(IJITR) INTERNATIONAL JOURNAL OF INNOVATIVE TECHNOLOGY AND RESEARCH
Volume No.5, Issue No.2, February – March 2017, 5895-5901.

Performance Analysis of Multi-Hop Routing Protocols For WSN'S

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Abstract: **A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to monitor physical or environmental conditions. A WSN system incorporates a gateway that provides wireless connectivity back to the wired world and distributed nodes. A key concern in WSN technology is to enhance the network lifetime and to reduce the energy consumption of the sensor network. Many routing protocols available for maximizing the network lifetime. In this paper, we have been propose a gateway based energy efficient routing protocol (GEAR) for Wireless Sensor Networks (WSNs) and also compare the performance of our protocol with LEACH (Low Energy Adaptive Clustering Hierarchy). Performance analysis and compared statistic results show that our proposed protocol perform well in terms of energy consumption and network lifetime.**

Keywords: **Wireless Sensor Network; Routing Protocol; LEACH; GEAR;**

I. INTRODUCTION

A key concern in WSN technology is to enhance the network lifetime and to reduce the energy consumption of the sensor network. Wireless sensor nodes are dispersed typically in sensing area to monitor earthquake, battle field, industrial environment, habitant monitoring, agriculture field, physical atmosphere conditions and smart homes. Sensor nodes sense the environment, gather information and transmit to BS through wireless link. This technology also helps to record the meteorological parameters.

Wireless sensor networks (WSNs) have gained worldwide attention in recent years, particularly with the proliferation in Micro-Electro-Mechanical Systems (MEMS) technology which has facilitated the development of smart sensors. These sensors are small, with limited processing and computing resources, and they are inexpensive compared to traditional sensors. These sensor nodes can sense, measure, and gather information from the environment and, based on some local decision process, they can transmit the sensed data to the user. Smart sensor nodes are low power devices equipped with one or more sensors, a processor, memory, a power supply, a radio, and an actuator.

In WSNs, nodes sense data and send information to sink. Wireless sensor nodes can be mobile or stationary and can be deployed in their environment randomly or with a proper deployment mechanism. For random deployment there is even distribution of nodes over the field, while for regular deployment nodes are static. Some of energy of nodes is consumed during sensing as well as some part of it is reduced due to transmission and reception of data.

In order to prolong the network lifetime, a network routing protocol with high energy efficiency is necessary besides designing low-power sensor nodes. A current research challenge is to develop low-power communication with low-cost on-node processing and self-organized connectivity/protocols. Several protocols were developed to make the communication energy-effective to prolong the life of the networks. These protocols were different in how they improve the communication and transmission of the packets in the network but they all based on clustering approach in the network.

II. ROUTING PROTOCOL

A routing protocol specifies how routers communicate with each other, disseminating information that enables them to select routes between any two nodes on a computer network. Routing algorithms determine the specific choice of route. Each router has a priori knowledge only of networks attached to it directly. A routing protocol shares this information first among immediate neighbors, and then throughout the network. This way, routers gain knowledge of the topology of the network. In this section we describe some routing protocols.

LEACH Algorithm

Low-Energy Adaptive Clustering Hierarchy (LEACH) is one of the most popular cluster-based routing protocols in wireless sensor networks.The operation of the LEACH protocol consists of two phases: setup phase, steady-state phase. Where each round begins with a set-up phase, when the clusters are organized, followed by a steady-state phase, when data transfers to the base station occur. In order to minimize overhead, the steady-state phase is long compared to the set-up phase. To reduce management consumption, the steady-state phase is much longer compared to the set-up phase.

A. Set-up phase

In the set-up phase, initially the node becomes a cluster head with a probability P and broadcasts its decision packet. The regular nodes choose their cluster-head based on the least communication energy to reach the cluster-head. The role ofthe cluster-head keeps on rotating among the nodes of the cluster to enhance the network life time. The selection of cluster-head depends on decision made by the node by generating a random number between 0 and 1. If the number is less than a threshold T (n), the node becomes a cluster-head for the current round. The threshold is set as

$$T(n) = \begin{cases} \frac{p}{1-p*(r \bmod (\frac{1}{p})}, & if \ n \in G \\ 0, & if \ n \notin G \end{cases}$$

Where P equals the suggested percentage of cluster-heads, r is the current round, and G is the set of nodes that have not been cluster-heads in the last 1/ P rounds. By using this threshold, each node will be a cluster-head at some point within 1/ P rounds. During the first round (r = 0), each node has a probability P of becoming a cluster-head. The nodes that are cluster-heads in round 0 cannot be cluster-heads for the next 1/ P rounds. Thus the probability that the remaining nodes are cluster-heads must be increased, since there are fewer nodesthat are eligible to become cluster-heads. After 1/ P −1rounds, T =1

For any nodes that have not yet been cluster heads, and after 1/ P rounds, all nodes are once again eligible to become cluster-heads.

Once the cluster-heads have been chosen, the cluster-heads use CSMA MAC protocol to broadcast advertisement messages to the rest of the nodes. The regular nodes must keep their receivers on during this phase to hear the advertisements of all the cluster-heads. After this phase, each regular node decides which cluster to join for the current round. Then the regular node will inform the cluster-head that it will become a member of the cluster. Each regular node transmits this information back to the cluster-head again using a CSMA MAC protocol. The cluster-head receives all the messages for nodes that would like to join in the cluster. Based on the number of regular nodes in the cluster, the cluster-head creates a TDMA schedule telling each regular node when it can transmit. This schedule is broadcast back to the regular nodesin the cluster.

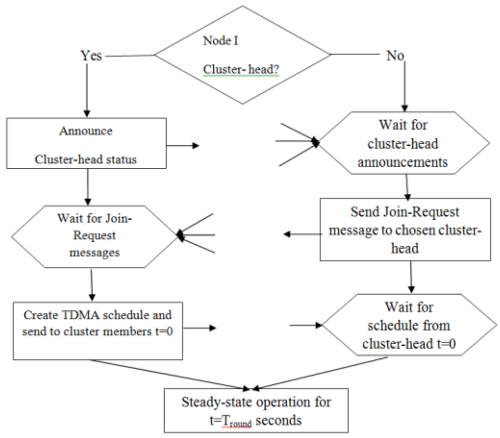

Figure 1: Flow Chart for Set-up phase

B. Steady-State phase

After the clusters are created and the TDMA schedule is fixed, data transmission can begin. The regular node will send data during their allocated transmission time to the cluster-head according to the TDMA schedule. The radio of each regular node can be turned off until the node's allocated transmission time. The cluster-head will keep its receiver on to receive all the data from the nodes in the cluster. When all the data hasbeen received, the cluster-head performs data fusion functions to compress all the data into a single signal. After that the composite signal is sent to the base station directly by the cluster-head. Since the base station is far away, this is a high energy transmission. This is the steady-state operation of LEACH networks. After a certain time, which is determined a priori, the next round begins.

LEACH is targeted at proactive network applications where as TEEN and APTEEN are targeted at the reactive network applications. In proactive network, the sensed data is sent periodically to the sink which provides the snap shot of relevant parameters at regular intervals. In reactive networks the nodes react immediately to the sudden change in the sensed data and transmit it to the sink. Since they remain in the sleep mode most of the time, the number of transmissions is reduced, thus reducing the energy consumed.

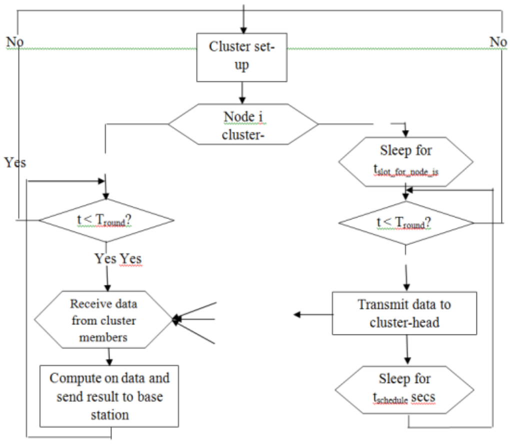

Figure 2: Flow Chart for Steady-State phase

LEACH enhances the network lifetime by utilizing the resources efficiently, distributing the load uniformly, aggregating data at the CH to contain only the meaningful information, rotating the CH randomly to achieve balanced energy consumption. Also, the sensors do not need to know the location or distance information. Depending on the applications, the different variations of LEACH such as LEACH-C (centralized), E-LEACH (enhanced) and MLEACH (multi-hop) can be used.

Pros & Cons

Pros:

- ✓ LEACH is that it outperforms conventional communication protocols, in terms of energy dissipation, ease of configuration, and quality of the network.
- ✓ LEACH uses single-hop routing where each node can transmit directly to the cluster-head and the sink. Therefore, it is not recommended for networks that are deployed in large regions.
- ✓ Providing such a low energy, wireless distributed protocol will help pave the way in a WSN
- ✓ Better energy utilization and system life time.
- ✓ The algorithm provides prolonged network coverage (low latency).
- ✓ The dynamic clustering may results toextra overhead, e.g. head changes, advertisements etc., which may diminish the gain in energy consumption

Cons:

- ➢ The simulations are still to be performed using the Network simulator
- ➢ Fault-tolerance issues when nodes fail or behave unexpectedly
- ➢ The nodes with low remnant energy have the same priority to be a cluster head as the node with high remnant energy. Therefore, those nodes with less remaining energy may be chosen as the cluster heads which will result that these nodes may die first
- ➢ The cluster heads communicate with the base station in single-hop mode which makes LEACH cannot be used in large-scale wireless sensor networks for the limit effective communication range of the sensor nodes.
- ➢ LEACH protocol prolongs the network lifetime in contrast to plane multi-hop routing and static routing, it still has problems.
- ➢ The cluster heads are elected randomly, so the optimal number and distribution of cluster heads cannot be ensured.

GEAR Algorithm Implementation

In this article, we assume S sensors which are deployed randomly in a field to monitor environment. We represent the i-th sensor by Si and consequent sensor node set S= s1, s2...Sn .We assume the network model shown in fig 3.

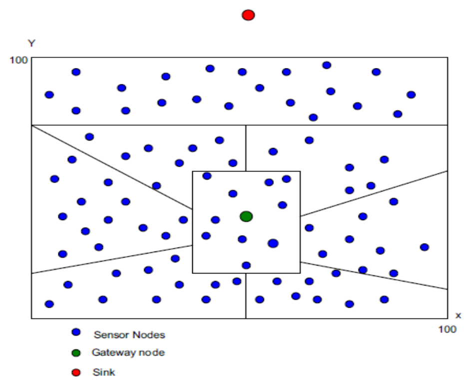

Figure 3: Network Model

- ➢ We deploy the BS far away from the sensing field. Sensor nodes and the BS are stationary after deployment.
- ➢ A gateway node is deployed in the same network field at the center of the network.Gateway node is stationary after deployment and rechargeable.
- ➢ We use homogeneous sensor nodes with same computational and sensing capabilities.
- ➢ Each sensor node is assigned with a distinctive identifier (ID).

Steps involved in GEAR Protocol

The proposed protocol is implemented as follows: Sensor nodes have too much sensed data for BS to process. Therefore, an automatic method of combining or aggregating the data into a small set of momentous information is required. The process of data aggregation also termed as data fusion. In order to improve network lifetime and throughput, we deploy a gateway node at the centerof the network field. Function of gateway node is to collect data from CHs and from nodes near gateway, aggregation and sending to BS. Our results ensure that network lifetime and energy consumption improved with the expense of adding gateway node. We add rechargeable gateway node because it is on ground fact that the recharging of gateway node is much cheaper than the price of sensor node.

A. Initial Phase

In M-GEAR, we use homogenous sensor nodes that are dispersed randomly in network area. The BS broadcast a HELLO packet. In response, the sensor nodes forward their location to BS. The BS calculates the distance of each node and save all information of the sensor nodes into the node data table. The node data table consists of distinctive node ID, residual energy of node, location of node and its distance to the BS and gateway node.

B. Setup Phase

In this section, we divide the network field into logical regions based on the location of the node in the network. BSdivides the nodes into four different logical regions. Nodes in region-one use direct communication and transmit their data directly to BS as the distance of these nodes from BSis very short. Similarly nodes near gateway form region-two and send their data directly to gateway which aggregates data and forward to BS. These two regions are referred to on-clustered regions. All the nodes away from the gateway node and BS are divided into two equal half regions. We call them clustered regions. Sensor nodes in each clustered region organize themselves into small groups known as clusters.

C. CH Selection

Initially BS divides the network into regions. CHs are elected in each region separately. Let ri represent the number of rounds to be a CH for the node Si. Each node elect itself as a CH once every r i = 1/p rounds. At the start of first round all nodes in both regions has equal energy level and has equal chance to become CH. After that CH is selected on the basis of the remaining energy of sensor node and with probability p alike LEACHES. In each round, it is required to have n x p CHs. A node can become CH only once in an epoch and the nodes not elected as CH in the current roundfeel right to the set C. The probability of a node to (belong to set C) elect as CH increases in each round. It is required to uphold balanced number of CHs. At the start of each round,a node Si belongs to set C autonomously choose a random number between 0 to 1. If the generated random number for node Si is less than a predefined threshold T(s) value then the node becomes CH in the current round. The threshold value can be found as:

$$T(s) = \begin{cases} \dfrac{p}{1 - p^{x(rmod(\frac{1}{p}))}}, & if\ s \in c \\ 0, & otherwise \end{cases}$$

Where P = the desired percentage of CHs and r = the current round, C = set of nodes not elected as CH in current round. After electing CHs in each region, CHs inform their role to neighbor nodes. CHs broadcast a control packet using aCSMA MAC protocol. Upon received control packet fromCH, each node transmits acknowledge packet. Node who find nearest CH, becomes member of that CH.

D. Scheduling

When all the sensor nodes are structured into clusters, eachCH creates TDMA based time slots for its member nodes. All the associated nodes transmit their sensed data to CH in its own scheduled time slot. Otherwise nodes switch to idle mode. Nodes turn on their transmitters at time of transmission. Hence, energy dissipation of individual sensor node decreases.

E. Steady-State Phase

In steady state phase, all sensor nodes transmit their sensed data to CH. The CH collects data from member nodes, aggregates and forwards to gateway node. Gateway node receives data from CHs, aggregates and forwards to BS

Flowchart

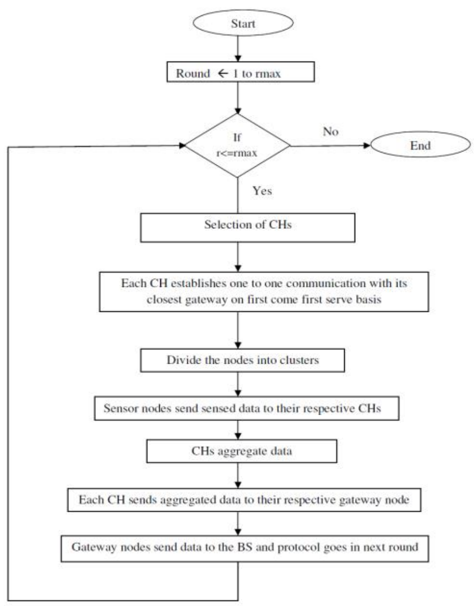

Figure4: M-GEAR Flow Chart

- Periodically the base station starts a new round by incrementing the round number.
- Selects cluster heads on the basis of leach protocol with probability 0.1 and the CH should not be more than 10 in number, in each round. In each round a sensor node elects itself as a cluster head by selecting a random number to compare to the threshold value. The threshold *T (n)* is set as: *T (n)* = {P / 1 – P * (r mod1/P)} if n belongs to G, if not its 0. P is the desired percentage of cluster heads, r is the current round, and G is the set nodes that have not been cluster heads in the last (1/P) rounds.
- As soon as a CH is formed, it selects a gateway node which lies closest to it.
- Make Clusters by allocating the cluster head to each node of the network on the basis of minimum distance between nodes to Cluster head (CH).
- Sensor nodes wake up, senses data, and forwards sensed data to respective CHs.
- The CHs aggregates data receiving from all cluster members and then send data to the gateway nodes on the basis of one-to-one communication.
- Now the gateway nodes further send the data to the BS and protocol goes in next round till the last round is not encountered.

III. PERFORMANCE PARAMETERS

In this subsection, we present performance metrics. In this work, we evaluated three performance parameters given below.

- **Network lifetime:** It is the time interval from the start of the network operation till the last node die.
- **Throughput:** To evaluate the performance of throughput, the numbers of packets received by BS are compared with the number of packets sent by the nodes in each round.
- **Residual Energy:** The residual battery energy of network is considered in order to analyze the energy consumption of nodes in each round. Residual energy ensures graceful degradation of network life.

IV. RESULTS AND DISCUSSIONS

We assess the performance of our proposed protocol and compare it with existing protocol in WSN, known as LEACH.

Simulation Setting

In order to appraise the performance of our proposed protocol, we simulated our protocol using MATLAB. We consider a wireless sensor network with 100 nodes distributed randomly in 100m X 100m field. A gateway node is deployed at the Centre of the sensing field. The BS is located far away from the sensing field. Both gateway node and BS are stationary after deployment. We consider packet size of 4000 bits. We compare our protocol with LEACH protocol. To assess performance of our protocol with LEACH, we ignore the effects caused by signal collision and interference in the wireless channel.

Table 1: Presents the radio parameters

Parameter	**Value**
EO	0.5j
E_{elec}	5nJ/bit
Efs	10pJ/bit/m2
Emp	0.0013 pJ/bit/m4
Eda	5pJ/bit
Message size	4000 Bits

Network Lifetime:

In fig 5, we show the results of the network lifetime. Nodes are considered dead after consuming0.5 joule energy. M-GEAR protocol obtains the longest Network lifetime. This is because the energy consumption is well distributed among nodes. Network is divided into logical regions and two of them are further sub divided into clusters. M-GEAR topology balance energy consumption among sensor nodes. On the other hand, in LEACH, nodes die quickly as stability period of network ends. It is not evident that predestined CHs in LEACH are distributed uniformly throughout the network field. Therefore, there is a possibility that the selected CHs will be concentrated in one region of the network. Hence, some nodes will not have any CHs in their environs. Fig 5.1 shows interval plot of network lifetime with99% confidence interval. We note that, the results of M-GEAR protocol are statically different and perform well

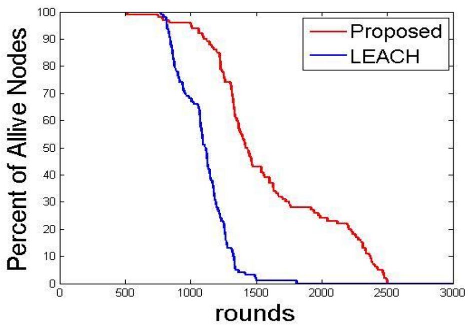

Figure 5: Interval plot- Analysis of network lifetime

Throughput:

Average packets sent to BS are assessed through extensive simulations. Simulation results of M-GEAR protocol illustrate increased throughput. Interval plots of M-GEAR and LEACH in fig 6 clearly epicts performance of both protocols. To calculate throughput, we assume that CHs can communicate freely with gateway node. Simulation results show an increase throughput of 5 times then LEACH. Sensor nodes near gateway send their data directly to gateway; similarly nodes near BS transmit data directly to BS. Sensor nodes in both regions consume less transmission energy therefore; nodes stay alive for longer period. More alive nodes contribute to transmit more packets to BS

Residual Energy:

Fig 7 shows average residual energy of network per round. We assume that a node has 0.5 joule energy. The total energy of 100 node network is 50 joule M-GEAR protocol yields minimum energy consumption than LEACH. Fig clearly depicts that our protocol outperforms LEACH routing protocol in terms of energy consumption per round. Deployment of gateway node at the center and high probability of CHs in all regions ensures minimum energy consumption.

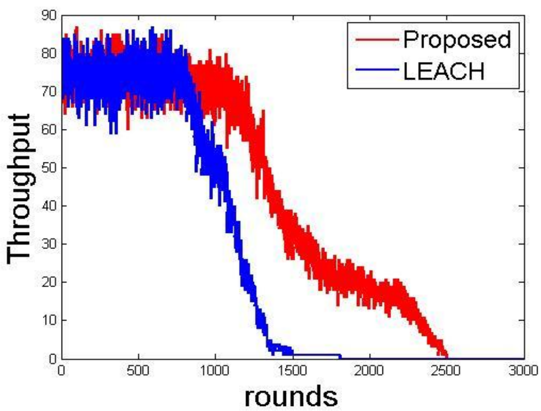

Figure 6: Interval plots- Analysis of Throughput

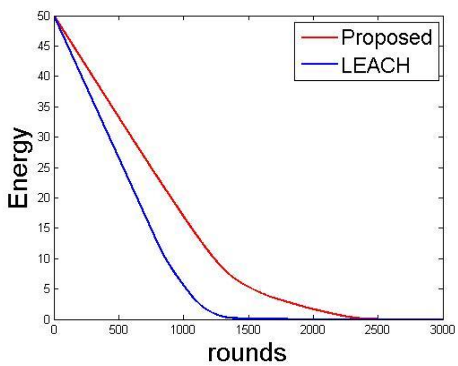

Figure 7: Interval plots- Analysis of Residual energy

V. CONCLUSION

In our thesis of project an energy-efficient multi-hop routing protocol using gateway nodeto minimize energy consumption of sensornetwork. In this work, dividing the network into logicalregions. Each region use different communication hierarchy.Two regions use direct communication topology and tworegions are further sub-divided into clusters and use multi-hopcommunication hierarchy. Each node in a region elects itself as a CH independent of other region. This technique encourages better distribution of CHs in the network. Simulation results show that our proposed protocol performs well comparedto LEACH. In this work, studied the three performancemetrics: Network lifetime, Residual energy and throughput.

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