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A newer method and its comparison with other available methods in wireless sensor network

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Abstract:

The real challenge for wireless sensor network is to design optimal routing protocol which enhance the network lifetime by reducing energy consumption. Energy saving is the main component in designing of network architecture.

Many routing protocol have been developed in the past years and research is still going on for the best possible solution .One of the best routing protocols between them is clustering based protocol. It is the most efficient method of reducing energy consumption by load balancing over the nodes. In this thesis, a new routing protocol is proposed to improve network lifetime by reducing energy dissipation. AODV protocol is modified to improve leach protocols transmitting capability, enhancing throughput and reducing packet loss and delay. It had used TDMA MAC protocol for the transmission of data among the nodes and base station. This reduces collision in the channel and provide real time guarantees by eliminating packet losses and delay. Then multi hop routing protocol is used instead of direct transmission as it gives better results in transmission of data. It helps in reducing energy consumption in far away nodes during transmission. .

Keywords: *Cluster head ,Leach, Multi hop routing, Network Simulator, TDMA*

Introduction

This MS mainly focuses on energy preservation and optimization with its proper adjustment in the wireless sensor networks. As we know sensor nodes are battery operated with limited life span, low processing capability and limited bandwidth which requires more energy to sense and transmit a data from a far away region to base station. So it is necessary to provide an energy efficient routing protocol to enhance network lifetime. The main aim of routing protocol is to properly maintain the energy dissipation of sensor nodes and to ensure reliable path for the transmission of data from nodes to base station. This is achieved with the help of multi hop routing and MAC protocol.

The flow of power in the wireless sensor network should be balanced in order to make a

symmetrical power distribution in the overall transfer phase. This research primarily concentrates on minimizing the energy dissipation in all sensor nodes equally. This is served by balancing the transfer and introducing new clustering algorithm. LEACH is the hierarchical routing protocol which is modified to improve its potential. Multi hop routing is used to obtain an optimal path between nodes and base station as well as reducing its energy consumption and increasing network lifespan.

Thus, this research proposed a new technique and methodology for wireless sensor to reduce communication overhead for data transmission with the help of clustering method

SENSOR NETWORK ARCHITECTURE

Network architecture plays an important role in energy consumption in the transmission of data , overhead traffic ,congestion and delay of information in network. Routing protocol depends directly on network architecture. Single hop routing is deployed in layered architecture as sensor nodes are organized in a layer form where as multi hop routing is used in Clustered architecture in which data is transmitted in a relay pattern.

CLUSTERING

Wireless sensor network (WSN) applications should possess the power to work in harsh and hostile environments where human intrusion , monitoring of devices is not managed regularly. not feasible to change energy resources and their maintenance cannot be scheduled . According to these situations, in various WSN application sensor nodes have to be deployed randomly over a harsh and hostile environment through uncontrolled means (i.e., programmed to fly or dropped by helicopter) and to develop a network. Thousands of sensor nodes are deployed on a large scale development of network .These nodes have limited duration of battery power and low management possibilities in a harsh environment. So energy efficiency is an important aspect to be considered while designing a network architecture. To provide reliable and scalable network topology we need to provide specialized data gathering nodes along with an energy efficient routing protocol. To improve routing protocol one of the technique used nowadays is clustering that is grouping of various sensor nodes into disjoint groups and randomly select a head among them.

To maximize power consumption and to improve the network lifetime of wireless sensor network, clustering technique is widely being adopted by the researching society. In this technique is widely used in the hierarchical routing protocol in which nodes are organized in a group known as clusters. Every cluster has its own leader, which is selected according to a threshold value. Cluster head is one with the highest energy residues presented in the entire cluster. Every node is given an equal opportunity to become a leader. Cluster head is given a special responsibilities of data aggregation, data fusion and transmission to the base station. The cluster formation process ultimately leads to a two-level hierarchy where the CH nodes form the upper level and the cluster-member nodes forms the lower level .

All the nodes present in network transmits their data to a higher level to CH which is retransmitted to the next level of the base station directly or through an intermediate path via other CH nodes. The transmission of data takes place through low level to high level in the cluster. As CH nodes transmit data more frequently and to a longer path it requires more energy for communication. So periodically CH node is selected on the basis of energy level , one with the highest energy level becomes CH(thus rotating their responsibility over all the sensor nodes). Now to maintain energy level over a longer distance multi hop routing is used instead of direct transmission, thus workload is balanced among other cluster head which reduce energy consumption to greater extent.

The base station is the processing point for the data received from different sensor nodes, and where the data is actually accessed by the end user. Generally it is considered fixed and place at a far away distance from the sensor nodes. The CH nodes act as a gatewy between the sensor node and BS. The function for each CH is to perform general function for each node in cluster, like aggregating data before transmitting.it to BS.However we can say BS is sink for CH and CH acts as a sink for all nodes.

CLUSTER HEAD SELECTION-

As the first round of cluster head selection begins ,every node publishes its probability of becoming the cluster head on the basis of their residual and current energy level. Node with the highest probability is chosen as cluster head. Then cluster Head publishes a message (ADV) using CSMA MAC protocol. This advertising message has two fields, one is the Node's ID to recognize every node with whome transmission of data will take place and second field has a control information stored in the header. The member of cluster chooses a cluster head among themselves on the basis of their energy level. This process is repeated for every round and cluster heads are changed randomly over time balance the energy consumption of nodes. Selection of cluster head is done on the basis of a threshold value. Every node chooses a random number between 0 and 1.This node becomes a cluster head if randomly chosen number is less than a threshold value . Threshold value is calculated by a formula.

$$T(N) = \frac{P}{1 - P\left(r \bmod \frac{1}{P}\right)} \qquad \forall n \in G$$

Where T(n) is threshold

P is probability of selection of node as cluster head

r is the present round

G is the node that is not selected as cluster head in 1/p round

In this way every node has an equal opportunity to serve as a cluster head.

CLUSTER FORMATION

After the selection of cluster head a short message is broadcasted to all the remaining non cluster head nodes . This is a join-request message (Join-

REQ) sent through the head which is responsed back by the interested sensor nodes according to their signal strength. This process is used to form disjoint cluster with a randomly chosen cluster head . Every joint –REQ message has three fields. First field has a Sensor Node's ID which is used to identify every node uniquely in the network. Second field has a Cluster head ID is a number used to identify every cluster head uniquely for every cluster in the network. Third field has a header that is used to store control information such as source and destination address. Sensor nodes communicate to their cluster head using TDMA protocol, this is used for the transmission of data to the cluster head by providing channel for a particular time period. Cluster head aggregates the data from all nodes, compress it and forwards it to the base station in a scheduled time slot through an optimal path. All the nodes have radio transmitters that are turned on or off according to scheduled slots.

MAC

When multiple messages are sent through a shared medium at the same time , there is a need of a protocol to manage them properly to avoid collision. This is done with help of MAC protocol as they are responsible of moving data over a shared medium.

The Media Access Control Layer (MAC) is one of the sub layers of Data Link Layer in the OSI model.. This MAC sub layer acts as an interface between physical layer and the logical link control (LLC) sub layer. It controls the access of the physical layer to transmit data over the network. MAC sublayer uses multiplexing techniques for several parallel data stream to avoid collision on moving from logical layer to transport layer. This type of channel can provide unicast, multicast, or broadcast communication service. It has the responsibility of encrypting data for a secure transmission over a shared medium. So data from multiple nodes share communication medium for transmission and this is regulated and controlled through medium access control (MAC) protocol.The selection among different MAC protocol has a direct consequence on the dependability and efficiency of transmission due to interferences and errors in wireless communications and other challenges.

Some of the responsibilities of MAC layer include:

- For mapping Logical layer to Physical layer.
- To determine when a node can access a shared medium.
- Doing operations like priority handling/scheduling.
- To remove communication errors occurred at the physical layer.
- To encrypt data for secure communication.
- To perform activities such as addressing, framing , synchronizing and traffic control.

The main job of the MAC protocol is to manage the usage of shared medium, and this is achieved by a channel access mechanism. A channel access mechanism is a process of dividing main

resources between nodes and radio channel to regulate the use of the medium. It provides information to each node about the sending and receiving of data . The channel access mechanism is the core of the *MAC protocol*. In this section, we describe *TDMA, CSMA.* They are the main channel access mechanisms for radio.

TDMA

Time division multiple access (TDMA) is one of the channel access method for any shared medium networks. It is very simple and allows multiple users to share the same frequency channel by sub dividing the signal into multiple time slots of fixed size. A particular node such as base station controls the accessibility of network through nodes. Each node is provided with a time slot for sending and receiving of data to avoid collision .These nodes transmit in rapid succession back to back according to their slot allotment in network. Time slots are of three types – TRS (Transmission slot) used for sending and receiving of data, RES (reservation slot) that is used by sensor nodes to transmit a signal(beacon) for the allocation of transmitting slot in current frame,TES (Termination slot) which is broadcasted by base station to end communication in sensor network . RES and TES are relatively short than TRS as they are used to send signal for informing termination and reservation in sensor network. These slots are organized in a frame , which is repeated on a regular interval. This factor allows different nodes to transmit data through the same communication medium (like, radio frequency channel) with using only a particular portion of its channel capacity. Same frequency band can be used by multiple devices with the help of TDMA. A great advantage of TDMA is that the radio module part of the node needs to transmit and listen for its own time slot alone. It helps in duty cycling of any sensor node for turning it on/off (Fig 1).

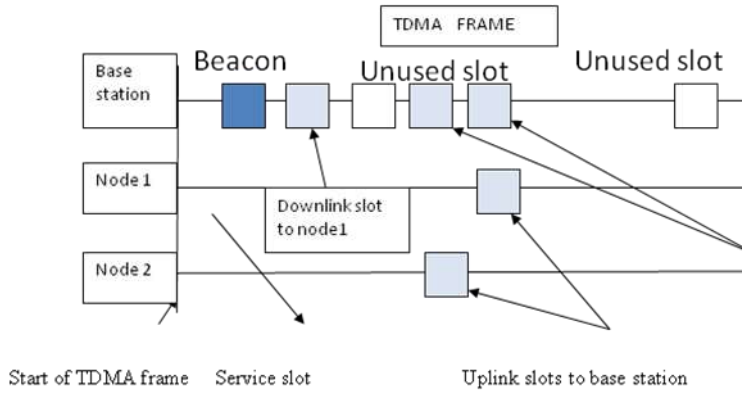

Fig 1 -TDMA channel access mechanism

The base station specifies in the beacon (a management frame) about the organization of the slots in the frame. Base station gives instruction to every node which is followed blindly. The frame is organized in two ways, downlink (base station to node) and uplink (node to base station) slots, and all the communications goes through the base station. A service slot is used by nodes to request for the allocation of a connection, by sending a connection request message in it and for termination by sending end communication message.In some standards, uplink and downlink frames are in different frequencies, and the service in a separate channel.

CSMA/CA

CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance) is a protocol which is used as carrier transmission in 802.11 networks**.** It is another *channel access* mechanism of MAC protocol used by most wireless networks. The basic principles of CSMA is to listen before talk that is to sense a channel for a free path. The chances of collision reduces if node senses the channel before its use.So to improve the performance and minimize the chance of collision, CSMA was used. But CSMA could only sense the collision and not eliminate it. To eliminate this problem CSMA/CD (carrier sense multiple access with collision detection was introduced. In this collision is detected in the medium if it is not transmitted to the destination, but loss of packet takes place. Nodes needs to send this data again after sensing the shared medium. To avoid packet losses another mechanism was introduced named CSMA/CA. It is derived from CSMA/CD (Collision Detection), which is the base of *Ethernet* . It is suited for web protocols such as TCP/IP, as it conforms rather easily with the variable condition of traffic and is quite robust against interferences (Fig 2).

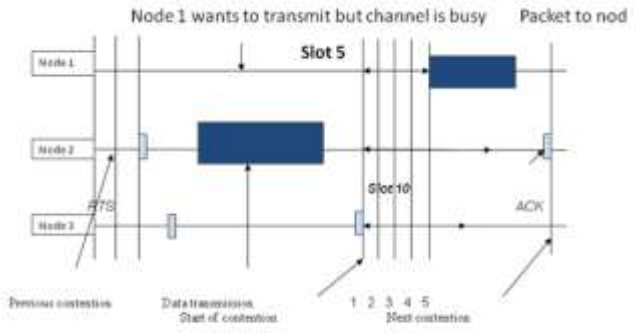

Fig 2 CSMA/CA channel Access Mechanism

CSMA/CD was avoided in wireless LAN for following reason

- To detect collisions a node must be able to transmit data and receive collision signal at the same time. This will lead to costly nodes and larger bandwidth requirement.
- Hidden station problem still leads to collision.
- If area between the nodes is greater then signal fading could prevent a station at one end from hearing collision at the other end.[9]

The main difference that leads to betterment is the *collision avoidance* , the transceiver has the ability to listen while transmitting and so to detect collisions altogether.The protocol starts by listening on the channel (carrier *sense*) and checks for free channel. If it is found idle, node sends its first packet in the transmit queue. If suppose it is busy (due to another nodes transmission or interference), the node waits till the completion of the current transmission and starts the **contention** (wait for random period of time).

When its contention timer expires and channel is idle, the transmission of data takes place but if it is still busy it waits for another contention period. During the transmission of data from one node the other nodes just wait for the next contention (end of this packet). Because the contention is a random number and allotted for every packet and each node is given an equal chance to access the channel.

Algorithm for CSMA/CA

1. Before transmitting a frame nodes senses the channel. By checking the energy level at carrier frequency.

- If channel is not free , node waits for a random amount of time known as back - off.
- After channel is idle, node wait for a particular period of time called(DIFS) distributed interframe space.
- After this node sends a control frame named (RTS) request to send.

2. On destination node after receiving RTS, it waits for another period of time (short interframe space) SIFS.Then it sends a control frame named clear to send(CTS) to indicate it is ready to receive.

3. Node sends the data after waiting for SIFS.

4. After receiving the data destination node sends the acknowledgement

5. When node receives the acknowledgement in a time limit then communication is completed.

MULTI HOP ROUTING

Routing is the technique used to transmit data over the network or to route the packet to its destination. Many routing protocols are used to determine the optimal path to the destination. They are classified as single hop and multi hop network depending on the number of hops to connect source to destination (Fig 3).

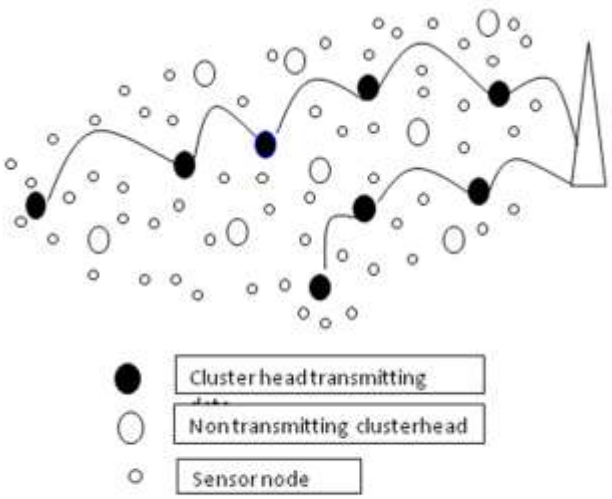

Fig 3 Multi hop routing

- The amount of energy used in direct transmission can be calculated with this formula:

  EampN(3d1+d2)^2

- The amount of energy used in multi hop transmission can be calculated with this formula:

  EampN(3d1^2 +d2^2)

Intra-cluster communication assumes single hop data transmission, while the inter-cluster communication implements multi-hop data transmission to avoid long distance data transmission that causes excessive energy depletion and CH's premature death.[26]

The main aim of research is to find an energy efficient routing protocol and to obtain an optimal path for transmission of data to reduce energy consumption ,overhead traffic, delay and interferences. This improves the performance and enhance the network lifetime.It is defined that multi hop transmission can be more efficient than

direct communication. Transmission of data in multi hop routing focuses on the energy used to communicate over medium. The path selection is on the basis of number of hop counts, energy consumption, packet delivery ratio and end to end delay. Any one or combination of these metrics can be used to select the path[10]. Forwarder list is prioritized and nodes with the highest priority is selected as the mid way node to deliver data to destination in multi hop transmission in WSN. In this traffic overhead ,delay and congestion in network is reduced with the help of dynamic path selection from source to destination

NODE INCLUSION/EXCLUSION

Node Inclusion

We had introduced another technique to improve the network lifetime by introducing a sensor node in far away cluster. As we know Battery replacement is difficult in far away network as they are placed in isolated areas where human intrusion is difficult . So to keep the network alive a programmable sensor node is sent from the base station to the cluster. To add this sensor node in a cluster it is needed to be programmed before hand. Our protocol is programmed in a way to accept a charged sensor node on the replacement of dying node. This can be used in harsh and hostile environment where management of nodes is difficult.

Node Exclusion

One more dynamic operation is done in this protocol that is node exclusion from the network. When a node is excluded it tries to balance energy levels in the network and network reconstruction is called. This maintains energy efficiency of network and improves network lifetime.

ENERGY MODEL

Every routing protocol deals with the energy consumption problem and tries to improve it by different strategies. Sensing and Data transmission causes energy dissipation and leads to exhaustion of nodes . To keep the network alive, we need to keep a watch on the energy level of every node. This is done with the help of energy model. Energy model is used to accurately measure the energy consumption by every node present in network to maintain energy level (Fig 4).

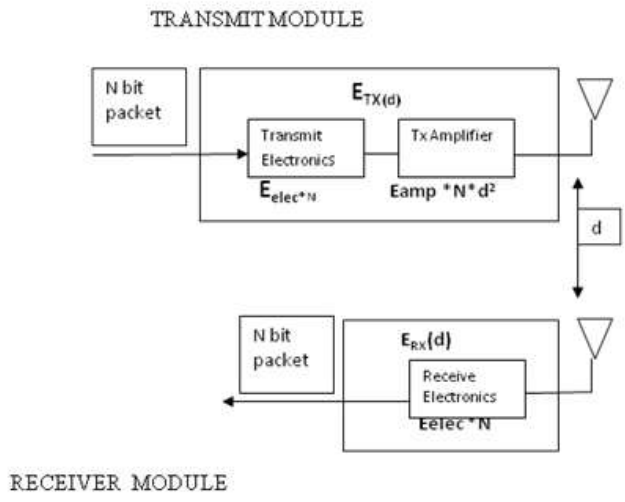

Fig 4 Radio model for wireless sensor network

This radio model consists of Transmit electronics, Receiver electronics and amplifier.

Transmit Electronics(ETx elec) is a device consisting of an electronic circuit to perform signal modulation.

Transmit Amplifier(Tx amplifier) is a device used for amplifying the modulated signal for the transmission through an antenna.

The *Receive Electronics* is a device used for demodulation of modulated signal.

Eelec- Energy required for modulating or demodulating one bit of the data

E amp-This is the energy required for amplifying one bit of data for transmission.

Transmit module (*Transmit Electronics* and *Tx Amplifier*) of energy model remains in sleep mode , it only wakes up when data is to be transmitted.

Receiver module (*Receive Electronics*) is kept ON while waiting for the receiving data.

Some of the formulas used for transmitting a N-bit message to a distance *d*

- Energy consumption formula for transmitting a N-bit message

$$ETx\ (N, d) = ETx\ elec\ (N) + ETx\text{-}amp\ (N, d)$$

$$ETx\ (N, d) = Eelec * N + Eamp * N * d^2$$

- Energy consumption formula for receiving a N-bit message

$$ERx\ (N) = EelecRX\ (N)$$

$$ERx\ (N) = Eelec * N$$

Assumptions-

Some of our assumptions to calculate energy dissipation in our simulation.

- Energy consumption for modulating .

$$EelecTx = 50nJ/bit$$

- Energy consumption for demodulating.

$$EelecRx = 50nJ/bit$$

- Energy consumption for spreading one bit to an area of radius r = 1 meter (i.e., πm^2):

$$Eamp = 100pJ/bit/\ m^2 = 0.1nJ/bit/\ m^2$$

- Data rate = *2000bits/s*
- Data package size = *2000*-bit
- For each received data message, energy consumption is

$$ERx(N) = Eelec * N\ bit/message$$
$$= 50nJ/bit * 2000\ bits/message$$
$$= 100\ \mu J/message$$

- For transmitting a data message to a distance d, energy consumption is

$$ETx(N) = Eelec * Nbit/message + Eamp * N * d^2$$

$$= 50\ nJ/bit * 2000\ bits/message + 0.1\ nJ/bit * 2000\ bits/message * d^2$$

$$= (100 + 0.2 * d2)\ \mu J\ /message$$

SIMULATION AND RESULT

Simulation tool

This thesis uses Network Simulator NS2 as experiment platform. NS 2 is an open source discrete event simulator which is used by the research community for the purpose of research in networking domain. It has support for both wireless and wired networks and may simulate several network protocols such as UDP, TCP, multicast routing, etc. Recently, support has been added for simulation of ad hoc wireless and large satellite networks. The NS 2 simulation software was developed at the University of Berkeley. It is constantly under further development by an active group of researchers. In this thesis version NS 2.28 has been used for simulation (Fig 5).

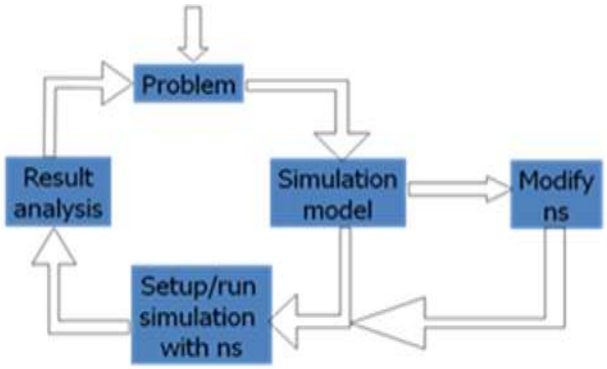

Figure 5 Working model of Network Simulator

NS uses simple model with single thread of control and without locking or race conditions to worry about which is very easy to understand.

Network animator(NAM)

NAM is a Tcl/TK based animation tool for viewing network simulation traces and real world packet traces. It supports topology layout, packet level animation, and various data inspection tools. It is mainly intended as a companion animator to the ns simulator. When program runs in ns we can visualize wireless network in the NAM.

Proposed LEACH Simulation- This tool is used to display the result of program running on NS2. It shows the startup process of simulation of proposed methodology (Fig 6).

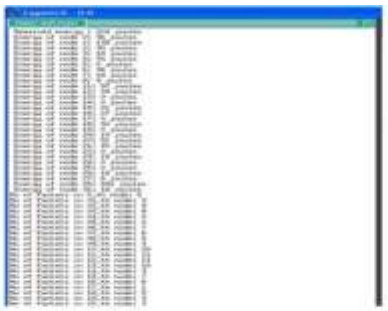

Fig 6 shows the start up simulation process of proposed work.

This shows the graphical representation of proposed work in Network animator tool which is the tool used to display NS2 simulation . In this figure 7 nodes are generated to form a network.

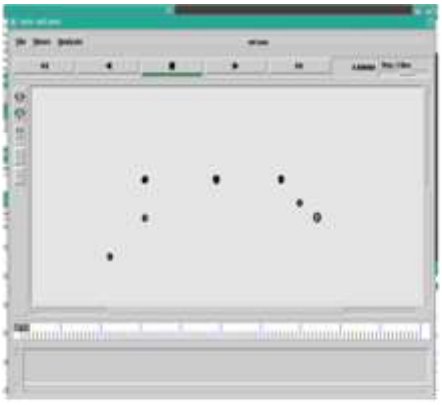

Fig 7 Starting the animation by the help of NAM tool

Here all nodes are forming a cluster. There are 33 nodes in our proposed method. All the nodes are making cluster according to their distance from base station. For making cluster they are connected by join ARQ MAC protocol for making cluster. Here in this figure 8 blue circle shows the signal flow between nodes.

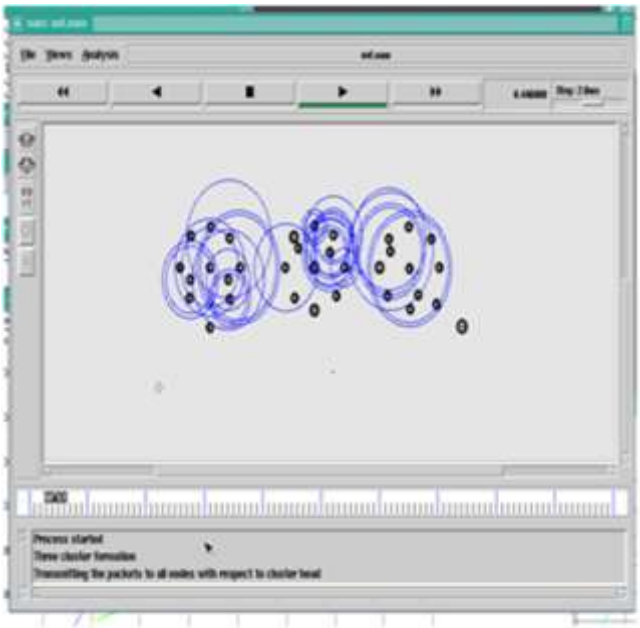

Fig 8 Clustering shown in NAM

Here in figure 9 nodes join to make a cluster and also select a cluster head. All red color dots denote sensor nodes and green dots denote the cluster head.

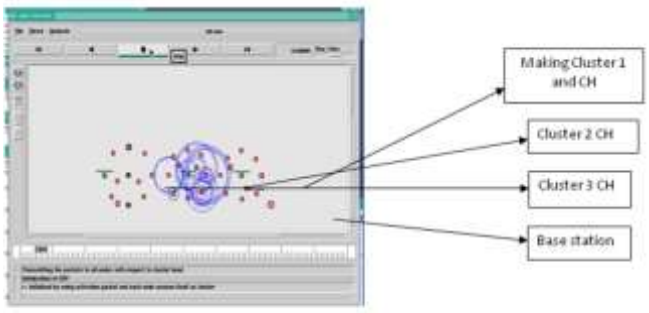

Fig 9 Cluster Head Selection in NAM

Here in figure 10 multi hop routing between all three clusters, cluster head and base stations is shown. One of the most important thing shown is randomization of nodes which means that one node is going far away from its own cluster and another node is entered in the network.

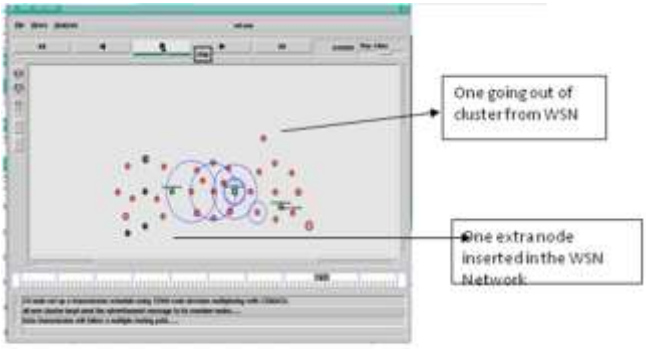

Fig 10 Randomization

Initially input is given in NS 2 simulation software and then results were displayed with the help of Network Animator. It is an animation tool and a companion to NS2 simulator.These graph shows the performance of proposed methodology. They compare proposed method with the present methodology of Leach protocol.

Cost and Data packetIn Figure 11 it shows the Cost of data packet sending in a different time slot. Here an XY axis graph is generated between Time and data packet. SIMULATION TIME is taken on X axis and DATA PACKETS are taken on Y axis. A higher rate of data transmission is shown through red line (modified LEACH) whereas green line (Present LEACH) sends lower data packets. We clearly see that proposed method sends 10000 more data packets from present Leach . So it shows improvement in proposed method.

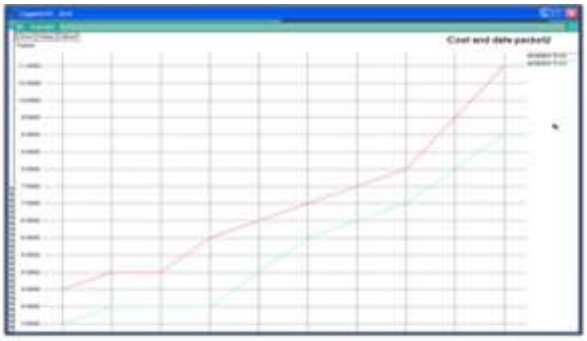

Fig 11 Graph for cost and data packet

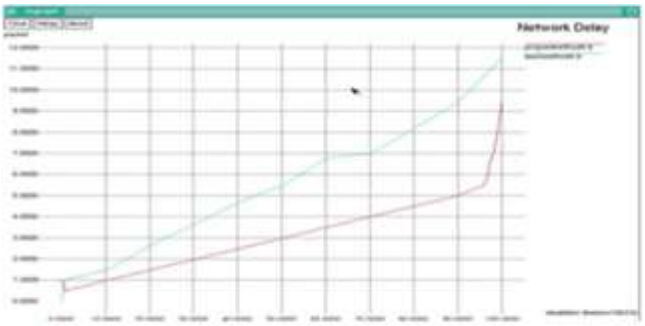

Fig 12 Graph for network delay

Network delay

Here in Figure 12 second result is shown that is based on the Network delay. One of the important design and performance character of a computer network like Wireless sensor network telecommunications network is Network delay. Network delay describes the amount of time required for a bit of data to travel across the network from one node or another node in end point. Measuring unit is in multiples or fractions of seconds. It is location dependent and may differ slightly, depending on the location of the specific pair of transmitting sensor nodes. Although users only care about the total delay of a network. Here modified leach is denoted by red line and leach is denoted by green line. Comparisons of Network delay of leach and our proposed method shows that the Network Delay of modified leach is much lower than the present leach. Reason behind them is that in modified leach we have used multi hop routing in which packets are not send through direct transmission to the base station, instead from an optimal path through various cluster head. It works as a relay station and helps in reducing energy consumption of CH

Packet delivery ratio

Packet delivery ratio: The ratio of the number of delivered data packet to the destination. This shows the level of delivery of data to the destination.

PDR =∑ Number of packet receive / ∑ Number of packet send

Greater the value of packet delivery ratio , better is the performance of protocol.

End-to-end Delay: The average time require by a data packet to arrive in the destination. It also includes the delay caused in finding optimal route and data packet transmission in queue. Only the data packets that successfully delivered to destinations that counted.

EED=∑ (arrive time – send time) / ∑ Number of connections

Lower the value of end to end delay , better is the performance of the protocol.

Figure 13 shows that the packet delivery ratio between modified leach and present method. Simulation Time is assigned on X axis and slots are shown in Y axis. In multi hop routing protocol packet delivery ratio plays an important role for

checking the network performance. Here it clearly shows that the packet delivery ratio of modified leach is much higher as compared to leach.

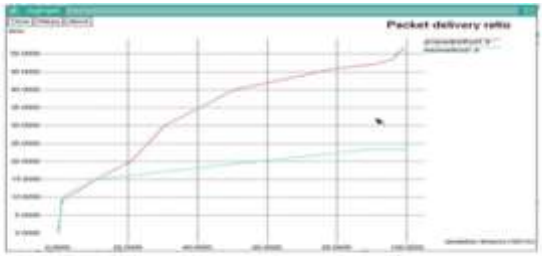

Figure 13: Graph for Packet delivery ratio

Network performance

The performance of LEACH protocol in WSN is tested or checked through network performance rate.. In the Network performance we will create a graph in between simulation time and slots. This graph indicates that our modified leach provides a better network performance (Fig 14).

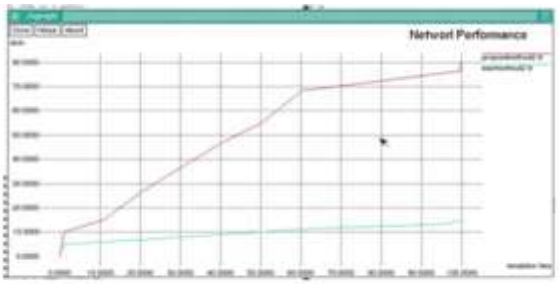

Figure 14 Graph for Network Performance

CONCLUSION

In this MS, a brief introduction of wireless sensor network and its application is given. As every technology has its pros and cons , this technology also has many constraints. One of its constraint is its dependency on energy . So to improve its performance and network lifetime, it is a requirement to provide an energy efficient routing protocol for the transmission of data. This thesis includes survey of various routing protocols based on clustering technique and found Leach as one the efficient routing protocol. In this thesis an improvement to Leach protocol is done by further modifying it to bring better results. In this proposed method CSMA/CA and TDMA are used for improving data transmission by sensing channel for avoiding collision and packet loss. Then randomization is done which means a node inclusion /exclusion technique is used for far away cluster to improve its lifetime. For the transmission of data, optimal path is chosen with least number of hops and higher energy residual and least traffic load. Then a comparison of simulation result are on the basis of network performance, network delay, packet delivery ratio, data packet . The graphs show satisfactory results of proposed method.

Wireless sensor network is an emerging technology and has a huge scope of research and development. In this field energy is the main constraint and has huge research possibilities. Certainly further energy improvement is possible by improving routing protocol and cluster head selection technique.

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