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An Energy Efficient Multi-master Zone Based Hybrid Routing Protocol in Wireless Sensor Networks

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ABSTRACT: Wireless sensor networks became an ever growing research area due to its wide variety of applications. WSN which consists of set of nodes deployed in a sensing filed is limited by battery power. So our aim is to increase the network lifespan by making the sensor zone energy efficient. Here we are proposing an integrated centralized with distributed zone based clustering approach to increase the network longevity by mitigating the energy consumption problem. Initially centralized approach is implemented to divide the deployed area into zones and to select primary and secondary zone masters. Each nodes sends their data to the corresponding primary zone master. Then it will forwards the collected data to the base station through an energy efficient optimal path. After each round, energy of primary and secondary is compared and one having the highest residual energy will become primary zone master and other become secondary. Here new zone masters get selected only if current zone masters energy is less than average energy. Our paper ensures uniform distribution of energy by selecting optimal number of zone masters and provides energy efficient data delivery through an optimal path.

KEYWORDS: WSN, energy consumption, zone based cluster approach, residual energy, zone master.

I. INTRODUCTION

Advancements in electronics and wireless communication paved the way for the development of low-cost, low power, small sized and multi-functional wireless sensor networks [1]. Since sensor node works on battery, it is very important to conserve battery power [2] so as to increase the network lifetime. Normally energy dissipation of sensor nodes occurs at sensing, processing and communication subsystem. Recently researches are focusing on designing and developing of energy aware routing protocols for sensor networks. Fig 1, Shows the communication Architecture of WSN.

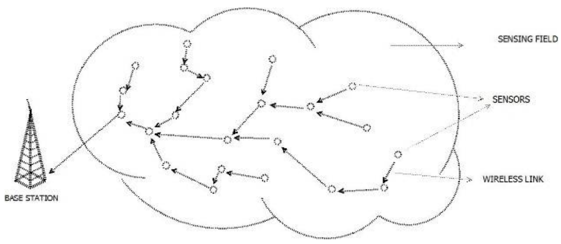

Fig1. WSN communication Architecture

WSN which consists of randomly placed sensor nodes are applied in monitoring applications [3-4]. Within the limited battery capacity, how to extend the network lifespan is one of the major challenges that researches face. Many routing protocols are developed so far, in which hierarchical routing protocol [5] can considerably reduce the energy consumption. Here, sensed data by the nodes are collected by CH and then after aggregation, it will forward the data to the BS. This will reduce overall energy consumption with limited communication overhead. Most of the energy efficient routing protocols are differed each other by means of cluster head selection, cluster formation and data transmission.

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Some protocols use single hop communication to transmit the aggregated data to the BS which results in energy deterioration since the nodes farther from the sink requires high energy. On the other hand, multihop [6] communication will cause unbalanced energy distribution as it creates energy hole nearer to the BS. This is because the fact that the nodes closer to BS suffer high traffic which depletes the energy of those nodes quickly. So it is very important to develop an energy efficient routing protocol which elongate the network lifetime by considering this type of constraints.

Here in our paper, the entire network is divided into several number of zones and two zone masters (primary and secondary) are selected for each zone. A combination of centralized with distributed approach is used for selecting the zone masters. Initially zone masters are elected by the BS which is replaced by the nodes itself in successive rounds. We are using zone IDs to distinguish each zone in the network. Only one of the master will be active at each round of transmission, the other will be in sleep state. Here the masters are selected based on the energy they have. Once sensor nodes sense the data it will forward the same to primary zone master. Primary zone master will aggregate and transmit the data to the BS through a path which is selected based on some parameters: energy of receiver, distance between sender and receiver, distance between sender and BS. After the data transmission, energy level of primary and secondary zone masters are compared witheach other. One having the highest residual energy is again compared with average zone energy. If its energy is lesser than average zone energy, new zone masters get elected and process continues. Otherwise one having the highest residual energy will act as primary and other became secondary zone master. One of the main advantage of this method is that there is no need to select new zone master at each round of data transmission. Therefore communication overhead can be minimized effectively.

This paper is structured as follows: Section II gives a review of various routing protocols so far developed in WSN, Section III describes system model, the proposed energy efficient routing protocol is presented in Section IV, and this is followed by conclusion with future enhancements in Section V.

II. RELATED WORK

Researchers done a number of works for the advancement of routing protocols in WSN based on the application and network structure. However, there are some factors that must be considered while developing such routing protocol. Energy efficiency is one of the most glittering factor that directly affects the network life span. Here we are illustrating some of the energy efficient routing protocols so far developed.

Low Energy Adaptive Clustering Hierarchy (LEACH) [7] protocol proposed by W.Heinzelanet. was the first the clustering protocol that uses a distributed approach to select CHs. Here CHs are randomly selected based on some probability. All other nodes will join under a CH based on the distance towards the head. Here CH selection doesn't consider energy of the nodes. Also this method lacks uniform distribution of cluster head. Since all the nodes have equal probability to select as CH, there is a high chance for low energy node to become CH. This will affects the network lifetime. LEACH-C [8], improved version of LEACH suggests centralized approach to select CHs. Here every node will send its id, energy and position value to the BS. It's the function of BS to picks up some nodes as CH based on their energy. Nodes with energy greater than average energy will be elect as CH for the current round. The main disadvantage of this method is that it dissipates energy of all nodes in each round for sending their information to BS.

D.S. Kim, et.al proposed LEACH-M [9] which describes node mobility that results in large number of packet losses if CH keeps moving before selecting new CH. HEED [10], which uses energy and communication cost for cluster head formation introduces an extra overhead since every node has to communicate each other for specific number of rounds. SEECH [11] protocol suggested by Mehdi Tarhani et.al divides the network into three layers as normal nodes, CHs, and relay nodes. Normally a CH willact as relay to transmit data to BS. Here, energy is saved by selecting relay node to forward the data towards destination. But it introduces an extra workload to select relay nodes for each rounds. Also if the distance between relay to BS is larger, then relevance of selecting relay node will become unnecessary.

R-HEED [12] introduced by W. Mardiniet is an enhanced HEED protocol which conducts cluster reformation based on some rules. At each round, CHs must wait for receiving cluster reformation message. Each cluster will be retained if they doesn't get any message; only CHS get rotated. Here, energy is not considered while rotating the CH. The method of selecting alternate CH is mentioned V-LEACH [13] in which a vice-CH will become a CH in case of CH death. But it is silent on giving a solution in case of vice-CH death. In EDIT [14], CH is selected not only based on energy but also delay is considered. Authors in [15] specifies load balancing by considering hop distances for various clusters.

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S.Lindsey proposed PEGASIS [16] suffers delay for constructing chain to transfer the data to sink. This method selects a leader for the chain which will collect and aggregate information received. In TEEN [17] proposed by A.Manjeshwar, et al; nodes will reports data only when the sensed attribute touches a particular threshold. Hence it is not suitable for periodic data collection. A solution to this was mentioned as APTEEN [18] that can be used in reactive as well as proactive conditions. CCS [19] introduced by Jung illustrates a combinational approach of clustering and PEGASIS. Here a chain with a leader is selected for every cluster without taken into account residual energy. It introduces unbalanced distribution of nodes. TL-LEACH proposed by Loscrì et al. [20] specifies a two-level hierarchy with primary and secondary CH selection without considering energy. It suffers communication overhead due to lots of message passing.

DHAC [21] requires only one hop neighbour information for creating clusters. They create a resemblance matrix based on the input they received from the nodes. Maintaining this matrix imposes an additional overhead to this approach. EECS proposed by Ye et al. [22] requires a complete picture of node distances for making network the more energy efficient. BCDCP [23] proposed by Murugananthan uses single hop communication which makes it not suitable for long distance communication. In [24], an energy efficient load-balanced clustering algorithm (EELBCA) have been proposed that addresses load balancing with energy efficiency. It constructs a min-heap based on CHs and other nodes.

In our proposed paper, an integrated centralized with distributed approach is used for selecting zone masters. Two masters are selected for each zone, but only of them will be active at a time. During each round, energy of zone masters are compared with average zone energy and decides which one should be selected for next round zone masters. Our paper guarantees uniform energy distribution and optimal number of zone masters which provides energy efficient data delivery through an optimal path.

III. SYSTEM MODEL

Sensor nodes N_1, N2 ….Nn are randomly deployed in a square region. Assumptions that we have taken into account while designing our protocol are:

- Nodes are homogeneous in nature and have unique id.
- Initially all the nodes have same energy
- BS is fixed and have a knowledge on nodes location, energy, and id.
- BS is placed outside the deployed square region and all nodes are stationary.
- Nodes are capable to operate in active and sleep mode depending on the situation.
- BS have powerful storage, computational and processing capability.

IV. ENERGY EFFICIENT MULTIMASTER ZONE BASED HYBRID PROTOCOL

The proposed method tries to improve the energy efficiency of WSN by using a combinational strategy of centralized with distributed approach. Here the masters for collecting the sensed data are elected based on energy and an optimal path between nodes are selected for forwarding the data towards BS. Here, entire area is divided into several zones and two masters are chosen for each zone.

Features of this approach:

- Guarantees uniform distribution of zone masters
- Ensures fixed number of masters covering all the nodes
- Zone masters are selected based on energy of nodes
- At first stage, primary and secondary zone masters (PZM and SZM) are selected by BS and pass this information only to the PZM through an optimal path thereby reducing communication overhead.
- Nodes will itself select PZM and SZM in successive round without broadcasting their current status to the BS.

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- Only one of the zone mater will be active and other is in sleep state.
- Once zone is partitioned, it will remain their forever; only zone master will get updated.
- Zone master will get updated only if the current zone masters energy is lower than average zone energy.
- Uses multi-hop communication and suitable number of next hops for transferring the collected data to BS.
- Next hop is selected based on some parameters: distance between sender and receiver, distance between sender and BS.

Major steps to be carried out in our proposed protocol:

a) Zone partition
b) Initial PZM and SZM selection
c) Announcing master information
d) Joining of sensor nodes under each master
e) Data collection and transmission
f) Zone masters updating

A. ZONE PARTITION & INITIAL MASTERS SELECTION

Initially sensor nodes are randomly deployed in a square plot (XxY) where X and Y are same. BS having a knowledge on node position, initial energy and id will partition the entire network area into equal sized zones and allot unique zone ids. Here width of the zone can be taken any positive integer value that must divide the area equally and cover entire nodes.

```
Algorithm1: Zone_Partition()

Input: Node id, location and X and Y co-ordinate of
       Region

Output: Partitioned zone with id, total number of
        Zones n

Initialize x=0,zn=0
Set width of zone as w
while(x<X)
        Initialize y=0
    while(y<Y)
        ((x,y),(x+w,y),(x+w,y+w),(x,y+w))←Zid
        y=y+w
                zn=zn+1
        x=x+w
n=zn
```

Once zones are formed, then two masters called primary and secondary zone masters (PZM and SZM) are selected for each zone having highest energy. In Fig.2. Gray colour circle denotes PZM and black coloured circles denote SZM.

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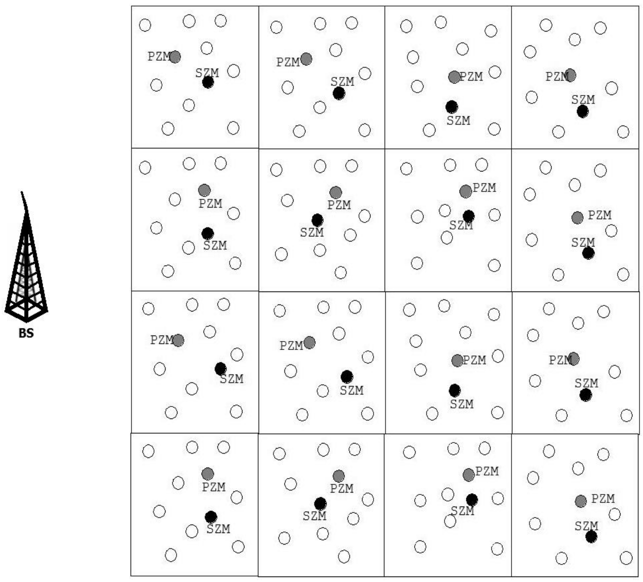
B. ANNOUNCE MASTER INFO & JOINING OF NODES

After selecting PZM and SZM, BS will forward the (PZM,SZM,Zid,XPZM,YPZM,,Ni) list to the PZM nodes nearer to it. Then each PZM determine a shortest path to other PZM and send this master info. Here the decision list is passed only through the PZMs. This will reduce the network traffic and communication overhead.

Each PZM then send this master information to every node under that zone. A SZM which receives this information will move on to sleep state. All other nodes will reply PZM with JOIN_MSG.



Algorithm2: Announce_Master_Info()

Input: a constant c, (PZM,SZM,Zid,X_{PZM},Y_{PZM},N_i)
Output: next-hop PZM forming shortest path

for i=1 to n
    d_{ref}=c
    for j=i+1 to n
        d=dis(PZM_i,PZM_j)
        if($d<d_{ref}$)
            dref=d
            next_hop=PZM_j
    end for
    next_hop←(PZM,SZM,Zid,X_{PZM},Y_{PZM}, N_i)
end for

Fig2. Zone partition and PZM,SZM selection

C. DATA COLLECTION AND TRANSMISSION

Nodes joining under each PZM will forwards the sensed data to their corresponding PZM. Fig.3. shows data collection by PZM from sensor nodes. Later PZM transmit the aggregated data to the BS via multiple hops.

The hops are selected considering mainly two parameters: distance between PZM sender and PZM receiver, distance between PZM sender and BS (Fig.4) . If dis(PZMi,PZMj) is lesser than dis(PZMi,BS), then next hop is PZMj where each PZMi will compare its distance towards every PZMj.. Otherwise data can be directly send to BS. TDMA can be used to scheduling the data collection from each zone.

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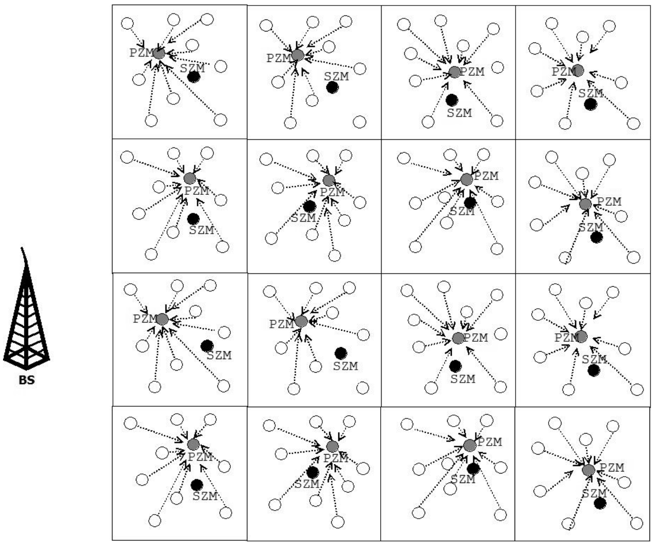

Fig3. Data collection to PZM

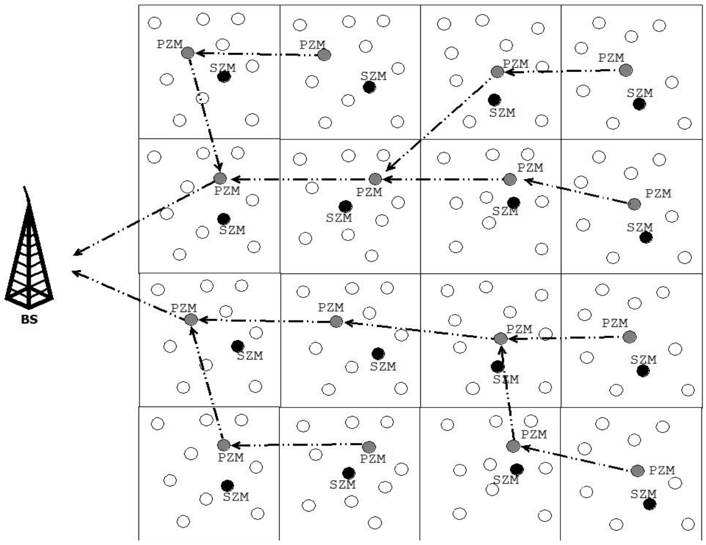

Fig4. Data transmission to BS

D. ZONE MASTERS UPDATING

After every round of data transmission, a decision should be taken whether to select new zones masters or not. This is done by comparing the energy of zone masters with average zone energy.

If any of the current zone masters energy is greater than average zone energy, then there is no need to select new masters. Also if PZM is still having energy higher than SZM and average zone energy, then no need of selecting new masters. A swapping of PZM and SZM will takes place if SZM have energy greater than PZM and average zone energy. Before all this, the SZM should be waked up from sleep state. Fig 5 shows this energy comparison.

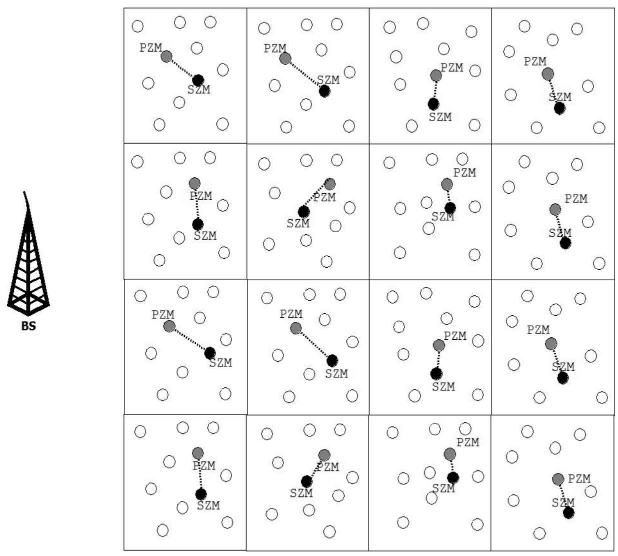

Fig.5. Energy comparison of Zone Masters with Average Zone energy

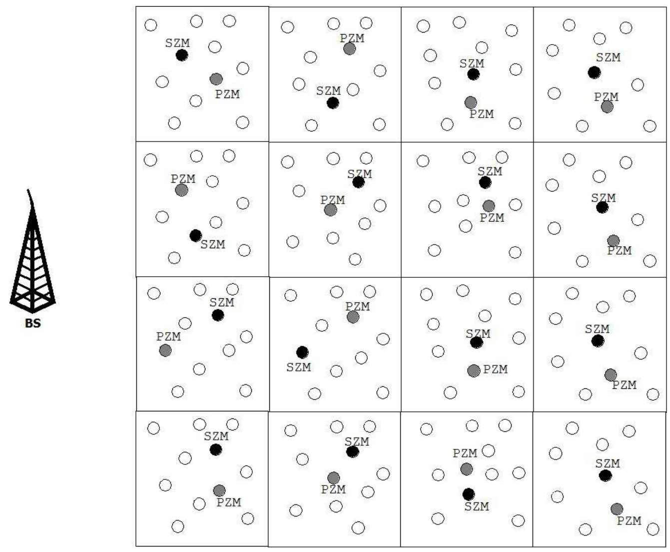

Fig 6. New Zone masters.

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Based on the energy comparison some zones undergo swapping and others will find out new PZM and SZM. Fig 6 shows the New Zone masters for the next round. The New zone masters should inform their status to other nodes and process continues. The flowchart illustrating the working of proposed protocol is shown in Fig.7.

The complete algorithm is given below:

```
Algorithm 3: EEMZH
  Input: set of sensor nodes N1,N2…..Nn  deployed in XxY
        region
  Output: Energy efficient data delivery through optimal
        path

 1.  Zone_Partition()
 2.  for each zonei,
 3.    select PZMi and SZMi with highest energy
 4.  end for
 5.  Announce_Master_Info()
 6.  for each zonei,
 7.    for each PZMi,
 8.          Ni←(Zid,PSMi,SZMi)
 9.          if Ni=SZMi then
10.                 goto sleep state
11.          else
12.                 send JOIN_MSG to PZMi
13.    end for
     //Data Collection
14.    Each node Ni sense data
15.    PZMi←data(Ni)
     //Data transmission to Base Station
16.    for each PZMi,
17.          if dis(PZMi,PZMj)<dis(PZMi,BS)  then
18.                 next_hop=PZMj
19.          else
20.                 next_hop=BS
21.    end for
22.    wake up SZMi for next round.
         //Masters updating
23.    if EPZMi>ESZMithen
24.          if EPZMi>Ezone_avgthen
25.                 no change in masters
26.                 process continues
27.          else
28.                 Select PZMnew, SZMnewhaving
                    highest energy
29.    else
30.          If ESZMi>Ezone_avg
31.                 Swap PZMi and SZMi.
32.          else
33.                 go to step 28.
34.  end for
```

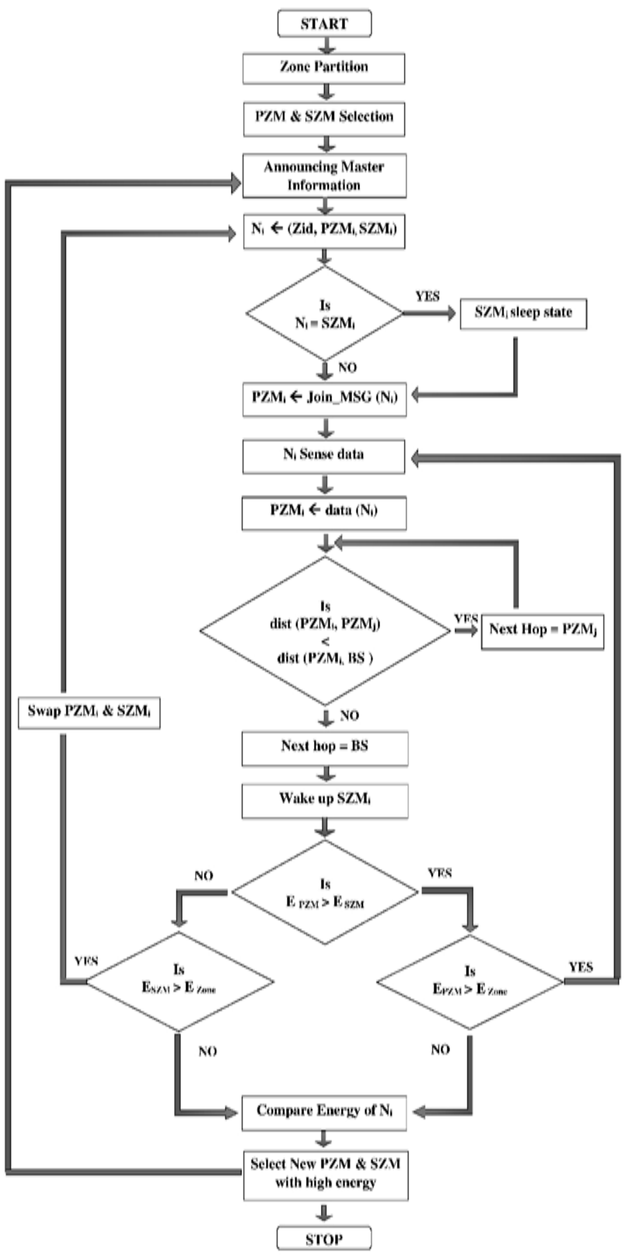

Fig.7. Flowchart of EEMZH Protocol

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V. SIMULATION AND RESULTS

To evaluate performance and working, we implemented our project in NS2. Main parameters to be initialized are given below:

Table.1.

Parameters	Values
Number of nodes	53
Channel Type	Channel/Wireless Channel
Initial Energy	100
Packet Size	128 bits/packet

Initially, topology was created with given number of nodes. After that it is divided into specific number of zones and zone masters are selected (Fig.8). Once the nodes identifies their masters, they send the data to the corresponding PZM. (Fig.9).

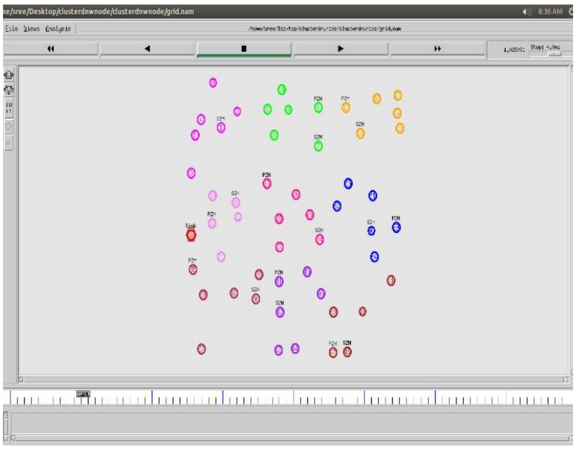

Fig8.Zone divion and master selection

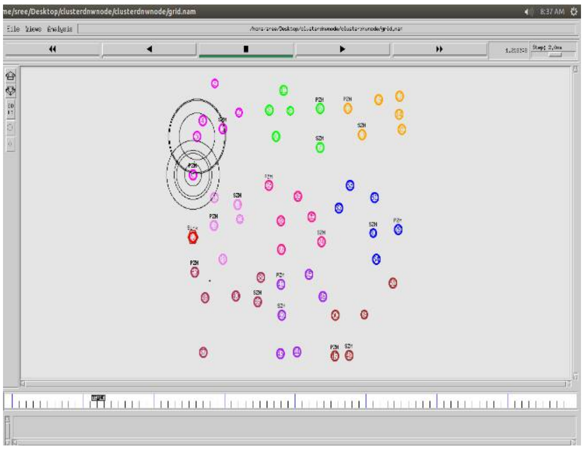

Fig.9.Data to PZM

Once data is collected, they will forward the data to BS by choosing suitable number of hops based on distance. (Fig.10). After specific time period, zone masters get updated based on their energy and average zone energy. (Fig11).

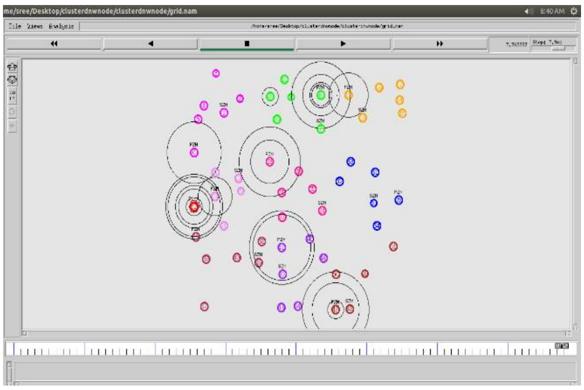

Fig.10.Data transmission to sink

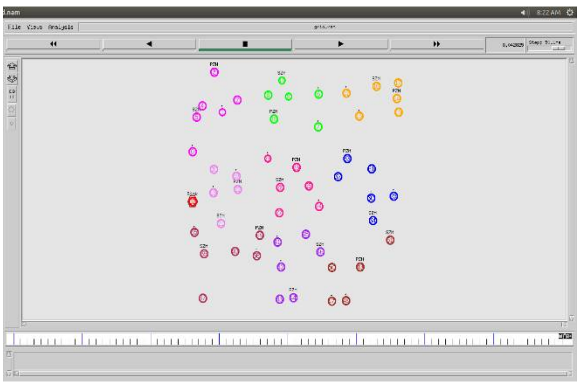

Fig.11.Zone masters updation

We consider average energy consumption (Fig12) and residual energy (Fig.13) for evaluating performance.

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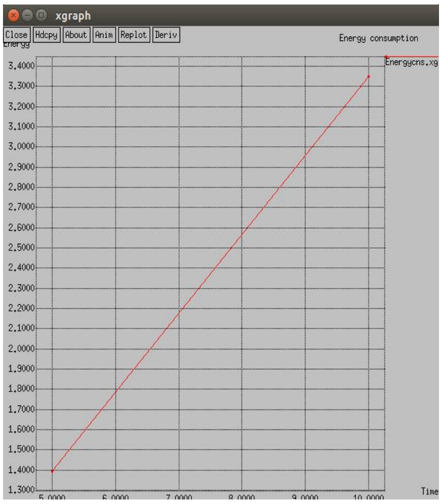

Fig.12.Average energy consumption

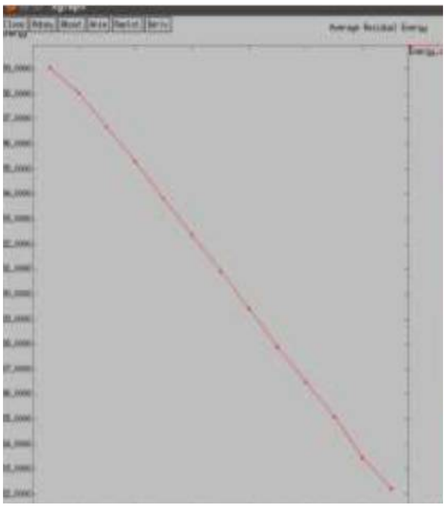

Fig.13.Average residual energy

Average energy consumption is the amount of energy consumed in average by all nodes in the deployed area. We can see that the amount of energy consumed in each time interval is low. Initially the nodes have an energy of 100. At each round, this energy will reduce, but the amount of reduction is low. From the figure we can see that the nodes have sufficient amount of residual energy after each round of communication.

VI. CONCLUSION AND FUTURE WORKS

Wireless sensor networks play a key role for the efficient data collection and delivery. One of the most challenging issue faced by WSN is energy efficiency due to limited battery power. Due to this, an energy efficient techniques and routing mechanisms should be used that will assure network connectivity and data delivery.

Here we are proposing a method that combines centralized with distributed approach for selecting zone masters based on energy. Nodes having highest energy are selected as PZM and SZM for each zone. Each nodes sends their data to the corresponding primary zone master. From there it will be transmitted to BS via other PZMs. That is here multihop communication is used which will reduce the overuse of energy in direct communication. During the beginning of each round a decision is taken “whether new zone masters to be elected”. New zone masters are taken only average zone energy is higher than master’s energy. Our paper guarantees fixed number of zone masters and ensure uniform distribution of energy. It also reduces communication overhead by announcing master information to PZMs only through selected next hop based on distance. There arise a need for selecting new zone masters only if their energy is less than average zone energy. Data is delivered to the BS by selecting a path that covers PZMs having shortest distance.

As future work, we can consider node density and centrality as an extra parameters for selecting ZMs along with energy. To make it more efficient fuzzy logic can be used in master selection. Also we can address any of the security mechanism to make it free from attacks.

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