Maximizing the Lifetime of Multi-hop Routing Protocol Using Gateway for Wireless Sensor Network

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Abstract: Energy efficient is the most important design goal for wireless sensor network. Many types of existing routing protocols are designed to increase the lifetime for the network. In these protocols, cluster-based routing protocols are found to be more energy efficient. A cluster head is chosen to aggregate the data received from nodes and forwards these data to the base station in cluster-based routing. The most important part in the network is the selection of cluster heads which should be efficient to save energy and prolong the lifetime for the network. In our proposed protocol, to make the selection of cluster head optimal and more efficient we use the idea of static clustering. For an optimal number of cluster head selection, we divide a large field sensor into three logical regions on the basis of their location in the sensing field. We install Base Station (BS) out of the sensing area and a gateway node at the center of the sensing area. If the distance of a sensor node from BS or the gateway is less than the threshold distance, the node uses direct communication. The proposed protocol combines the idea of clustering and multi-hop communication. The cluster heads who are far away from BS communicate with BS through the transit cluster heads. While, in fact, these who are near BS can communicate with it directly. We compare performance of our protocol with LEACH (Low Energy Adaptive Clustering Hierarchy). In terms of energy consumption, network lifetime our proposed protocol performed better than LEACH protocol.

Keywords: Routing Protocol, Wireless Sensor Networks, Clustering, LEACH.

1. INTRODUCTION

In the last few years, wireless sensor networks have gained a lot of interest in the many research fields, due to their various applications. Theses wireless sensor nodes have limited energy, processing capabilities, and sensing abilities. Initially WSNs were used only in the battle fields for military purpose but now their use is extended for monitoring and controlling the different processes in many other civilian areas. A sensor node is consisted of the following blocks: sensing unit, processing unit, power unit and communication unit. [1]. There are many routing protocols have been already proposed for WSNs. They can be classified into flat, hierarchical, location-based network routing protocols [2]. LEACH [3], TEEN is well known hierarchical protocols. One of the most important techniques is clustering which network energy consumption is well managed by minimizing the transmission range of the sensors. In this technique, CH manages the group communication with the BS. The new method of clustering suggest that sensor nodes will not transmit

data directly to the BS instead CHs receive the whole group messages, aggregates and forwards to BS. After that all nodes in cluster transmit their data to corresponding CH. The CH issues a Time Division Multiple Access (TDMA) schedule for its member nodes to avoid collision. To avoid collision in the network each member nodes send its information to CH only in defined allocated time slot therefore, sensor nodes turn off their transceivers otherwise. Using TDMA scheduling will help the network to save energy and the sensor nodes will stay alive for longer period. For all cases, sensor node sends its information to nearest CH therefore; sensor nodes need minimum energy to send their information. CHs perform computation on gathered data and filter out the redundant bits; in this case the network reduces the amount of data that has to forward to the BS.

The rest of the paper is ordered as follows: section 2 briefly reviews the related work. In section 3, we describe motivation of this work. Section 4 describes the network model. Proposed algorithm is explained in section 5. In section 6, we define the performance

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parameters and show the performance of our proposed protocol by simulations and compare it with LEACH. Finally, section 7 gives conclusion.

2. RELATED WORK

In wireless sensor networks there are large numbers of protocols which deal with energy consumption and network lifetime. This paper is proposed for dealing with clustering based routing for WSNs. From pervious literatures we can conclude that there is many homogenous clustering based protocols, such as LEACH [3] PEGASIS [4] and HEED [5]. CHs gather information from its members or primary nodes, aggregate and then forward to far away locate BS. Using this This process make cluster head consumes more energy. The cluster heads in LEACH protocol are chosen randomly and consume uniform energy by selecting a new CH in each round. Any node may be chosen as CH in current round on the basis of probability P. Any way LEACH protocol performs well in homogenous network, the main disadvantages of this this protocol is not considered good for heterogeneous network. LEACH protocol suffer from uneven distribution of cluster heads, also if the network has large area, the required transmitted power will increase, and some region suffers from instability due to the early death of its sensor nodes. LEACH-C [6] the base station is responsible for choosing cluster heads in each round by using the centralized cluster head selection mechanism. All sensor nodes send their current location and remaining energy in each round, the average energy for each node will be computed by the base station, if the value of remaining energy for each node is greater or equal to the average energy of the node then this node will be chosen to be as cluster head in that round. As a result, the base station decides the number of cluster heads in the network [7]. In this algorithm (simulated annealing) the candidate cluster head set to find the optimal cluster head. Once the optimal cluster head and clusters are chosen, the base station sends the cluster heads IDs to all cluster head members, cluster member node IDs, and transmission schedule for each cluster to all nodes in the network. Each node compares its ID with the cluster head ID, and if it matches, then it will be chosen as the cluster head. Otherwise the node decides its slot in the transmission schedule and sends information to cluster head in its slot.   In LEACH-C one of the main disadvantages of this protocol [6] is repeated cluster formation overhead. Besides to there is extra information and energy consuming since the time is fixed. A hybrid Protocol Energy Efficient Reactive Protocol for WSN is proposed in [8].

3. SYSTEM MODEL

In this model, we assume there are N sensor nodes which are deployed randomly in a field to control environment. We assume the network model shown in Fig. 1. The nodes in rectangle shapes (1 and 2) do not belong to any cluster and are sending their data directly to the Gateway or BS. This is due to the fact that their distance from the BS is less compare to any of the CHs and if the distance is less than less energy will be dissipated in the transmission. The node in region 3 are sending their data to the base station in single hop (one cluster head) or multi-hop (two cluster heads) depending on the distances, here we used single hop if the distance between the CH and BS is less than 70 m else we used multi-hop.
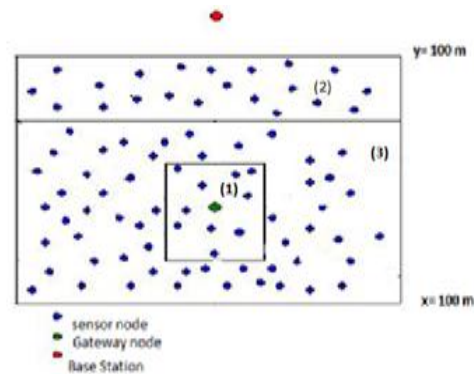

Fig. 1. Network Model

- We deploy the gateway at the center of network.
- The BS is located far away from the sensing field and remain fixed after deployment.
- Nodes are dispersed in a two dimensional and cannot be recharged after deployment.
- We use homogenous sensor nodes with same computational and sensing capabilities.
- Each sensor node is assigned with a distinctive identifier (ID).
- The BS has the information about the location of all sensor nodes.

Same model was used as in [5] which is first order model. This model represents the energy dissipation of sensor nodes for transmitting, receiving and aggregation data. The transmitter dissipates more energy than receiver as it requires more energy for the transmitter electronics and amplifier. On the other hand, in receiver, only electronic circuit dissipates energy, as shown in Fig. 2.
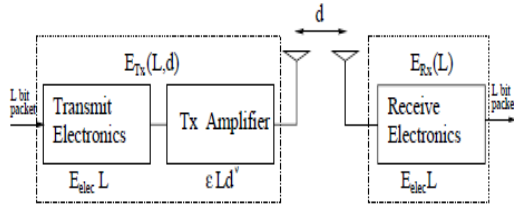
Fig.2. Radio Model

The energy required to transmit a data packets of L bits to distance d and to receive a data packets of L bits, is given as:

$$E_{Tx}(L,d) = \begin{cases} LE_{elec} + L\varepsilon_{fs}d^2, & d < d_0 \\ LE_{elec} + L\varepsilon_{mp}d^4, & d \geq d_0 \end{cases} \quad (1)$$

$$E_{Rx} = LE_{elec} \quad (2)$$

A. THE PROPOSED PROTOCOL:

The main goal of our paper is to improve network life time and throughput, so we divided the network into three logical regions.

B. INITIAL PHASE

During this stage, the BS transmit a message packet. In response, the BS received information from all sensor nodes in the network. The BS makes some calculations for example it calculates the distance of each node and store all information of the sensor nodes into the special data table. This table contains the identity of every node, residual energy of node, location of node and its distance to the BS.

C. SETUP PHASE

In this stage, it is more efficient if we divide the network field into three logical regions based on the location of the node in the network. Nodes in regions (1 and 2) use direct communication and transmit their data directly to BS and Gateway since the distance of these nodes from gateway is very short. This region is referred to as non-clustered region. Similarly, nodes near to the BS from region two send their data directly to the BS. All the nodes away from the BS and Gateway are using one cluster head (single hop) if the distance between the

sensor node and the BS less than specific distance or using two cluster head (multi-hop) if the distance between the sensor node and BS is greater than a specific distance.

D. CH SELECTION

Assume that r symbolizes the number of rounds to be a CH for the node S. Each node chooses itself as a CH once every round. At the beginning of first round all nodes have same energy level and have same opportunity to be CH. After that CH is selected on the basis of probability p like LEACH. In each round. A node can become CH only once in an epoch and the nodes not selected as CH in the current round feel right to the set G. The probability of a node to elect as CH increases in each round. At the start of each round, a node S belongs to set G autonomously choose a random number between 0 to 1. If the generated random number for node s 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:

$$T(s) = \begin{cases} \dfrac{p}{1 - p*(r \bmod \left(\dfrac{1}{p}\right))} & , if \ \ s \in G \\ 0 & , otherwise \end{cases}$$

$$(3)$$

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

E. SCHEDUALING

When all the sensor nodes are divided into clusters, each CH originate TDMA established a special time slots for its member nodes. All the related nodes send their sensed data to cluster head in its own appended time slot. Else nodes turn to idle mode. Nodes turn on their transmitters at time of transmission. therefore, energy dissipation of individual sensor node reduces.

F. STEADY STATE PHASE

During this stage, every node sends its sensed data to CH. The cluster head gathers data from all member nodes, aggregates and forwards to BS. Proposed protocol introduces two tier architectures concept for cluster-head. In a round after cluster-heads had been chosen, then after collecting the data from its members it aggregates the data and then each cluster-head will decide of sending data directly to the base station (single hop) or to other cluster head (multi-hop) such that: distance between this cluster head and any other cluster head less than between the cluster head and base station. If the cluster head does not find any such cluster head that fulfills the above mentioned condition, then it will send the aggregated data directly to the base station. Thus by introducing two tier architectures for cluster heads, proposed protocol has reduced the energy consumed in transmission to prolong the network lifetime and stability period.

4. SIMULATIONS AND ANALYSIS

This paper makes MATLAB as experiment platform. The parameters of simulation experiment see the following table 1. We assess the performance of our proposed protocol and compare it with existing protocol in WSN, known as LEACH.

A. PERFORMANCE PARAMETERS

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

TABLEI: Simulation Parameters

Parameter name	Value
E_0	0.5 J
Packet size	4000 bits
Number of nodes	100
$E_{tx} = E_{rx}$	50 nJ/bit
E_{fs}	10 pJ/bits/m^2
E_{mp}	0.0013 pJ/bits/m^2
E_{DA}	5 nJ
Area of network	100*100 m
Base station Location	(50,150 m)
Gateway Location	(50,50 m)

1). Network lifetime: It is the time interval from the start of the network operation till the last node die.

2). Throughput: To evaluate the performance of the throughput, the numbers of packets received by BS are compared with the number of packets sent by the nodes in each round.

3). 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.

B. LIFETIME

Figure 3 is the networks lifetime in 100x100 m^2 scenes. In this scene, the First Node Death time (FND) of the propose protocol is times more than LEACH, and the Half Nodes Death (HND) time of the proposed protocol is about times more than that of LEACH.

Our proposed protocol obtains the longest network life time. This is because the energy consumption is well distributed among nodes. It is known from the figure 3 that it can save energy consumption by using multi-hop.
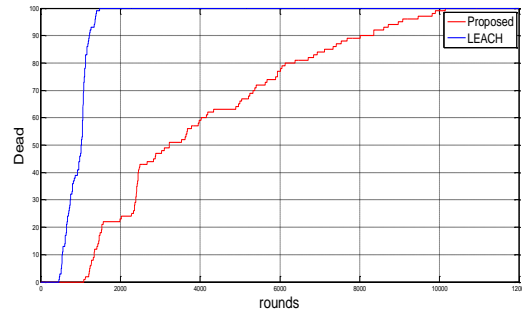

Fig.3. Total number of dead nodes in each round.

C. RECEIVED NUMBER OF PACKETS (THROUGHPUT)

Figure 4 is the numbers of cluster heads selected in each round, we see that the proposed protocol guarantees more packets to the cluster head in each round in comparison with the LEACH. Figure 5 is the sum of data packets which is the cluster-heads sending to the BS. The sum of data packets transmitted by the proposed protocol is more than of LEACH, because the purposed protocol selects multi-hop and then this effectively resolves routing overhead of network and energy consumption. There is uncertainty in the selection of cluster heads in LEACH.
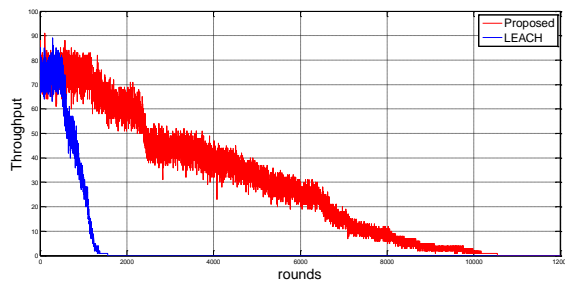
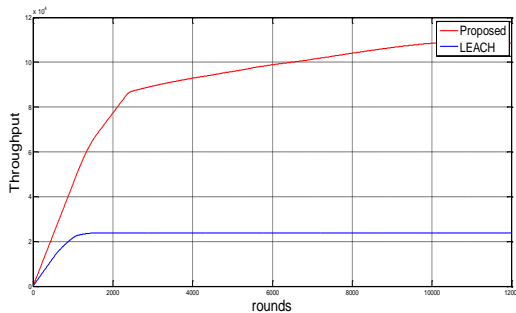**Fig.4. Cluster heads in each round.**

Fig.5. Number of packets received by BS in each round.

Fig. 6 shows average residual of network per round. We assume that a node has 0.5 joule energy. The total energy of 100 node network is 50 joule rounds, The proposed protocol reaches the threshold level of 50 joules in 10150 rounds, while LEACH consumes 50 joules of energy in 1480 respectively. this shows that our proposed protocol is more better in energy consumption than LEACH. Our proposed protocol yields minimum energy consumption than LEACH.
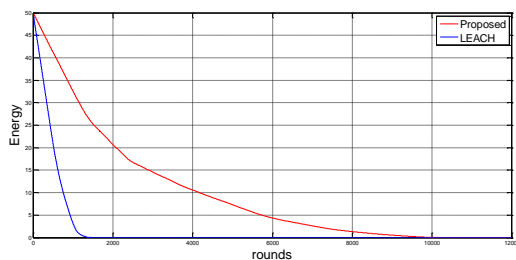

Fig.6. Remaining Energy in each round.

consumption of sensor network. In this research, the Gateway node is located at the center of the sensing filed area. The base station is located away from the sensing field. This scheme encourages better transmission of data which further increase lifetime of the network. The main advantage of using multi-hop is that it reduces distance for transmitting data to the base station. Simulation results show that our proposed protocol performs well compared to LEACH. In our proposed protocol, the stability period of network and network life time have been optimized.

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5. CONCLUSIONS

We proposed an optimized routing scheme for multi-hop WSNs. The main focus was to minimize energy

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