rx} = E_{elec} * L \quad (4)$$

4 Proposed Evaluation

It is assumed that n number of S sensor nodes are randomly placed in the network field. The ith sensor is given by S_i. The Network Model follows these assumptions:

1. BS and sensor nodes are fixed after deployment. BS is placed far away from the sensing field.
2. A rechargeable gateway is placed at the centre of sensing field which is fixed after deployment.
3. Sensing field consists of homogeneous sensor nodes having same energy capabilities.
4. Each node has different distinctive identifier (ID).

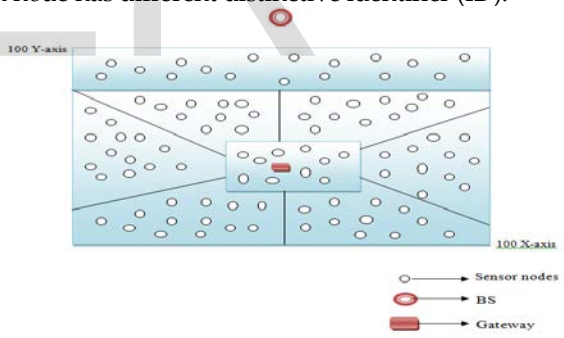

Fig. 2. Network model

The sensor nodes have large data to process before sending it to the base station. Due to this, there is a need of aggregating the data into a small set consisting of significant information. A gateway node is deployed at the centre of the network field to improve the network lifetime and throughput. Gateway node collects the data from CHs and nearby sensor nodes and aggregate this data and finally, sends it to the BS. Adding a rechargeable gateway node at the centre of network field improves the energy consumption and network lifetime. The cost of gateway is much lower as compared to the cost of the sensor node. The proposed algorithm consists of five phases which are discussed below:

5.2 Initial Phase

Initially nodes are distributed in the network area which is homogenous in nature. In order to collect the information about the sensor nodes, the BS sends the HELLO packet to all the sensor nodes. In response sensor nodes forward their location to the BS. Then BS measures the distance of each node and keeps it in the BS node data table. The node ID, remaining energy of node, position of node and its distance to BS and gateway node are stored in the BS node data table.

ii) Setup Phase

On the basis of the location of each node in the network, the BS partitions the network field into four logical regions. Region one (R1) transmits its data directly to the base station because of its small distance from the BS. The second region (R2) nodes transmit its data directly to the gateway which aggregates the data and sends it to the BS. Region R1 and R2 are also called as non-clustered region. All the sensor nodes which are away from BS and gateway are divided into two equal regions and known as clustered regions.

iii) CH Selection

In third phase, the network is separated into regions by the BS. Each node decides whether to become CH for current round or not.. This decision of the node is based on suggested percentage of number of CHs in the network and number of times a particular node has become a CH before. This process is based on random number between 1 and 0. If the number is less than threshold then the node become CH for current round. Initially all the sensor nodes have same initial energy, after that CHs are formed based on Energy Consumption Rate (ECR) of each node. ECR is given by

$$ECR = \frac{Eint - Er}{r - 1} \qquad (5)$$

Where $Eint$ is initial energy and Er is residual energy of each node. r is current round. In the next round CH will be formed based on the value of ECR in the previous round. The node having least value of ECR in the previous round will be elected as CH in the next round.. Previous round CH will not be selected as CH for current round due to large ECR as compared to the other cluster members in a cluster. The threshold is given by

$$T(n) = \begin{cases} \frac{P * ECR}{1 - P(r \bmod \frac{1}{P})} & , if\ n \in C \\ 0 & , \quad otherwise \end{cases} \qquad (6)$$

where P is desired percentage of CH, r is current round; C is set of nodes not elected as CH in the current round. Initially all the sensor nodes have same initial energy, after that CHs are formed based on Energy Consumption Rate (ECR) of each node. After the selection of CHs in each region CH inform their role to the nodes which are near to it. After that CH send control packet to all nodes. Then nodes send reply message to CHs. The nodes which are nearest to a CH become a cluster member of that CH.

iv) Scheduling

After CH has been formed, CH schedule Time Division Multiple Access (TDMA) scheduling for their cluster members. Sensor nodes in the cluster transmit their sensed data in its own schedule time slot. Otherwise nodes go into idle mode to save their energy. Nodes switch ON their transmitter during transmission time due to which energy dissipation of each sensor node decreases.

iv) Scheduling

In steady state phase, cluster members send their data to the CH. After receiving the data from cluster members CH aggregates the data and transmits it to the gateway node. Then gateway node collects the data from CHs, aggregates the data and transmits it to the BS.

5 Performance Evaluation

In this review the performance of proposed protocol and evaluate it with existing protocol in WSN, known as LEACH, M-GEAR.

5.1 Simulation Results

In proposed protocol a network field is considered which is consisting of 100 nodes which are randomly distributed whose area is 100m × 100m. A gateway which is stationary after deployment is placed at the centre of sensing field and BS is placed far away from the sensing field. Packet size is considered to be of 4000 bits. E_0 is the initial energy of sensor node. The results of the proposed protocol are compared with LEACH and M-GEAR protocols.

Table 1
Simulation parameters

Parameter	Value
E_o	0.5J
E_{elec}	5nJ/bit
E_{mp}	0.0013pJ/bit/m^4
E_{da}	5pJ/bit
E_{fs}	10pJ/bit/m^2
Packet size	4000 bits

In this subsection, simulation results are explained. Extensive

simulations are carried out and the results are compared with LEACH and M-GEAR protocol.

5.2 Stability Period

It is the time measured from the start of operation until the death of its first node.

As it can be seen in Table 1 First Node Dead (FND) for LEACH is after 724 rounds and Last Node Dead (LND) is after 1721. FND and LND for M-GEAR are after 1057 and 2595 rounds respectively. For ECR based Multihop routing protocol FND and LND are after 1401 and 2499 respectively.

Table 2

Stability period for different Protocols

	Number of rounds		
Protocol Name	LEACH	M-GEAR	ECR based Multihop Routing Protocol
FND	724	1057	1401
LND	1721	2495	2499

So, ECR based multihop routing protocol provides more stability than existing protocols.

$$Improvement = \frac{Stable\ period\ of\ ECR\ based\ multihop\ protocol - Stable\ period\ of\ M-GEAR}{Stable\ period\ of\ M-GEAR}$$

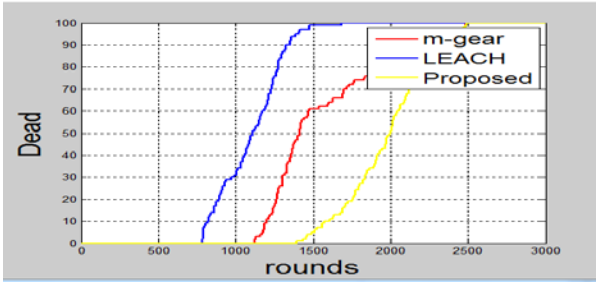

Fig.3. Comparison of the dead nodes for 100mx100m network with 100 nodes

Table 3

Comparision Table Showing Imrovement in Stability for Different Protocols

Protocol Name	Stability Period	ECR based Multihop protocol stability period	Improvement
LEACH	724	1401	93.50%
M-GEAR	1055	1401	32.79%

5.3 Throughput

The number of packets sent to BS are referred as throughput. From the Table 3 it has been concluded that due to increase in stability, the throughput of ECR based multihop routing protocol is large as compared to LEACH and M-GEAR protocol. The M-GEAR protocol increases the throughput 5 times to that of LEACH protocol. But the throughput of ECR-based Multihop routing protocol is more than that of the M-GEAR.

Table 4

Comparision of Packets sent to BS

Protocol Name	Packets sent to BS
LEACH	27854
M-GEAR	107524
ECR based Multihop Routing protocol	145860

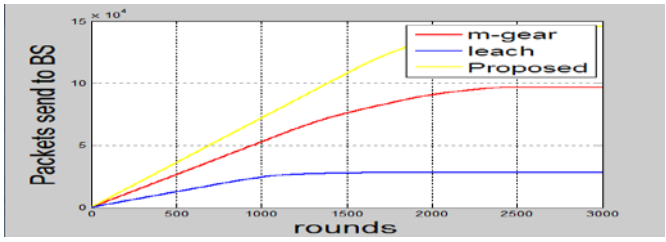

Fig. 4. Comparison of Packets sends to BS

6 Conclusion

To reduce the energy consumption a network has been designed in which a rechargeable gateway is placed at the centre of the network field. The whole network is alienated into four logical regions. Two regions (R1, R2) use direct communication topology and other two regions (R3, R4) are alienated into clusters uses multihop communication. In regions R3, R4 CHs are elected on the basis of the value of ECR in the previous round. The node which has least value of ECR in the current round node becomes CH in the next round. Simulation results show that ECR based multihop protocol performs better than

the existing protocols.

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