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Minimizing Transmission Energy of Wireless Sensor Network

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Abstract*: Recent advances in electronics and wireless telecommunications provide the opportunity to design and manufacture wireless sensors with low power consumption, small size, appropriate price and various applications. These small sensors which are capable of sensing environmental data, processing and transmitting information have led to a novel idea for developing networks called wireless sensor networks (WSNs). WSNs are contains a various number of tiny small-cost, resource limited and limited energy devices that can sense, compute, store, and transmit data of surrounding environment with limited capabilities across the network to the base station. But these resource and battery limitations have direct effect on the life span of wireless sensor networks. So, authors aim to minimize the transmission energy of the network through minimizing the communication distance between each sensor nodes of the network. They proposed to improve Multi-Hop LEACH routing protocol. The network in the proposed work incorporates homogeneous types of sensors nodes randomly deployed in different portion of an environment to gather data about the environment that they are deployed. The sensors are organized in cluster-based structure to sense the different physical parameters of the environment and route the readings to a BS for visualization and data management purpose. The proposed work improved the existing routing protocol which is Multi-Hop LEACH cluster-based routing protocol by integrating the communication way of existing appropriate routing protocols. Such as: Minimum Transmission Energy and Multi-Hop LEACH cluster-based routing protocol for WSN. Authors have implemented the proposed routing protocol for WSN and the performance is evaluated using MATLAB simulation tool. Finally, Researchers present numerical results that validate the feasibility of the proposed technique. The proposed protocol achieves significant improvement in terms of network lifetime and provides improved performance energy efficiency for WSN.

Keywords:* Wireless sensor network, routing protocols, Communication Protocols, Transmission energy, Energy Consumption

I. INTRODUCTION

Now days Wireless sensor networks have been a very important tool in many fields, including industrial control, environmental monitoring, agriculture, disaster prevention, military defense, meteorology, etc. Wireless sensor networks (WSN) are contain of a several number of small-cost sensor nodes through wireless communication. Sensor nodes collect the information sensed from the environment and it forwards to Base Station (BS). The nodes are usually; resource and battery limited. Therefore, Energy conservation of nodes are the important issues considered in designing of WSN. The most important resource in the WSN that directly effects the wireless sensor network lifespan is the energy of sensor node that the battery provides. This battery is un rechargeable once deployed especially in the remote or hostile environment. As the nodes are usually; resource and battery limited, energy conservation of the nodes are the important issues needed to be considered in the design of WSNs. Therefore, nodes have required to operate in low power modes to improve the lifetime of their network [1]. In order to operate in low power, they have to forward their data through the shortest path. Because transmission energy consumption is the most critical issue in WSN. Various researchers have conducted several routing and communication protocols related to energy consumption and the life time of the WSNs. But these are not sustainable solution to improve the network lifetime. Cluster-Based routing approaches are the most widely used technique due to its less energy consumption. This approach divides the whole network into clusters, each cluster has one representative node called CH. The CH collects all the sensed information form the cluster members then forwards it the to the BS [2]. Cluster-Based WSN uses either single-hop routing technique or Multi-Hop routing techniques between source nodes destination nodes.

In single hop routing communication, nodes send their sensed information directly to CH. But this approach is not efficient for large networks. In large network BS is fixed and it is placed far away from sensor nodes. 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 transmission energy.

This will reduce the energy efficiency of the entire network. For large network, inter-node as well as inter-cluster communication is big issue to be considered. Multi-Hop routing approach is the energy efficient approach in cluster-based network. In this approach sensor node forwards sensed data to CH through intermediate nodes by selecting shortest path. This communication way minimizes transmission energy [3].

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II. RELATED WORKS

Literature shows that there have been a number of works that have been done on routing protocol of wireless sensor networks to improve the network life time and have drawn some conclusions. Here authors have summarized those that are relevant and related to our study.

Low Energy Adaptive Cluster Head (LEACH) routing technique is the first cluster-based routing protocol in WSNs [4]. It is self-organizing and also adaptive clustering protocol. It randomly distributes the load of energy evenly between all sensor nodes of the network. This routing protocol assumes that, all sensor nodes and the BS are placed at fixed position and they are energy constrained and also homogeneous network type. In this cluster-based protocol, each node organize itself into local clusters, where one representative node in the cluster acts as a cluster head (CH) and then randomly rotates the position of the CH in order not to drain the battery of each sensor node in the network. In this protocol the communication is based one-hop communication way, that means the communication between the sensor nodes and selected CH node and also the communication between CHs and the BS is based on single-hop. Finally, it creates cluster topology where nodes can send their data directly to the CH nodes and thereafter CH nodes to the BS. Because of this single-hop communication nature, this kind of cluster formation is not appropriate for large size networks, where due to it too long distance, CH may not reach the BS.

Authors in [5] describes minimum transmission energy (MTE) routing algorithm for WSNs. In this routing algorithm every sensor selects a path based on minimum transmission energy consumption. After selection of path with minimum transmission energy, source nodes transmit their packet data to the Base station via net-hop neighbor sensor nodes in the direction to the base station. This routing algorithm improves energy efficiency of wireless sensor network by minimizing transmission energy of sensor nodes by transmitting their data to BS through minimum distance. But as sensor nodes forwards their da to BS through multi-hop directly to BS, there is no central control or header node that controls sensor nodes in MTE routing algorithm, it is difficult to set up fixed regular communication in the network. so, before transmitting its data, each node has to listen to the channel. If the channel is busy, the nodes back off; but if the channel is not busy, then nodes transmit their data to the next node. The drawback of his routing algorithm is that, when nodes run out of energy, the entire routes are recomputed to make sure connectivity of a node with the BS. So, this continuous routing computation in results early drainage of the energy of the network.

Multi-Hop LEACH (Multi-Hop Low Energy Adaptive Clustering Hierarchy) routing protocol is cluster based multi-hop routing protocol for WSNs [6]. This routing protocol is based on Multi-Hop communication approach that helps source nodes to forward their data to destination CH node through multiple intermediate nodes. This is in order to minimize transmission energy by minimizing communication distance between source sensor nodes and CH nodes. In Multi-Hop LEACH cluster-based routing protocol inter node communication in a cluster is based on Multi-hop. communication approach in which sensor nodes sends their data to their attached CH through intermediate nodes. This routing protocol increases energy efficiency the network by minimizing communication energy. Though Multi-Hop LEACH protocol conserves energy of sensor nodes in the network, and improves energy efficiency of the network. But it requires each CH node to forward its data directly to the associated BSs. This direct communication between CH nodes and BS drain CH energy due to the long-distance transmission energy consumption. And also, in addition to this constraint, CH nodes consume more energy than ordinary member nodes. Therefore, CH that are far away from the cluster head waste high amount of their energy than other CH nodes.

III. THE PROPOSED SYSTEM ARCHITECTURE

The proposed architecture is based on cluster based multi hop network strategy. Ordinary sensor nodes transmit their data to CH through intermediate nodes. And also, CHs forward their data to the BS through intermediate or another CHs. It contains of transmitting data through intermediate nodes that act as routers. The intermediate nodes in the clusters forward other sensor node's data that are destined for CHs. And also, CHs forward their data to BS through another CHs. Ordinary Sensor nodes and CHs calculate the distance to CHs and to BS respectively by applying MTE.

The figure above Fig 1. shows the proposed technique architecture and the effect of distance between source nodes and destination nodes on energy consumption of the entire network. Which means, if the distance from ordinary sensor nodes to the attached CH and from CHs to BS is the minimum distance, the sensor nodes forward its data directly via one-hop to their attached CH nodes and all CHs in the clusters forward their collected data directly to the BS by single hop. On the other hand, if the distance between ordinary sensor nodes and their CHs and also from CHs to BS is not the minimum distance, the ordinary sensor nodes forward their packet data through intermediate nodes in the clusters within the minimum distance to CH and CHs transmit their data to BS via intermediate CH nodes within minimum distance. The source nodes and CHs node transmit their data through multiple minimum hops to the CH and BS respectively.

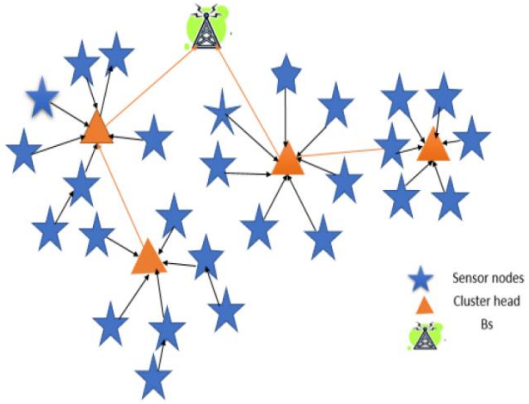

Figure 1 the proposed system architecture

IV. RADIO ENERGY MODEL

In order to estimate the energy consumption of the network, it is required to know energy consumption for each sensor. The author in [7] discussed the energy consumption model which is called the first order radio energy model.

Two models have been used for the examination of energy consumption of the network The transmission energy of nodes for free space propagation model is directly proportional to the distance d^2 and the transmission energy of nodes for multi path propagation model is directly proportional to the distance d^4 because of different paths that take the sent data to reach the destination. The radio energy model presents the energy consumption to send and to receive L-bit packet over a distance d. Both free space and multi-path models are depending on the distance between the receiver and transmitter. Free space and multi path propagation models are radio wave propagation model that the radio hardware energy dissipation [8]. This model assumes that the transmitter consumes energy to run the power of amplification and radio electronics. And the receiver consumes energy to run the radio electronics as shown in the figure Fig 2. below.

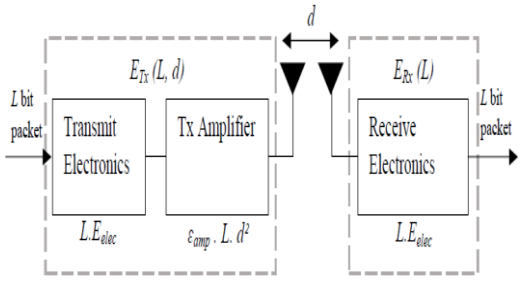

Figure 2. The First Order Radio Energy Model

Hence, the consumed energy to send data of L bit packet over a distance d from a transmitter to a receiver node is calculated based on the following equation.

$$\mathbf{E_{TX}(L,d) = E_{TX-elec}(L) + E_{TX-amp}(L,d)} \dots\dots\dots\dots (1)$$

The energy expended for free space propagation $\boldsymbol{E_{TX-fs}}$ is described by:

$$\mathbf{E_{TX-fs}(L,d) = E_{elec}.L + \varepsilon_{fs}.Ld^2} \dots\dots\dots\dots (2)$$

$$\boldsymbol{E_{TX-fs}(L,d) = E_{elec}.L + \varepsilon_{fs}.L.d^2} \dots\dots\dots\dots (3)$$

The energy expended for multi-path propagation $\boldsymbol{E_{TX-mp}}$ is given by:

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

Where:

E_{elec}: is the dissipated energy by electronic circuit to send and receive L bits.

E_{TX}: the energy consumption for packet transmission.

$\boldsymbol{E_{RX}}$: required energy utilization for packet receiving.

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

$$\boldsymbol{E_{RX}}(L)=\boldsymbol{E_{elec}.L} \dots\dots\dots\dots (5)$$

Equating the above equations, eq (3) and (4), gives the threshold distance d_0 (Equation 6) that defines the propagation transition from direct path to multipath model:

$$\mathbf{d_0 = \frac{\sqrt{E_{fs}}}{E_{mp}}} \dots\dots\dots\dots (6)$$

If the distance from the source sensor node and the destination node is greater than the threshold distance d0, the multi-path model is applied. Otherwise, the free space model is employed.

V. ANALYSIS OF THE PROPOSED TECHNIQUES

In this research work the proposed method aims to increase the energy efficiency of wireless sensor network by minimizing communication energy consumption as much as possible by minimizing individual node transmission energy consumption. This implies that if the communication energy of individual sensor node is minimized, the overall energy consumption of the network also minimized. In this work two optimal existing routing protocols which are Multi-Hop LEACH and Minimum Transmission Energy (MTE) routing protocol. integrated in order to improve the energy efficiency of the network. It uses LEACH as clustering algorithm which is a commonly used clustering protocol. The energy expended in communication in each cluster using MTE mode is expressed as:

$$\mathbf{E_{MTE} = E_{RX-MTE} + E_{TX-MTE} = m.E_{TX} + (m-1)(E_{RX})} \dots\dots (7)$$

Where:

$E_{MTE:}$ Energy consumption in minimum transmission energy algorithm.

m: Number of transmissions in each cluster.

$\mathbf{E_{RX-MTE}}$: Receiving energy consumption of a node based on minimum transmission energy algorithm.

$\mathbf{E_{TX-MTE}}$: Transmission energy consumption of a node based on Minimum transmission energy.

In the proposed protocol, transmission from member sensor nodes to the CH nodes, and from selected CH nodes the BS is occurred based on MTE algorithm. The total energy consumption in the proposed protocol at round r is expressed as follows.

$$E_{M-LEACH-MTE} = \sum_{i=0}^{r} E_{MTE} + E_{CH-BS} \dots\dots\dots\dots (8)$$

Energy consumption for inter-node communication in a cluster for frees pace propagation and multi path propagation based on MTE is calculated as follows.

$$E_{node-CH} = E_{MTE} \dots\dots\dots\dots (9)$$

I n this approach, sensor nodes transmit their data to CH nodes through intermediate nodes by applying minimum transmission energy algorithm.

For free space propagation:

$$E_{node-CH} = m.\left(L.E_{elec} + \varepsilon_{fs}L.d^2\right) + (m-1)E_{elec}.L = L(2m-1)E_{elec} + \varepsilon_{fs}.m.d^2 \dots\dots\dots (10)$$

For multi-path propagation:

$$E_{node-CH} = m.\left(L.E_{elec} + \varepsilon_{mp}.L.d^4\right) + (m-1)E_{elec} = L(2m-1)E_{elec} + \varepsilon_{mp}.m.d^4 \ldots\ldots\ldots(11)$$

But as communication between cluster heads and BS is in multi-hop routing protocol it is based MTE approach to calculate energy expended in cluster head to base station communication. And also, amplification energy of free space and multi-path propagation.

Inter CH and BS communication through shortest path is:

$$E_{CH-BS} = E_{DA} + E_{MTE} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(12)$$

For free space propagation:

$$E_{CH-BS} = E_{DA} + m.\left(L.E_{elec} + \varepsilon_{fs}.L.d^2\right) + (m-1)E_{elec}.L = E_{DA} + L\left((2m-1)E_{elec} + \varepsilon_{fs}.m.d^2\right) \ldots\ldots\ldots\ldots(13$$

E_{CH-BS} is the energy consumption for transmission between CH and BS. It includes data aggregation energy E_{DA} which is the energy that CH nodes required to collect data from member nodes and to transmit the collected data to BS through intermediate CH nodes based on minimum transmission energy algorithm.

For multi-path propagation:

$$\boldsymbol{E_{CH-BS} = E_{DA} + m.\left(L.E_{elec} + \varepsilon_{mp}.L.d^4\right) + (m-1)E_{elec} = E_{DA} + L(2m-1)E_{elec} + \varepsilon_{mp}.m.d^4 \ldots\ldots\ldots\ldots(14)}$$

VI. SIMULATION AND RESULT DISCUSION

This section describes the simulation and result discussion of the proposed technique using MATLAB simulation tool. Authors also discuss the evaluation metrics based on energy efficiency of wireless sensor network. Authors validated the proposed technique for different scenarios and calculated specific performance metrics. Our focus was the energy consumption of wireless sensor networks, and comparison between the proposed technique and existing technique which is M-LEACH routing protocol is made.

A. Simulation Parameters

Researchers created the cluster-based network topology with 1000 nodes. In this case, authors used two different network sizes. Because, the size of the network has a great impact on the energy consumption of the network. So, in order to analyze the lifetime of the network for the existing routing protocol and the proposed one authors in this work tries one network size which is (500mX1000m. In this network topology, 1000 nodes are randomly deployed on 500mX1000m area and the BS is located at the center which means at 2500mX1000m. And finally, the performance of the proposed and the existing protocols are evaluated based on performance measurement metrics, such as: Alive node, packets transmitted to BS and dead nodes. Each cluster with one leader node or cluster head node. As all nodes are homogeneous, initial energy of all nodes is 0.5 J. A packet size of L = 4000 bits is used and 0.1 is the probability of a node to be a CH. E_{TX} and E_{RX} are 50nj/bit is the energy of electronics to receive or to transmit data, initial energy of all node before starting computation is 0.5J. Amplification energy for free space ($\boldsymbol{\varepsilon_{fs}}$) and multi-path ($\boldsymbol{\varepsilon_{mp}}$) propagation are 10pj/bit/m^2 and 0.0013pJ/bit/m^4 respectively. E_{DA} is 5nJ/bit/message which is data aggregation energy that CH nodes consume to collect data from sensor nodes and another CH node. P=0.1J is the initial probability that a node to be CH. The simulation parameters used in this network shown below in table 1.

Table 1. Simulation parameters

Parameters	Values
No. of nodes	1000
Size of network	500mX1000m
BS position	250mX500m
Size of packet	4000bits
No. of rounds	2500
initial energy of	0.5J
nodes	50nj/bit
E_{TX} and E_{RX}	10pj/bit/m^2
E_{fs}	0.0013pj/bit/m^2
E_{mp}	0.1J
P	5J/bit/message
E_{DA}	

B. Performance Evaluation and Comparison

This section discusses the simulation results and the performance evaluation of the energy efficiency of the network based on performance evaluation metrics. And finally, performance comparison is made. The comparison is performed between the measured results of the proposed approach with Multi-Hop Cluster based routing protocol based on performance metrics. Such as alive nodes, data transmitted and died nodes of the network in each round.

The Fig 3. describes that how the size of the network affects the number of alive nodes per round in the network. Because as the size of the network increases, the distance between nodes also increase. So, the energy consumption of the entire network also increases. The network size for the following simulation result is that 500mx1000m and 1000 nodes are randomly dispersed on this network area. So, as the result shows that, at round 20 number of alive nodes in the existing and the proposed protocols is 190, at round 30, alive nodes in both the existing and proposed protocols is 110. At round 50, number of alive nodes in Multi-Hop LEACH and I Multi-Hop LEACH are 70. But, only 2 nodes are alive at 180 rounds for the existing protocol and at 250 for the proposed protocol. These results imply that, in terms alive nodes during round, from round 1 to 50 the performance of both Multi-Hop LEACH and I Multi-Hop LEACH protocols is the same. But, after round 50, I Multi-Hop LEACH performs better than Multi-Hop LEACH routing protocol.

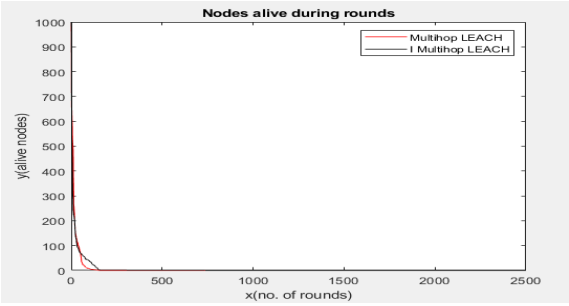

Fig 3. Alive Nodes in the network during round

Fig 4. explain the comparison of the two routing protocols based on the size of packets to be transmitted to Base station for the network size 250mx1000m. as shown in the figure the increasing in network size greatly affects the packets transmitted to BS due to the increase in energy consumption. The maximum packets sent to BS for the existing protocol which is Multi-hop LEACH and the proposed protocol which is I Multi-hop LEACH protocols are 1.635x103 and 1.01x104 out of 1.2x104 sent paces. therefore, the proposed work performs better than the existing protocol with respect to packets transmitted to BS.

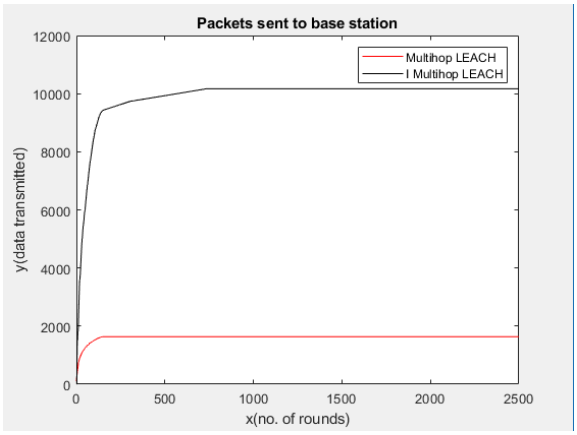

Fig 4. packets sent to base station

Figure 5. Shows that the number of nodes died in wireless sensor network of the for all routing protocols in each round for the network size 500mx1000m. As the figure describes that, in the existing protocol all nodes are died at the round 151. But, in the proposed protocol, all nodes are died at round 737. Therefore, the proposed routing protocol is more energy efficient than the existing one with respect to dead nodes.

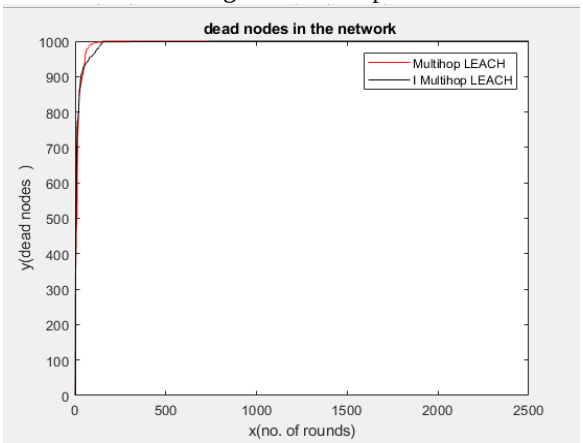

Figure 5. All Dead nodes in network during round

VII. CONCLUSION AND FUTURE WORK

As it has been discussed throughout the document, WSN have been attracting the attention of the research community due to its wide range of application areas. However, there are still several open issues related to the use of WSN technology. The energy constraint is one of the key concerns in the design of WSNs. To overcome these issues several approaches have been proposed. Minimizing transmission energy is one of them. The research undertaken in this research is aimed to improve the lifetime of wireless sensor network through minimizing transmission energy of each sensor node. Authors in this paper proposed to improve Multi-Hop LEACH routing protocol by modifying the transmission way of the network. Finally, performance of the proposed technique is compared with Multi-Hop LEACH routing protocol. Then, authors have evaluated, analyzed and proved that the proposed Routing Protocol for wireless sensor network, to have better performance based on performance metrics. Performance of the protocols is evaluated using MATLAB simulation tool. As an output from this research Improved the proposed protocol satisfies most of the requirements for increasing the energy efficiency of wireless sensor network.

Though authors tried our best in order to realize the proposed routing protocol for wireless sensor network to improve the energy efficiency of wireless sensor network with the objective of addressing the shortcomings of existing works, authors do not believe that the proposed work is generic enough to incorporate potential issue in routing protocols in wireless sensor networks. The line of enhancement is based on testing the proposed work on the physical wireless sensor nodes to evaluate its practical significance. Hence by taking this simulation as a platform, a more realistic implementation of the proposed protocol is another way enhancement so as to maximize its usability in real wireless sensor network in the future.

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