Energy Aware Intra Cluster Routing for Wireless Sensor Networks

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Abstract

Wireless Sensor Network (WSN) is an emerging technology that is predicted to change the human life in future. This technology is composed of tiny sensing objects called sensors that are wirelessly scattered in the environment. Due to wireless nature and having limited lifetime (battery operated) there are many challenges for researchers to make this technology more useful. In this research work an energy efficient routing technique Energy Aware Intra Cluster Routing (EAICR) is presented that has increased energy efficiency up to 17% and increased the network lifetime up to 12% when compared with a well known routing algorithm MultiHop Router [1] .

Keywords: *Wireless sensor networks, cluster Head, cluster formation, adaptive routing.*

1. Introduction

WSN is an emerging technology that can be deployed in such situation where human interaction is not possible like border area tracking enemy moment or fire detection system. Figure 1 shows an overview of WSN. Sensor are deployed in the environment which can be fire area, border or open environment. These tiny devices sense the area of interest and then communicate with Base Station (BS). On BS the gathered information is analyzed.

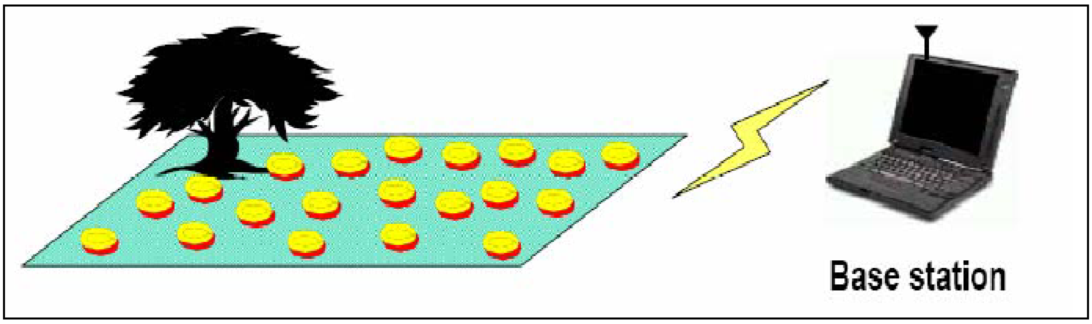

Figure 1. Overview of a wireless sensor network [2]

Mainly a sensor node is composed of five components including [3]:

1. Sensing Hardware
2. Processor

3. Memory
4. Power supply
5. Transceiver

Components of a typical wireless sensor node are shown in Fig 2.

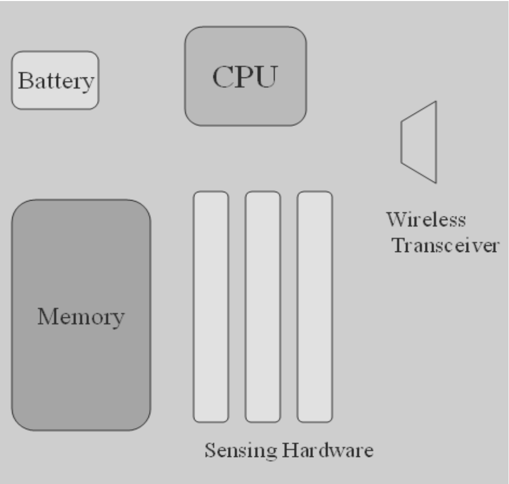

Figure 2. Components of sensor node [4]

WSN is composed of tiny nodes called motes, some well known models are mica2, micaz, micadot etc. The mica2 mote have a shape of rectangular block, with size 2.25 x 1.25 x 0.25 (in inches), weights about 18 grams as shown in Fig 3, the mica2dot mote have circular shape with size 1.0 x 0.25 (in inches) and weights 3 grams [3].

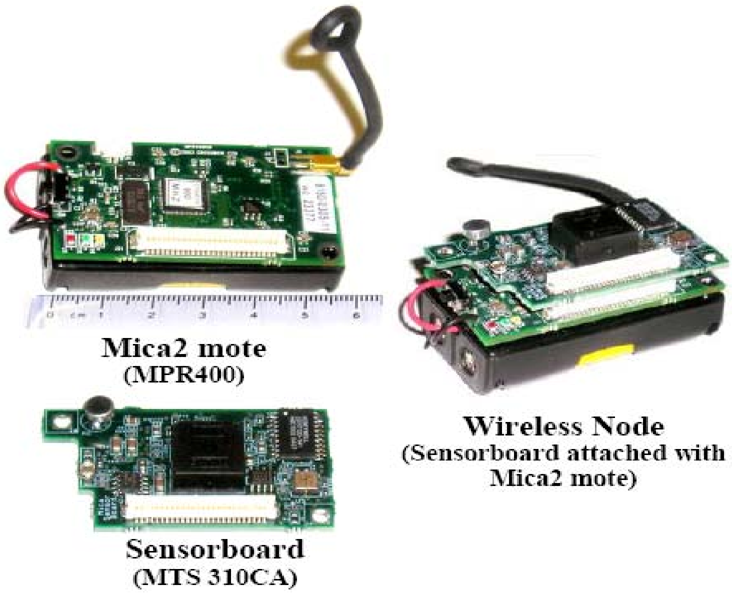

Figure 3. Mica2 mote, sensor board and their combination [3]

UC Berkeley is one of the leading hardware developing companies. Figure 4 shows some well known models of sensor nodes developed by Berkeley. The latest two are MicaDot and Micaz motes.

Mote Type	*WeC* 	*René* 	*René 2*	*Dot* 	*Mica* 	*MicaDot* 
Microcontroller						
Type	AT90LS8535		ATmega163		ATmega128	
Program memory (KB)	8		16		128	
RAM (KB)	0.5		1		4	
Nonvolatile storage						
Chip	24LC256				AT45DB041B	
Connection type	I^2C				SPI	
Size (KB)	32				512	
Default power source						
Type	Lithium	Alkaline	Alkaline	Lithium	Alkaline	Lithium
Size	CR2450	2 x AA	2 x AA	CR2032	2 x AA	3B45
Capacity (mAh)	575	2850	2850	225	2850	1000
Communication						
Radio	TR1000					CC1000
Radio speed (kbps)	10	10	10	10	40	38.4
Modulation type	OOK				ASK	FSK

Figure 4. Berkeley family of motes [5]

2. Related Work

Lot of research work has been done in this field to make this technology more scalable, energy efficient and robust.
Ibriq and Mahgoub in [6] described different routing models used for WSN. According to authors there are three models rouging in WSN including:

- One Hop Model
- MultiHop Model
- Cluster Based Model

2.1 One Hop Model

This is a simple model that uses direct data sending towards the BS [6].

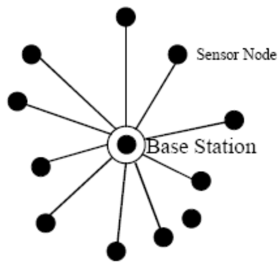

Figure 5. One hop model [6]

2.2 Multi-Hop Model

In this model nodes choose their neighbors to forward data toward the BS [6], this model is an energy efficient model of routing.

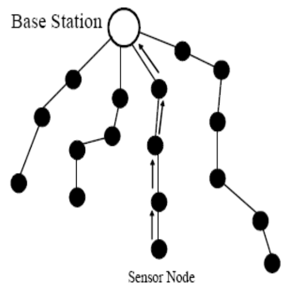

Figure 6. Multi-hop model [6]

2.3 Cluster Based Model

In this model network is grouped into different clusters [6]. Each cluster is composed of one cluster head (CH) and cluster member nodes. The respective CH gets the sensed data from cluster member nodes, aggregates the sensed information and then sends it to the Base Station.

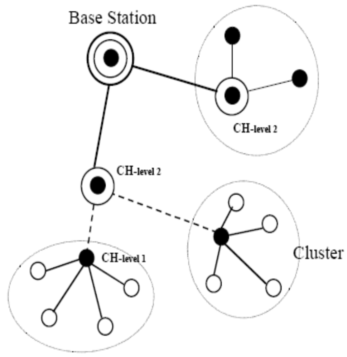

Figure 7. Cluster based model [6]

Researchers have developed many routing protocols for above mentioned models but still there are lots of advancements to be done.

Cluster routing is an energy efficient routing model as compared with direct routing and multihop routing. But there are some issues in cluster routing as well. Heinzelman et al [7] disused the problem of load balancing in cluster based routing and introduced a novel idea of rotation of CH role inside the cluster named LEACH (Low-Energy Adaptive Clustering Hierarchy), thus doing load balancing in the network. After simulation this is shown that LEACH has reduced factor 8 in energy consumption when compared with other protocols.

A distributed, randomized clustering algorithm to organize the sensors in a wireless sensor network into clusters [8] is presented by Bandyopadhyay. This technique has saved the energy by limiting the CH advertisement to k hops thus unnecessary advertisements have been avoided in this work.

Work on Hybrid Sensor Network is carried out by Ma and Yang in [9]. In hybrid network different type of sensing nodes are introduced. Authors have divided the nodes in two categories that are:

- Sensing nodes which are having normal battery life
- Cluster Head having high battery life time as compared with sensing nodes

The sensing nodes sense the environment and then transmit the data towards the CH and on other hand CH get the data aggregates it and then transmit toward the BS. By introducing CH with high powered batteries the network lifetime can be increased.
Goyeneche et al [10] have introduced a novel distributed data gathering algorithm for wireless networks has been proposed. A technique for data gathering is presented for WSN, in which each node sends its data to its neighbors and so on until data reaches to such node that has already sent its data to the BS. That node will become CH for the sending node.

To achieve load balancing in network concept of temporary Cluster Head is introduced by Israr in [11]. Temporary CH introduces two layer communication in the network. First data is sensed and transmitted to the CH now here role of Temporary CH is introduced. These temporary cluster heads gets the load of the cluster heads and thus prolongs the lifetime and performs the load balancing as well.

Research work on energy conservation is carried out by Hoang and Motani [12]. They considered the broadcast nature of sensor node, when ever data is broadcasted it is heard by all the nodes present in the coverage area, so a node can exclude the redundant information transmitted by the sending node. By using this property one node can compress its own data by overhearing other’s transmission. Thus energy conservation is achieved.

Energy Efficient Clustering Routing (EECR) algorithm is given by LiLi in [13]. Lifetime is increased by selecting the CH on the basis of weighted values. As CH selection in one of the most important task in network lifetime.

A Self-Reorganizing Slot Allocation (SRSA) mechanism presented by Wu and Biswas in [14]. A MAC layer protocol that reduces TDMA interference. This algorithm reorganizes the TDMA slot on the basis of feed back mechanism. Due to broadcast nature of the cluster member nodes many nodes fall in the coverage area of other cluster that causes the data collision. To avoid this collision SRSA algorithm is introduced which first detects the collision and in next round reorganizes the TDMA frame to collision. The proposed idea is simulated and compared with TDMA-over-CDMA, TDMA with random slot allocation and CSMA MAC protocols.

A new adaptive cluster routing algorithm CIDRSN (Cluster ID based Routing in Sensor Networks) has been presented by Ahmed et al [15]. Cluster routing is adopted in this research work. I this research work Cluster ID based routing is adopted and adaptive cluster size is proposed. In this algorithm Cluster ID is used as next hop rather than CH-ID in routing table. In this way cluster formation process is eliminated for each round. Cluster formation is only carried out in start thus reduces the energy consumption and increases the network lifetime to about 16%.

Lot of work is done in this field and after going through the related work one common problem is detected. Whatever technique is used for routing, in intra cluster routing either direct routing or multihop routing is adopted. This leads to development of an adaptive routing for intra cluster communication.

3. Problem Statement

After going through all of the above research works, we found a common problem or deficiency that needs to be solved. Researchers have done work either on multihop routing or direct hop routing in all of the above research works and in some cases both techniques are not feasible to be adopted. In case of using the traditional routing technique like Direct or MultiHop in large network size the energy and network lifetime are badly effected.

3.1 Limitations of Direct Routing

While considering large network size, if mode of routing is selected as direct routing then all nodes will send their data directly to CH. The node at maximum distance to CH will have to put in more energy to send its data to CH. So after sending very small amount of data packets its death will occur which leads to small network lifetime. So adopting direct routing in large network size is not feasible.

3.2 Limitations of MultiHop Routing

If the mode of routing is selected multihop in large network size, then network lifetime will be less. In multihop routing the nodes closer to the CH will get maximum load of the network because they have to send their own data as well as data from other nodes. If this scenario is considered in large network size, then huge number of data packets will be routed through these closer nodes. This will drain the energy levels of the closer nodes very quickly. So multihop routing in large network size is also not feasible.

As the network life is calculated with death of first node in the network. Hence in large network the lifetime of the network is a major challenge. So a routing technique is required that should be able to prolong the network life time, and it should perform load balancing as well especially for large network size. Our major objectives for the development of our new adaptive routing technique will be:

Development of such routing technique that:

1. Suitable for large network size.
2. Performs adaptive routing.
3. Is better than traditional routing techniques.
4. Is energy efficient.
5. Prolongs the network lifetime.

4. Proposed Solution

4.1 Adaptive Intra Cluster Routing

One of the major constraints of WSN is energy. In this research work this problem is kept in mind and a solution for limited energy source has been proposed. The proposed solution is “Energy Aware Intra Cluster Routing”. In this algorithm while keeping the scope to intra cluster communication each node is not identical to other for routing the data. Some nodes are considered in close region and they perform direct routing and outside the region nodes adopt multihop routing. In this way the closer nodes are not having extra load on them. In traditional routing like multihop the closer nodes exhaust energy very quickly because the are perform two task in their life time, one is sensing their own data and second is routing the data of other nodes. Thus closer nodes have extra load with them and there is no concept of load balancing as well. To perform load balancing EAICR is best solution. Nodes 2,3,6,7,8,12 and 13 are considered in close region for a network of 30 nodes places in 6x5 grid topology as shown in figure 8 below. Our protocol works in three phases.

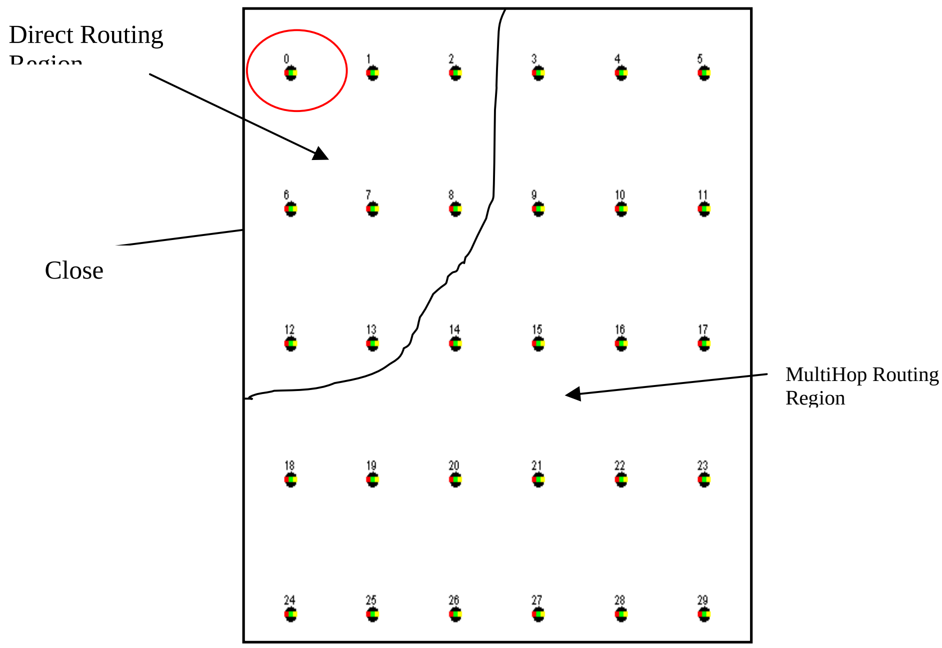

Figure 8. Topology Considered for Simulation

4.1.1 Phase I: Cluster Head Selection

This research work is designed for intra cluster communication for cluster formation and CH selection any algorithm can be applied with our work. For intra cluster routing first of all cluster head is selected then with the collaboration of BS clusters are formed and finally intra cluster routing is carried out. The cluster head selection phase starts and all the deployed nodes send their energy levels to the Base Station. Then on the basis of energy level, geographical area and least id cluster head are selected. Network deployment is considered as manual so the base station is well informed about the geographical locations of the nodes. Base Station will select the cluster heads and multicast this information to them. CH selection flow diagram is presented in figure 9.

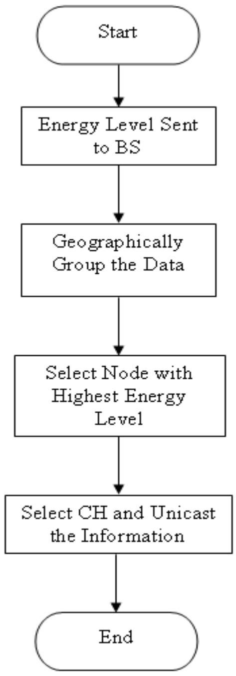

Figure 9. Flow diagram of CH selection

4.1.2 Pseudo Code for Cluster Head Selection

```
START
INITIALIZE
      Destination ID=Destination Address
       Source ID=Source Address
       Energy=Energy Level of the Node
       Data=usable information
       High Level=Max Energy Level
       Least ID
// End of Initialization
BS Function
      //Query Nodes about Hello Packets
      Call Node Function
      Group Data according to Geographical Locations
      IF (Energy = High Level AND Source ID = Least ID)
            CH = Source ID
            Data="you are selected as CH"
      ELSE  Discard Data
      ENDIF
```

```
    //Unicast Information to Selected CH
    Destination ID = Source ID
    Send Data to Destination ID
```

Node Function

```
    Read Energy Level
    Energy= Energy Level
    Calculate Destination ID
    Destination ID= BS
    Data = (Energy Level + Source ID)
    Send Data to Destination Address
END
```

4.1.3 Phase II: Cluster Formation

After cluster head selection the cluster formation phase starts. Each selected cluster head broadcasts its status as Cluster Head the nodes getting high Received Signal Strength Indicator (RSSI) value response to this beacon message and show their will to join this cluster. The node sends join request to the respective cluster head and in response join confirmed alert is sent by the cluster head. In this way clusters are formed with one cluster head each. figure 10 shows the flow diagram for cluster formation process.

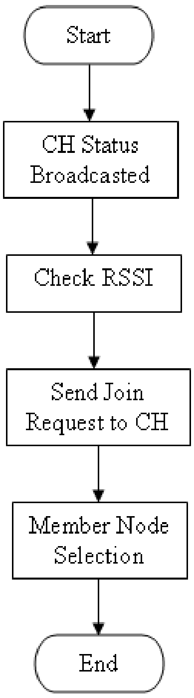

Figure 10. Flow diagram of Cluster Formation

4.1.4 Pseudo Code for Cluster Formation

START

```
 INITIALIZE
  Source ID=Source Address
  Destination ID=Destination Address
  High Data=High Value
  Load= Number of Nodes in a Cluster
```

// End of Initialization

```
 IF (Source ID = CH) THEN
      Broadcast Info "I am CH join me"
      Call CH Function
ELSE
      Call Node Function

ENDIF
```

NODE FUNCTION

```
      Get Broadcast info from CH
      Data=info
      Calculate RSSI Value

      IF (RSSI Equals to High) THEN
            Destination ID=CH
            Send ACK to Destination ID

      ELSE
            Discard Data

      ENDIF
```

CH Function

```
      Get Join Request from Source ID
      Check Load of Cluster

      IF (load is Less) THEN
            Include Source ID in Cluster
            Destination ID=Source ID
            Send ACK to Destination ID
      ELSE
            Send "Load in Cluster is High"

      ENDIF
```

END

4.1.5 Phase III: Intra Cluster Routing

This research contribution is for intra cluster routing as the routing phase starts the nodes first check their location if their location is inside the close region then the mode of routing for these nodes is direct routing and on the other hand if the nodes are out of close region their mode of routing is multihop. In our work nodes are deployed manually and we are considering static nodes so the node 2,3,6,7,8,12 and 13 are in close region so their mode routing is direct and rest of the nodes in the cluster adopt multihop routing. Flow diagram of EAICR has been shown in figure 11.

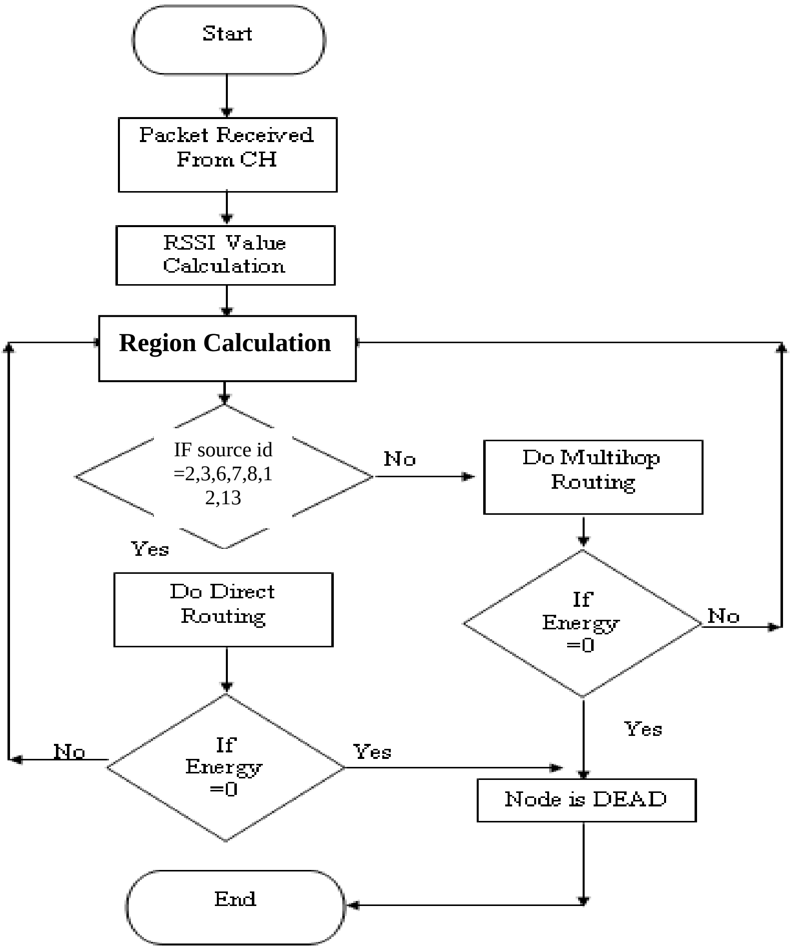

Figure 11. Flow Diagram for Energy Aware Intra Cluster Routing

So by using EAICR the problem stated in section 3 is solved, because now even in large size of cluster the farther nodes as well as closer nodes are sending the data without extra loss of their energies.

4.1.6 Pseudo Code for Intra Cluster Routing

```
START
INITIALIZE
  Source ID= Source Address
  Destination ID= Destination Address
  Parent ID= Parent Address
  Data, Energy Level
// End of Initialization
      Get Sensed Info
      Data= Info
```

```
      Select CH
      IF (Source ID==2 || Source ID==3 || Source ID==6 || Source
ID==7 || Source ID==8 || Source ID==12 || Source ID==13) THEN
            Call Direct Routing
      ELSE
            Call MultiHop Routing
```

Direct Routing

```
      Sense required info
      Data =Info
      Destination ID= CH

      WHILE (Energy Level ≠ 0)
            Send Data to Destination ID

      END WHILE

      Broadcast "Node is Dead"
```

MultiHop Routing

```
 Sense required Info
 Data =Info
 Calculate Parent ID for data Delivery
 Destination ID= Parent ID

WHILE (Energy Level ≠ 0)
      Send Data to Destination ID
      END WHILE
Broadcast "Node is Dead"
```

END

5. Simulation Parameters

We have performed three different experiments by simulating different scenarios. The topology taken for the simulation is grid and in a grid of 5x6 the network is established. Node to node distance is 10 feet. A java based application "Lossy Builder" is used to set the distance parameter for the simulation. Different experiments have been done using different parameters and numbers of results have been achieved to analyze the performance of algorithm.

5.1 Experiment No 1

To check the energy consumption of the algorithm the energy level of each node is considered 300 mJ. This simulation is run for 30 nodes, it is mentioned in future works that same algorithm can be checked on large network size. The nodes having less than 25 feet distance from the CH will adopt direct routing. Different distance factors have been checked for same topology but optimum results have been achieved at 25 feet. The simulation is run for approx 15 minutes. Results have been shown in next section while considering the parameters as discussed. Table 1 shows the list of parameters considered for the simulation.

Table 1. Simulation Parameters for Experiment no 1

Parameters	**Value**
Topology	Grid
Simulation Time	15 min
Maximum Energy level	300 mJ
Distance Unit	Feet
MAC Scheduling	S-MAC
Network Size (Nodes)	30
Area of Close Region	25 Feet
Cluster Head	Node 0
Broadcast ID	65535
Geographical Area	2000 Sq Feet

5.2 Experiment No 2

The simulation time for this experiment is taken 30 minutes and the initial energy level of each node is taken 600 mJ. All the other parameters are kept constant. Table 2 shows the simulation parameters considered for this experiment.

Table 2. Simulation Parameters for Experiment no 2

Parameters	**Value**
Topology	Grid
Simulation Time	30 min
Maximum Energy level	600 mJ
Distance Unit	Feet
MAC Scheduling	S-MAC
Network Size (Nodes)	30
Area of Close Region	25 Feet
Cluster Head	Node 0
Broadcast ID	65535
Geographical Area	2000 Sq Feet

5.3. Experiment No 3

Table 3 is showing list of parameters taken for this experiment. For this experiment, initial energy level of each node is taken 900 mJ and simulation is run for 45minutes. All the other parameters are kept constant.

Table 3. Simulation Parameters for Experiment no 3

Parameters	**Value**
Topology	Grid
Simulation Time	45 min
Maximum Energy level	900 mJ
Distance Unit	Feet
MAC Scheduling	S-MAC
Network Size (Nodes)	30
Area of Close Region	25 Feet
Cluster Head	Node 0
Broadcast ID	65535
Geographical Area	2000 Sq Feet

6. Simulation Results

We have used TOSSIM [1] with TinyOS to simulate our proposed technique. The results have been compiled and compared with a well known existing technique. Results show that proposed technique is more energy efficient. The simulation of proposed Adaptive Routing is run for 30 nodes and is compared with well known routing protocol, Multihop Router that performs multihop routing. We have used grid topology as shown in figure 12. Node 0 is selected as CH and rest of 29 nodes as cluster member nodes. Node 2,3,6,7,8,12 and 13 are considered as closer nodes so their mode of routing is direct and rest of all nodes perform multihop routing. In this way load of the network on closer nodes has been shifted towards backward in the network.

Figure 13 shows the energy consumed by the nodes at time t. This is clear that Adaptive technique is more energy efficient and the energy consumption is less in this technique as compared with multihop routing. After some time of simulation run, this check is performed to get the behavior of the network. Same behavior is also shown by the nodes in this graph. The nodes adopting direct routing will definitely consume less energy for the transmission of their respective data. On the other hand nodes far away from the CH will consume more energy for data transmission. Here energy efficient routing factor is also achieved.

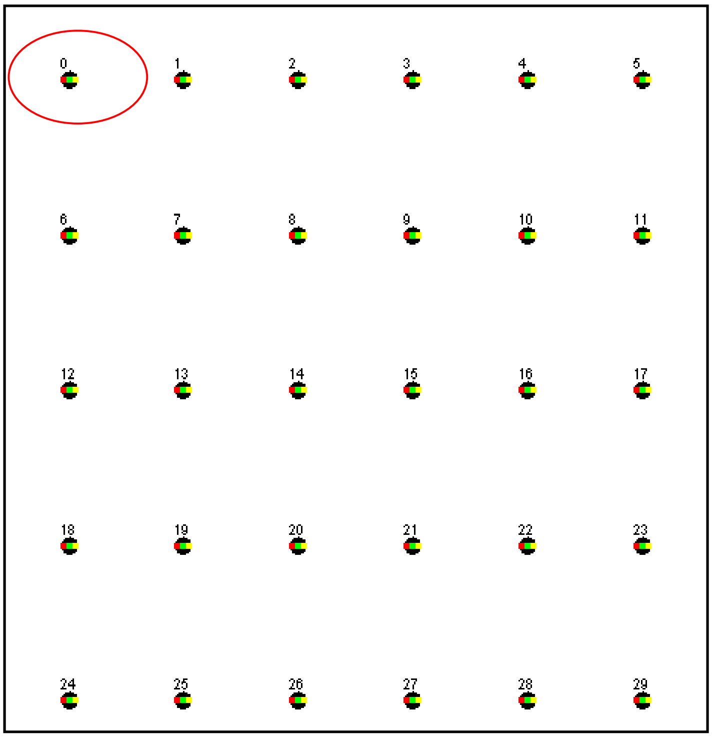

Figure 12. Topology considered for simulation

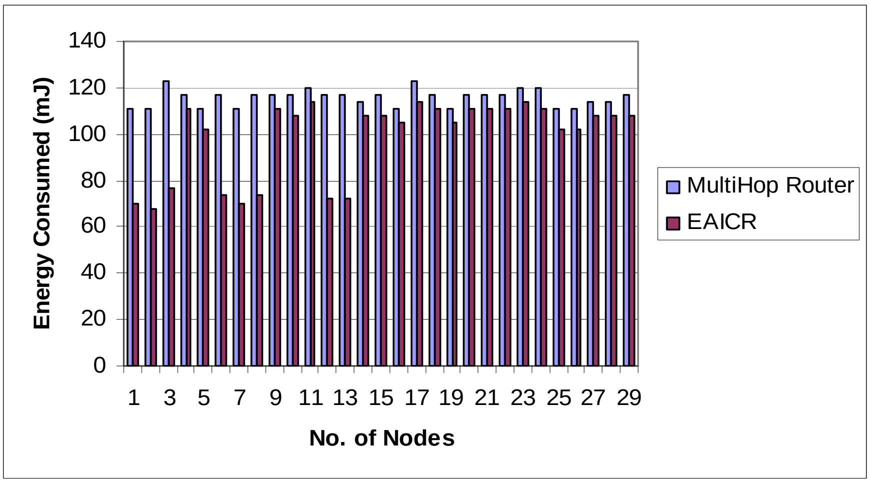

Figure 13. Energy Consumed

The graph plotted in figure 14 shows that the packet delivery rate is very high in close nodes in Adaptive Routing algorithm. The close nodes are 2,3,6,7,8,12 and 13. It is clear from the graph that the packet delivery ratio is very high in these nodes because they do not have any load of extra packet to send with them. On the other hand in Multihop routing the nodes close to the CH have to send their own data with additional load of other nodes. By having extra delivery of data with them causes more energy consumption, resulting the less number of packet delivery in the network. So we can say that the through put of proposed algorithm is more than the traditional technique.

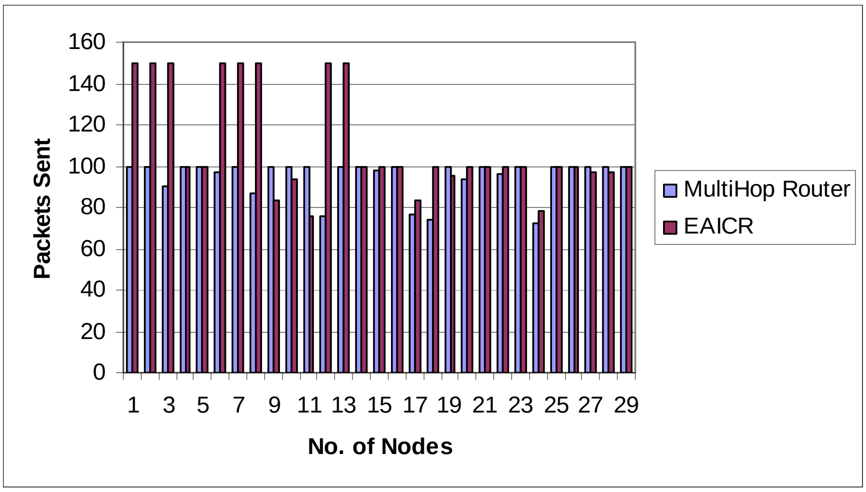

Figure 14. Total Packets Sent

One of the most important factors is network lifetime for WSN, which has been increased by proposed technique. Figure 15 shows the comparison of network lifetime in both techniques. The graph is showing that while using multihop routing the node death occurred earlier than in adaptive routing algorithm thus increased the network lifetime. Network lifetime of any network is calculated with the death of first node in the network.

In proposed technique the death of first node occurred after the death of first node in multihop routing technique. This is one of the major achievements of our proposed technique.

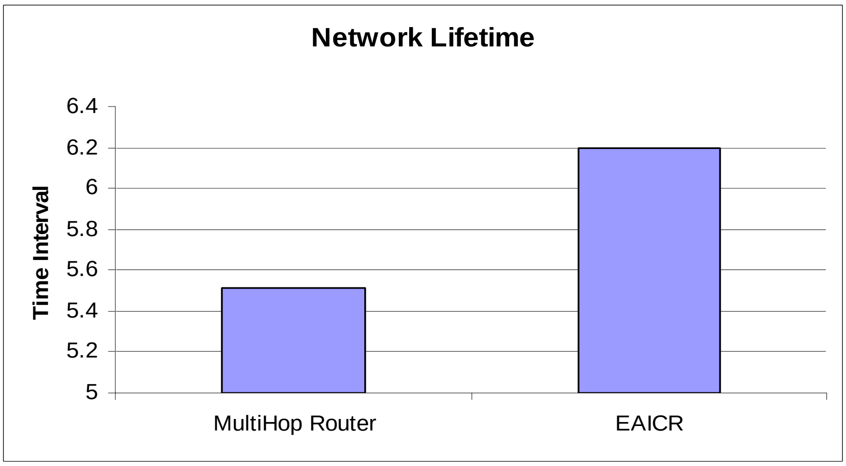

Figure 15. Network Lifetime

In figure 16 the comparison of total packets sent in the network is shown and the graph is showing that Adaptive routing is capable of sending more packets towards the CH. If we compare both the techniques we will see that Adaptive routing is sending 68% more packets towards CH than multihop routing. It is very obvious that such result has been achieved because we have seen above, if the technique is sending more packets to the CH, the remaining energy level is high at any time while routing and the energy consume by the nodes is also less. Then it is obvious that total number of packets sent in the network will be more. This is another proof of energy efficient routing technique that by having same level of power source the Adaptive Routing technique is capable of sending more packets toward the respective CH.

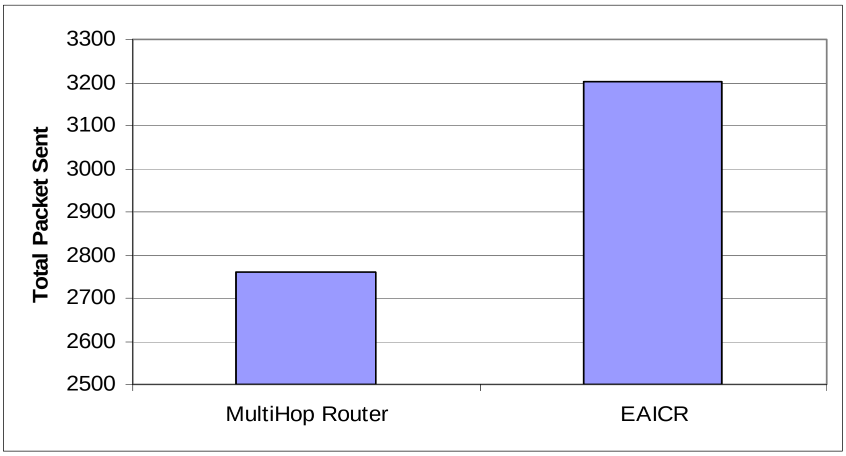

Figure 16. Total Number of Packets Sent

7. Conclusions

In this research work, we have proposed a new technique for intra cluster routing which is more energy efficient than a well known routing protocol *Multihop Router* that performs multihop routing. We have proved our idea by simulating a network of 30 nodes in TOSSIM. While justifying our idea through results of our simulation we have considered the parameters that include: number of packets sent in the network, energy consumed by the network, remaining energy level of nodes at specific time and network lifetime of the network. By using proposed technique we have increased the network lifetime and number of packet sent in the network. Finally it has been shown that by using EAICR network lifetime has been increased up to 12% and energy consumption is reduced 17%. Finally this has been shown that by using EAICR number of data packets send in the network has been increased up to16%. If the simulation time is increased these factors will give more commendable results for the proposed algorithm.

8. Future Work

We have developed a new routing protocol that is energy efficient than the traditional protocol but there is still room to work in this area to make WSN more reliable. This work can be extended in different dimensions that include:

8.1 Real Motes

Currently our idea is implemented and tested in a simulation using TOSSIM simulator. This work can be tested on real motes and then while considering real environment more mature results can be achieved.

8.1 Inter Cluster routing

At present the proposed idea is implemented and tested for intra cluster routing but this work can be extended to inter cluster routing. This will involve the issues of inter cluster communication as well.

8.2 Simulation time

Currently the simulation time is very short but still positive results have been achieved. This can be run for long time and the results after increased in simulation time will be more effective. Because if Adaptive routing technique is sending more packets in less time then more packets will be sent while running the simulation for a long time.

8.3 Network Size

The proposed routing algorithm can be tested in a large network size. As in our work we have considered the cluster size of 30 nodes, still this is a large cluster size but this can be checked on a cluster size of more than 50 nodes. Because in real networks dense deployment of the nodes is highly required.

Acknowledgement

This work was supported by Bahria University Islamabad Campus Pakistan.

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