Energy Efficient Cluster-Based Routing Approach for Wireless Sensor Networks

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Abstract: **Wireless sensor network (WSN) is consists of a large number of low-cost sensor nodes through wireless communication. Sensor nodes collect environmental information and transmit it to the base station (BS). The sensor nodes are usually; resource constrained and battery limited. Therefore, Energy conservation of the sensor nodes are the important issues considered in the design of Wireless sensor networks. So; designing of an energy efficient routing protocol can maximize the network lifetime. Multi-hop Low Energy Adaptive Cluster Head (M-LEACH) is energy efficient routing approach which improves the life time of the network. However, this routing technique has shown limitation in increasing life time of the network. This paper presents an improved multi-hop LEACH (IM_LEACH) routing protocol for cluster-based networks. The proposed protocol improves Multi Hop LEACH protocol based on energy efficient cluster head (CH) selection technique. The simulation results explain an Improved Multi-hop LEACH (IM_LEACH) routing protocol for cluster-based networks. The proposed protocol achieves. The simulation results illustrate the energy efficiency of the multi-hop cluster-based routing approach. The proposed method attains significant enhancement in term of network lifetime and provides improved energy performance for wireless sensor networks.**

Keywords: **Wireless sensor network, Multi-Hop Communication, Cluster-based Routing Protocol, Energy Consumption.**

I. INTRODUCTION

Wireless sensor networks (WSNs) consist of a large number of tiny low-cost and limited energy devices that can sense, process, store, and transmit data of surrounding environment with limited capabilities across the network to the sink node. The most significant resource in the sensor node that impacts on the lifetime of WSN is the energy provided by the battery which is difficult or impossible to replace or recharge it especially in the remote or hostile environment [1]. As the sensor nodes are usually; resource constrained and battery limited, energy conservation of the sensor nodes are the important issues considered in the design of Wireless sensor networks. Therefore, nodes must be able to operate in low power modes to improve the lifetime of their network. Hence, energy optimization and efficiency are extremely important factors to be considered in WSN. In order to operate in low power, designing of energy efficient routing protocol is necessary. Multi Hop cluster-based routing protocol is the most efficient routing technique. in multi hop communication protocol nodes forwards their data to the destination through the intermediate node until it reaches to its destination. Therefore, it improves network lifespan by minimizing transmission energy. Cluster-Based routing approaches are the most widely used technique due to its less energy consumption. In this approach, the entire network is divided into clusters, and for each cluster, one representative node, which called cluster head (CH), aggregates all the data within the cluster and sends the data to BS [2]. Cluster-Based WSN uses single-hop or Multi-Hop routing techniques between nodes of each cluster. In single hop communication, the CH gathers data from its member nodes and directly sends collected data to the sink. And CHs also forwards their data directly to BS [3]. But this approach is not efficient for large networks. In large network size the BS is fixed and located far away from the sensors. in results the long distance between sensor nodes and CHs and also the distance between each cluster. So as the distance between nodes increase single-hop routing approach consumes high communication energy. This will reduce the energy efficiency of the entire network. For large network, inter-node as well as inter-cluster distance is important, multi-hop routing approach is the energy efficient way in cluster-based network [10,11]. In this approach sensor node forwards sensed data to CH through intermediate nodes by selecting shortest path. This communication way minimizes transmission energy. In this work we proposed Improved multi-hop LEACH routing approach due to its high energy efficiency. [5] It improves Multi Hop-LEACH based on CH selection technique. Finally, it presents the simulation result of the proposed one and compare with LEACH and Multi-Hop routing protocols.

The remainder of this paper is organized as follows. In section 2, the analysis of existing routing approaches, the radio energy model. Section 3 presents the proposed approach. In section 4, Simulation result and analysis. Finally, section 5 conclusion.

II. ANALYSIS OF EXISTING APPROACHES

A. LEACH: (Low energy adaptive clustering Hierarchy)

This paper in [4] presents a commonly used clustering protocol LEACH. in this protocol cluster heads and their attached sensor nodes are periodically changed in order to enable efficient balance. However, as LEACH applies single Hop cluster-based communication approach it requires all source nodes to forward their data directly to the associated

CHs. This communication approach affects source nodes energy due to the significant cost of long-distance transmissions. Therefore, source nodes that are far away from the cluster head drain hastily their energy than other nodes. As a result, LEACH protocol may not be practical for large scale sensor networks. To resolve this energy constraint, minimizing transmission energy is required. Authors [5] in approach employs multi-hop inter-nodes communication using MTE algorithm where source nodes forward their data to the cluster heads through intermediate nodes inside each cluster. Each source node in the cluster sends its message to the closest node on the way the cluster head in order to minimize the transmission energy. However, the cluster head selection technique used in this protocol is not energy efficient. random CH selection approach is used which doesn't consider the energy level or the remaining energy of sensor nodes after each round. There are two phases in clustering approach. Setup phase and steady state phase. During setup phase After clusters are being created each node decides whether to be cluster head (CH) or not for the current iteration. This decision is based on a predetermined fraction of nodes and the threshold T(n), which is given by the following formula [4]:

$$T(n)=P/1-P*(r \bmod 1/P) \quad \text{if } n \epsilon G$$

$$0 \quad \text{elsewhere}$$

Where:

p: is the percentage of choosing cluster heads.

r: is the current round.

g: is the set of sensor nodes that have not been cluster heads in last 1/p rounds

Using this threshold, each node will be a CH at some rounds within 1/p rounds. After 1/p rounds, all nodes are once again eligible to become CHs. The nodes elect themselves to be CH in each round by choosing a random number between 0 and 1. The node becomes a cluster head for the current round if the chosen number is less than the threshold shown in equation above.

B. Multi-Hop cluster-based routing approach

This is clustering approach based on a combination of LEACH and MTE protocols [5]. It uses LEACH [5] as clustering algorithm in which LEACH is a commonly used clustering protocol. this approach is based on Multi hop communication approach that helps source nodes to forward their data to destination node through intermediate node in order to minimize communication distance between source and destination nodes. Multi Hop cluster-based routing approach applies inter-node communication in which sensor nodes sends their data to the cluster head attached to it through intermediate node. This protocol improves energy efficiency of the network by minimizing communication energy. although Multi-Hop LEACH protocol preserves energy in sensor nodes, and increases energy efficiency of the network. It still has some limitations. CH selection approach used in this protocol is not efficient. As for LEACH routing protocol, CH selection approach in Multi-Hop clustered protocol is also randomly without consideration of energy level of the nodes. In this CH selection approach any node in a cluster can be selected as a CH whether its energy level is low or not. [5]

III. RADIO ENERGY MODEL

In this paper, we use energy consumption model which is called the first order radio energy model. Two models have been used for energy consumption examination. The transmission energy in free space model is proportional to distance d2 for multi path propagation model this energy is proportional to distance d4 due to different paths that take the transmitted signal to reach the receiver. model to estimate the energy consumption of different nodes and the whole network lifetime. This model introduces the energy expended to send and receive L-bit message over a distance d. Both models are relying on the distance between the receiver and transmitter. The radio energy model is shown in Fig. 1. [8].

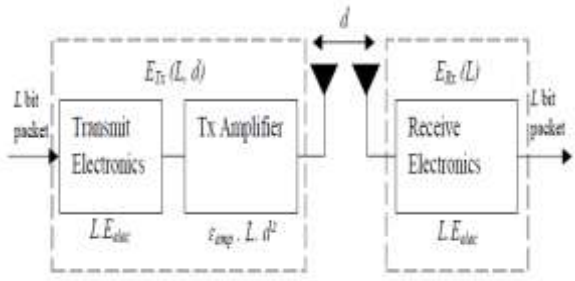

Fig. 1. The first order radio energy model

Hence, to transmit a L- packet at a distance d, the radio uses up is given as: the energy consumed to send data of L bit packet over a distance d from a transmitter node to a receiver node is calculated according to equation (1).

$$ETX(L,d)=ETX\text{-}elec(L)+ETX\text{-}amp(L,d) \quad (1)$$

The energy expended for free space propagation ETx-fs is described by:

$$E_{Tx\text{-}fs}(L,d)= E_{elec} .L+\varepsilon_{fs}.L.d^2 \quad (2)$$

The energy expended for multi-path propagation Etx-mp is given by:

$$E_{elec}.L+ \varepsilon_{mp}. L. d^4 \quad (3)$$

where:

Eelec: is the energy dissipated by electronic circuit to send and receive L bits.

Etx: the energy consumption for packet transmission.

Erx: required energy utilization for packet receiving.

The energy expended to receive L-bit message is defined as:

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

$$E_{Rx}(L)=E_{elec.}\,L \quad (5)$$

equating formula (2) and (3), gives the threshold distance d0 (Equation 5) that defines the propagation transition from direct path to multipath model:

$$do=\sqrt{Efs/Emp} \quad (6)$$

If the distance between the source node and the destination is larger than the threshold distance d0, the multi-path model is employed. Otherwise, the free space model is use.

IV. The Proposed Algorithm

The drawback of Multi-Hop LEACH protocol is inaccurate selection of cluster head. The proposed method aims to minimize the amount of the energy consumption of sensor nodes. The cluster head selection method is modified based on how to alter threshold T(n) to select the appropriate cluster head. The CHs are the representatives of sensor nodes of a cluster selected from all nodes in a cluster. The protocol has two phases. Setup and steady state phase. In setup phase; After the sensor nodes are deployed to the required geographical area, sensor nodes decide whether to be a cluster head or not. Selection of a node as a cluster head is the important process in routing technique. So, the proposed protocol Improved Multi-Hop LEACH protocol takes in to account the residual energy of the sensor nodes rather than random to select cluster head. The modified cluster head selection is as follows:

$$T(n)_{new}=T(n)*E_{resid}/E_{initial.} \quad n\epsilon G \quad (7)$$

$$0 \quad \text{elsewhere}$$

$$(E_{resid.}) =E_{initial\ Energy} - E_{cons} \quad (8)$$

Where:

E_{resid}: is the residual energy of sensor node in the current round.

$E_{initial}$: is the initial energy sensor node.

E_{cons} is total energy that the node consumed.

This method ensures that nodes which have a higher remaining energy will have higher chance to be selected as a cluster head in the current round.

$$E_{CH-BS}= E_{DA} +m.\ (L.E_{elec}+ \varepsilon_{fs}.L.d^2) + (m-1)E_{elec}\ .L=E_{DA} +L((2m-1)E_{elec}+\varepsilon_{fs}.m.d^2) \quad (9)$$

For multi-path propagation:

$$E_{CH-BS}= E_{DA}+m.(L.E_{elec}+\varepsilon_{mp}.L.d^4) +(\ m-1)\ E_{elec}=E_{DA}+L(2m-1)E_{elec}+\varepsilon_{mp}.m.d^4) \quad (10)$$

V. Simulation Result and Analysis

The proposed method is simulated using matlab2017a and its impact on the energy of the network is analyzed. The measured simulation result of the proposed approach is compared with the measured results of LEACH, Multi-Hop. The simulation parameters used in this network are shown in table 1. The wireless sensor network is represented by 100 sensor nodes that are deployed in 200mx200 m. initial energy of all nodes is 0.5 J. A packet size of L = 4000 bits is used, 1000 sensor nodes are randomly deployed in a network dimension of 200m x 200m. The base station is located at (x=100 m, y=100 m) and 0.1 is the probability of a node to be a CH is 0.1.

Table 1. Simulation parameters

Parameters	Values
No. of nodes	100
Network size	200mx200m
Size of packet	4000bits
No. of rounds	2500
initial energy of nodes	0.5J
E_{TX} and E_{RX}	50nj/bit
E_{fs}	
E_{mp}	10pj /bit/m^2
P	
E_{DA}	0.0013pJ/bit/m^2
Base station position	
	0.1J
	5nJ/bit/message
	100mx100m

The comparison is performed between the measured results of the proposed protocol with LEACH and Multi-Hop LEACH protocol based on performance metrics. Such as alive nodes, data transmitted and residual energy. Fig2. Shows the comparison of the network with the respect to alive nodes for the three routing techniques. The performance of the proposed approach is better than LEACH and Multi-Hop LEACH in terms of alive nodes per round. This is because of the accurate selection of cluster head which is based residual energy of the nodes. But LEAH and Multi-Hop LEACH protocols did not consider energy of nodes to be cluster head.

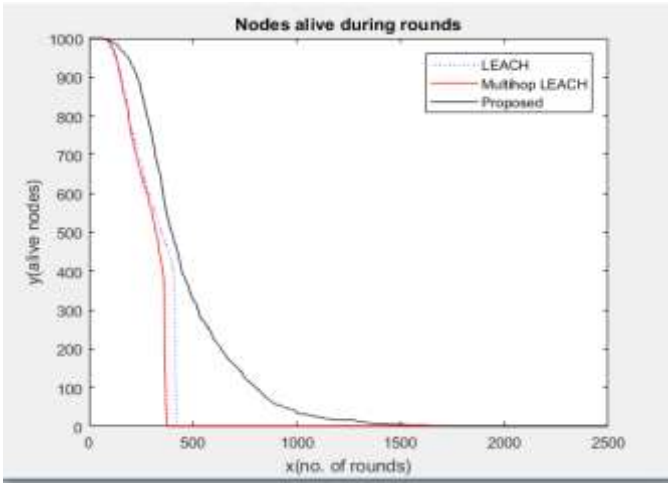

Fig.2 The life time of the network for the three protocols

Fig.3 explains the comparison of all protocols based on the number of packets that are transmitted to Base station. If the

base station receives high amount data packet, it means the routing technique is performing right. The comparison illustrates that the proposed technique performs better than LEACH and Multi-Hop LEACH by sending more data to base station. This is also due to the accurate cluster head selection which based residual energy of sensor node.

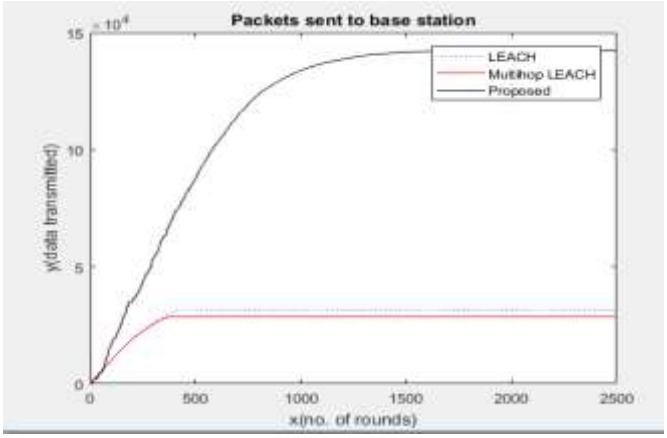

Fig.3 packets sent to base station

Residual energy of wireless sensor network is critical parameter to increase the network lifetime of the network. The lower the consumption energy s the long network lifetime span of the network. Fg.4 shows that the residual energy of the wireless sensor network for all routing protocols in each round. This figure explains that the residual energy of the network in the proposed protocol is better than LEACH and Multi-Hop LEACH.

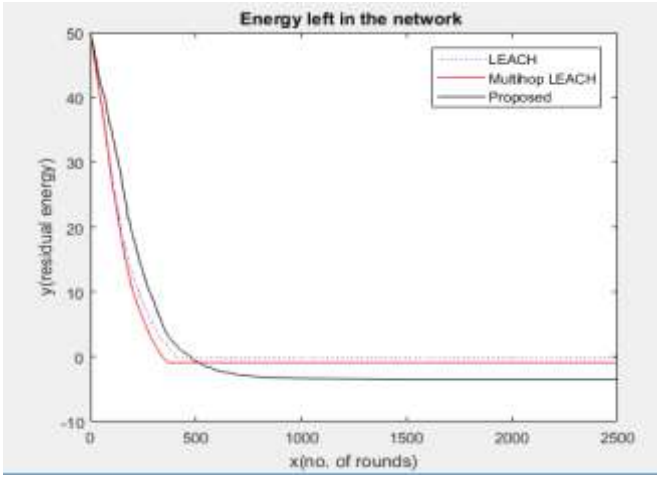

Fig.4. The residual energy of the network

VI. Conclusion

Energy consumption is the main design challenges in Wireless Sensor Networks. To overcome these issues Various approaches have been proposed. Designing of energy efficient routing protocol is one of them. For this reason, we first address the limitation of energy with respect to increasing network lifetime using accurate cluster head selection technique. In this paper We proposed new energy efficient Multi-Hop cluster-based routing protocol to improve the network life time of wireless sensor network by modifying the cluster head selection technique. This approach improves Multi-Hop LEACH protocol by modifying cluster head selection method. Finally, the performance of the proposed approach is compared with LEACH and Multi-Hop LEACH with respect to performance metrics. Such as alive nodes per round, packets transmitted to base station per round and remaining energy of the network per each round. The performance of the protocols is evaluate using MATLAB simulation tool. As concluded from the simulation result, the proposed protocol is the most energy efficient routing protocol of the wireless sensor network.

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