EEOCMR: An Energy Efficient Optimal Clustered Based Multi-hop Routing protocol for WSN

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Abstract

In wireless sensor network (WSN), the existing energy efficient aware routing protocols considers only energy of particular node which may not be sufficient judge the node state. Also there is necessity to increase the load balancing. Hence in this paper, we propose clustered based multi-hop routing protocol for WSN. Initially the nodes deployed in the network which are analyzed for identifying suitable cluster head. The main objective of this protocol is to identify the energy wastage while processing data transmission to the corresponding Base station. In this protocol we propose an optimal route selection and optimal cluster head selection strategy process to increase the network efficiency for heterogeneous WSN , we organized this experimental process using Ns2 simulator to determine protocol efficiency by comparing with existing Hierarchical Energy-Balancing Multipath routing protocol.[15].

Keywords : WSN, Energy Aware Routing, Clustering, QoS

1 Introduction

A wireless sensor network [1] is a group of specialized transducers with a communications infrastructure for monitoring and recording conditions at diverse locations. Commonly monitored parameters are temperature, humidity, pressure, wind direction and speed, illumination intensity, vibration intensity, sound intensity, power-line voltage, chemical concentrations, pollutant levels and vital body functions.

A sensor network consists of multiple detection stations called sensor nodes, each of which is small, lightweight and portable. Every sensor node is equipped with a transducer, microcomputer, transceiver and power source. The transducer generates electrical signals based on sensed physical effects and phenomena. The microcomputer processes and stores the sensor output. The transceiver receives commands from a central computer and transmits data to that computer. The power for each sensor node is derived from a battery.

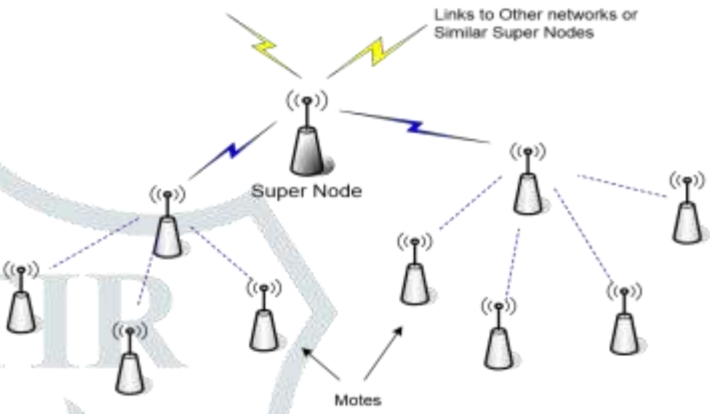

Fig 1 Wireless Sensor Network [2]

Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth. The topology of the WSNs can vary from a simple star network to an advanced multi-hop wireless mesh network. The propagation technique between the hops of the network can be routing or flooding.

Due to recent technological advances, the manufacturing of small and low cost sensors became technically and economically feasible. The sensing electronics measure ambient conditions related to the environment surrounding the sensor and transform them into an electric signal. Processing such a signal reveals some properties about objects located and/or events happening in the vicinity of the sensor. A large number of these disposable sensors can be networked in many applications that require unattended operations.

In WSN many energy efficient protocols have been specifically designed, where energy awareness is an essential design issue. To meet the new challenges, innovative protocols and algorithms are needed to achieve energy efficiency, flexible scalability and adaptability and good networks performance. A constraint of batteries is a big issue in WSNs. WSN will generally comprise of a multi-hop routing scheme. This and other routing challenges were discussed and brought to the front, as should be considered when designing any new routing protocols or algorithms. So one of the biggest issues in sensor networks is limited energy of network nodes; so making good use of energy is necessary to increase lifetime of networks. Based on the discussion, seeks to develop improved model of routing protocol for WSN by carrying out extensive simulations.

Nodes in a WSN are generally resource constrained such has low memory and energy. Energy consumption is an important aspect in WSNs and thus some algorithms [3-9] and energy awareness as a central focal point of interest.

After much study on merit and demerit of wireless sensor network routing protocols, we conclude that we will focus to work on these consideration to further reduce the energy consumption to enhance the lifetime of networks.

- The protocol should be scalable and effectively functioning for networks of big size.
- The protocol minimizes computational complexity for the nodes, increase the lifetime of network.
- The protocol must limit the number of required transmissions, thus enhance the lifetime of network,

In this paper we propose an Energy Efficient Optimal Clustered Based Multi-hop Routing protocol for WSN (EEOCMR) is developed. In the EEOCMR, the network is divided into virtual zones, and clusters are formed in each zone with a cluster head. The cluster head is selected based on its residual energy, node degree, and the distance from the centroid of the zone. Once a cluster head is selected, a route is formed using these cluster heads, i.e., all cluster heads are treated as the vertices of the routes. Cluster heads aggregate the data and transmit it to the sink via this optimal route. The number of cluster heads is restricted to the number of zones present in the network.

2 Background

From a technological viewpoint, there are two distinct ways for networking of wireless devices: infrastructure networking and multi-hop networking. Infrastructure networking is now widely used in cellular networks for mobile telephony. Wireless devices outside of transmission range of each other are linked together through centralized base stations (see Figure 1.1). Wireless multi-hop networks, on the other hand, allow device-to-device communication even if devices are not within each others transmission range. In this architecture, wireless devices detect each other, establish local links between each other, and form a wireless network in a completely self-organized way without the need for expensive establishment of an infrastructure.

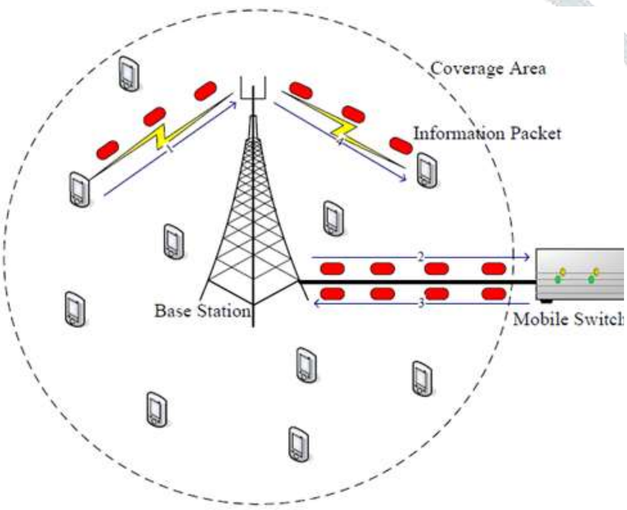

Fig 1.1 Infrastructure Wireless Communication [3]

Multi-hop communication is a well-established method in packet-switched networking. It has enabled scalable expansion of the Internet, where information packets are routed between hosts hop-by-hop through intermediate routers (see Figure 1.2(a)). This architecture could be used in wireless networks on a smaller scale to provide local services, i.e., each wireless device can act as a router to forward information packets on behalf of other wireless devices (see Figure 1.2(b)). While infrastructure-based communication in cellular networks provides country-wide coverage for mobile users, wireless multi-hop networks can support variety of localized applications.

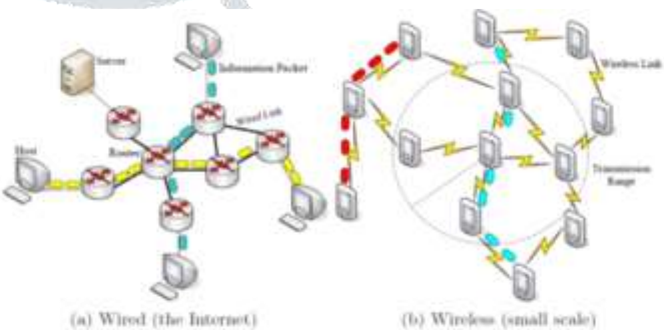

Fig 1.2 Wired and Wireless Multi-hop Communication [3]

3 Network model and assumptions

Without loss of generality, in our research, we consider a Heterogenous Wireless Sensor Network (WSN) of n energy-constrained sensor nodes, which are randomly deployed over a sensing field. The BS is located at a corner of the sensing area, and equipped with a directional antenna and unlimited power. As a result, the BS can adaptively adjust its transmission power level and antenna direction to send control packets to all nodes in the WSN. Besides, for easy discussion, we define some notations as follows: R: the transmission range of the BS. For simplicity, we use distinct integers (1 … n) to represent various ranges.

θ: the beam width (covering angle) of the directional antenna.

Also, similar to the definition of R, different integers (1 … n) are used to indicate distinct angles. $G\theta$, R : the group id. Theoretically, by changing different values of θ and R, the sensing area can be divided into $n * n$ groups. Those are $G1$, 1, $G1$, 2, …, $G1$, n, …, Gn, 1, …, Gn,, n. ni: the node i; the node set N={$n1$, $n2$, $n3$, …, ni}, where $1<i<|N|$. cx,y: the id of a route which was formed in group Gx,y. The route set C={$c1$,1, $c1$,2, ….}. lx,y: the leader node id of route cx,y. The leader set L={$l1$,1, $l1$,2, ….}.

neighbor(ni): the neighboring nodes of ni. The neighboring nodes mean the nodes which are locating in the transmission range of a specific node.

Res(ni): the residual energy of node ni.

dis(*x*, *y*): the distance between nodes *x* and *y*. The BS can be deemed as a special sensor node.

After the sensor nodes are scattered, the BS gradually sweeps the whole sensing area, by successively changing different transmission power levels and antenna directions, to send control information (including the values of *R* and *θ*) to all nodes. After all nodes receiving such control packets, they can easily determine which group they are respectively belonging to. In addition, by the received signal strength indication (RSSI), every node can also figure out the value of *dis*(*ni, BS*).

4 Energy Efficient Clustered Based Multi-hop Routing protocol

In this paper, we design an Energy Efficient Optimal Clustered Based Multi-hop Routing protocol (EEOCMR). This Protocol is the combination of four different schemes; one is for cluster formation in the entire network, cluster head selection, optimal multi-hop route selection, data scheduling. In the protocol, the entire network is divided into equal-sized zones, and clusters are formed within each zone. The cluster formation procedure presents the clustering process which is discussed in section 4.1, once the network was clustered, the cluster head selection process procedure was shown in 4.2, after the cluster head the route discovery process for data distribution was presented in 4.3. After the route selection process the data scheduling and load balancing process was explain in 4.4.

The main aim of this protocol to address the energy issues in WSN to enhance the sensor life, the main contribution of this research work is the novel way of selecting cluster head and optimal multi-hop route selection in WSN. While comparing to other routing protocols such as CELRP[16], and LEACH[14] where by cluster head selection process was organized randomly which are based on their respective residual energy. In EEOCMR we considered different parameters such as distance from the sink, energy level, and the average distance of neighboring nodes from the candidate CH node.

4.1 Cluster Formation

The zone formation considers each node location with the assistance of location finding GPS [10][11][12]. The cluster establishment in equally sized square zones which takes very less control overhead. Initially derive the each zone which can communicate with adjacent zones in horizontally $Z_h = \frac{S}{\pi r^2}$, where $Z_h$represent horizontal zones, S is the network size, πr^2 is the communication radius. Afterwards each horizonal zones divides into the equal vertical zones by dividing the each horizontal zone as $Z_v = \frac{Z_h}{\sqrt{\pi r^2}}$. The entire network formation of different clusters were shown in figure 4.1

The coordinates can be calculated based on the node's location (x, y) as:

$$X = \left[\frac{x}{Z_h}\right] \quad Y = \left[\frac{y}{Z_v}\right]$$

A cluster formation model organizes the equal zones and deployed all nodes by estimating nodes (X,Y) coordinates.

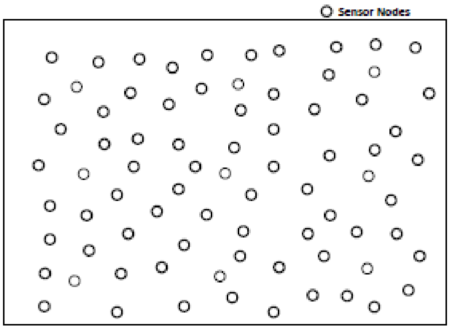

Fig 4.1: Initial network

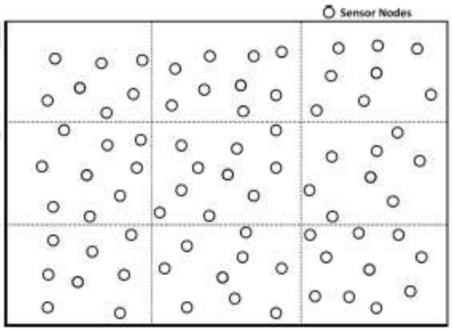

Fig 4.2: Network after zone partition

4.2 Cluster Head Selection

A cluster head selection process computed all the nodes characteristics such as energy threshold, node degree (Number of neighbour nodes), node position, distance to the sink node, to elect a suitable cluster head. To know each node characteristics, here we maintain node characteristics table, this table represents each node characteristics. The below table represents node characterstic table. The node energy status is measure as follows

Let consider each node status such as sensing, receiving, transmitting and idle status as $S = \{S_0, S_1, S_2, \ldots, S_n\}$

The state of node keeps changing during the process of data transmission or reception at time t_1. In time duration t_n, the probability that the node changes its state is denoted using Equation (1) [9]

$$P_{xy}^{n} = P\{S_n = y \mid S_0 = x\} \quad (1)$$

Where x and y represents two different stats

The node state probability P_{xy}^{n} is computed using the following equations:

$$P_{xy}^{n} = \sum_{z=0}^{n} P_{xz}^{(i)} P_{zy}^{(n-i)} \quad (2)$$

The probability of each node state in a same status is derives with the time duration T u using the equation (3)

$$TS = \sum_{t=1}^{T} P_{xy}^{n} \quad (3)$$

The energy dissipated in the subsequent time duration TS is estimated using Eq (4), which consider the four different node stats as sensing, transmission, receiving and idle.

$$E_d = \sum_{y=1}^{4}\left(\sum_{t=1}^{T} P_{xy}^{n} * E_y\right) \quad (4)$$

The remaining energy (RE_i) of each node (N_i) in the susbsequent time duration is measure as

$$REi = Eini - (Etx + Erx) \quad (5)$$

Where E_i = Initial energy of the node

E_{tx} & E_{rx} = energy utilized at the time of transmission and reception of data.

4.2.1 Node Degree

Each node have defined communication range, some of the nodes are placed at different positions, while choosing suitable cluster head its essential to consider number of neighbour nodes surrounded to the node. To determine node velocity, first we estimate the distance by using Euclidian distance function, this function contains distance across set of nodes in a cluster, in equation (6) we derive the each node distance, afterwards , the node degree threshold presents the threshold rate value to extract a neighbour nodes. The flowing equation (6) derives the node degree of each node.

$$D_{N_i} = \sum_{i=1}^{n-1} \sqrt{(X_i - X_{i-1})^2 + (Y_i - Y_{i-1})^2} \quad (6)$$

D_{N_i} represent distance of each node, X,Y represent each node coordinates. Based on the node distance from node to the sink node we determine the group of neighbour nodes

$for\ i: 1\ to\ n$
$if\ (D_{N_i} \leq CR)$
$Add\ node\ i\ to\ neighbor\ set\ \{S_i\}$
$end\ if$
$end\ for$

Where CR is communication range, S_i is neighbour set

Nodes	Energy Threshold	Neighbor nodes/ node Degree	Distance to Sink	Node position
A	RE_A	B,C,D,E,F / 5	D_A	(A_x, A_y)
B	RE_B	C,D,E,F,G / 5	D_B	(B_x, B_y)
C,	RE_C	E,F,G / 3	D_C	(C_x, C_y)
D	RE_D	E,G / 2	D_D	(D_x, D_y)
E	RE_E	B,C, / 2	D_E	(E_x, E_y)
F	RE_F	C,D,A /3	D_F	(F_x, F_y)
G	RE_G	E,F,C,D /4	D_G	(G_x, G_y)

Table 1: Node characteristics table

The CH selection derived based on the table-1 data, the following technique derives the CH selection process

Step 1: First, Initialize the parameters to 0 or null.

$CH_{cur} \leftarrow 0$
$CH_{prev} \leftarrow 0$
$Time_{prev} \leftarrow 0$
Curr () ← 0

Step 2: Calculate the Average Node character data based on the equations (5) (6)

$$CH_{i,j} = \sum_{i=1}^{n-1} P_E(i,j) + P_{Dist}(i, Sink) + P_{ND}(i)$$

P_E is energy probability, P_{Dist} distance probability, P_{ND} node degree proabability

Step 3: Compare the given condition to select CH

While ($Time_{prev}$_Curr () ≤ 1 =true) do
CH_{prev} remains as Cluster Head
End while

Step 4: Compare Average node character data of previous and current Cluster Head

If Avg(CH_{prev})=Avg(CH_{cur}) and Cost(CH_{prev})=Cost(CH_{cur})
then
both CH_{prev} and CH_{cur} remains as cluster heads
Else
select new Cluster Head
Select new cluster head(s)
end if

Algorithm 1: Clustering and CH selection

Step 1: Select the total number of nodes to be deployed to form wireless sensor network as 'N'.

The node Si is symbolized by its i-th value and corresponding set of sensor nodes S= {s1, s2, s3, ….sN} where mod S = N and N represents the total number of sensor nodes deployed.

Step 2: Select the deployment area for the sensor nodes. Also fix the location for BS

Step 3: Let the optimal number of nodes in a cluster be 'k'.

'k' can be any value from the maximum limit being 5% of remaining nodes i.e. 5% of all sensor nodes can become CH.

$$k = \frac{remaining\ nodes}{optimal\ CH}$$

Step 4: The cluster count begins initially with 0.

Step 5: Check condition for cluster count is less than or equal to 'k'.

a) If cluster count <= k

- Select 2 border nodes among the unclustered nodes as BN1 and BN2

- Form 2 clusters with 'k' nearest nodes to BN1 and BN2 i.e.

  cluster A = BN1 + (k-1) sensor nodes closest to BN1
  cluster B = BN2 + (k-1) sensor nodes closest to BN2 respectively
  where BN = border nodes

b) If cluster count not equal to k

- Select CH for all clusters

- Create MST where all CH are connected with each other to find a routing path which consumes minimum energy for each CH

- Select a forwarding CH (FCH) node to forward data to the distant BS

- Data transmission (each node to respective CH based on schedule creation ID)

Step 6: When CH receives all data from the nodes then performs data fusion to BS by FCH through the CH-to-CH routing paths and then fused data is transmitted to BS
Step 7: If a node doesn't die, we select CH for all clusters again i.e. step 5 b).
Step 8: If node dies, then
Remaining nodes = remaining nodes – dead nodes
Step 9: These steps are repeated until remaining nodes to form clusters becomes 0.

4.3 Cluster Based Optimal Route Selection

The cluster based route selection process need to derive the optimal path to avoid overhead, to derive the optimal path we modify existing routing packet, the following algorithm determines the optimal route discovery model. For route discovery process, a cluster head (CH) node in each cluster must be selected for collecting and forwarding the aggregated data to the Base Station(BS).

Each node in the network is assumed to be aware of the geographic position of itself and the destination too. This is further exchanged among 2-hop neighbours. This is achieved by two rounds of HELLO messages, with first HELLO message, each node informs its neighbours about its existence(ID, position, remaining energy etc), with second HELLO message each node sends message to all its neighbours informing about its one-hop neighbours.

Unlike the PEGASIS[13] and LEACH[14] schemes, in which the leader in each chain is elected in a round-robin manner, chooses the chain leader (*lx,y*) based on the maximum value *Res*(*ni*) of group nodes. Initially, in each group, the node farthest away from the BS is assigned to be the group leader. After that, for each data transmission round, the node with the maximum residual energy will be elected. The residual power information of each node *ni* can be piggybacked with the fused data to the cluster leader *lx,y* along the cluster *cx,y*, so that the cluster leader can determine which node will be the new leader for next transmission round.

Algorithm -2 Cluster Based Route Selection process
Step 1: Source node sends a RREQ packet to the neighbours for route discovery
Step 2: Neighbour node will check RREQ packet for future process to reach destination
Step 3: Discovery node distance to identify neighbour nodes and to identify optmal hop by hop communication
Step 4: In order to avoid the route rediscovery process when active route or link failure, EEOCMR determines the RREP packet with timestamp
Step 5: Relay value and forward vales are changed based on information provided in the duplicate RREQ packets.
Step 6: We modify RREQ packet format by organzing source address, destination address and previous interaction details (P) (Last address)
Step 7: The last address field maintains the last transaction of the forwarded node
Step 8: When a node receives a RREQ with TTL value as 0 or the duplicate RREQ, i.e. with the same broadcast ID that has been processed before, it will check for the P-Addr field in the RREQ.
Step 9 : If that particular node address is same as the P-Addr in RREQ with same packet, then the Relay value of that node will be set to 1. It means that the node will participate in the search process of the destination.
Step 10: Else, the node will not participate in the route discovery process.

4.4) Data Collection and Transmission Phase

After completed the previous three phases, the data collection and transmission phase begins. The data transmission procedure represent data collection and data distribution across network with a elected cluster heads. Initially a group of cluster members in a cluster shares a data to the cluster head, after wards, the cluster head distribute a data on over discovered optimal path to the next cluster head to distributed overall data to sink node or base station. The normal nodes in each group *Gx,y* transmit their collected data along the *cx,y*, by passing through their nearest nodes, to the cluster leader *lx,y*. And then, starting from the farthest groups, the chain leaders collaboratively relay their aggregated sensing information to the BS, in a multi-hop, leader-by-leader transmission manner. In order to avoid a longer transmission distance incurred between two cluster heads, and thus result in a great amount of energy dissipation,

5 Simulation Results

This section presents the performance evolution of energy efficient optimal cluster based multi-hop routing protocol for HWSN to determine the efficiency for various network scenarios and various energy rates, we configure multiple network models to achieve energy efficiency in Heterogenous WSN by configuring different energy rates to nodes, we measure the proposed model efficiency by considering various network topologies. This section presents the comparative results between EEOCMR and Hierarchical Energy-Balancing Multipath routing protocol (HEBM) [15]

5.1 Simulation Model and Parameters

We use Network Simulator Version-2 (NS2) to simulate our proposed protocol. In our simulation, the channel capacity of sensor nodes is set to the same value: 2 Mbps. We use the distributed coordination function (DCF) of IEEE 802.11 for wireless LANs as the MAC layer protocol. It has the functionality to notify the network layer about link breakage.

In our simulation, sensor nodes are deployed within the area of 1000 meter x 1000 meter region for 20 seconds simulation time. All nodes have the same communication range of 250 meters. Our simulation settings and parameters are summarized in table 2

No. of Nodes	20,40,60,80 and 100.
Area Size	1000 X 1000
Mac	802.11
Radio Range	250m
Simulation Time	20 sec
Traffic Source	CBR
Packet Size	512
Receiving Power	0.395
Sending power	0.660
Idle Power	0.035
Initial Energy	10.3 J
Rate	50,100,150,200 and 250Kb

Table 2: Simulation Settings

5.2 Performance Metrics

We evaluate mainly the performance according to the following metrics.

Average Packet Delivery Ratio: It is the ratio of the number .of packets received successfully and the total number of packets transmitted.

Average Throughput: It is the average number of packets reached at sink node at time instance

End-to-End Delay: It is the time taken by the packets to reach the receiver.

Energy Consumption: It is the amount of energy consumed by the nodes for the data transmission.

4.3 Results

A. Based on Nodes

In our first experiment we vary the number of nodes as 20,40,60,80 and 100.

Fig 4: Nodes Vs Delivery Ratio

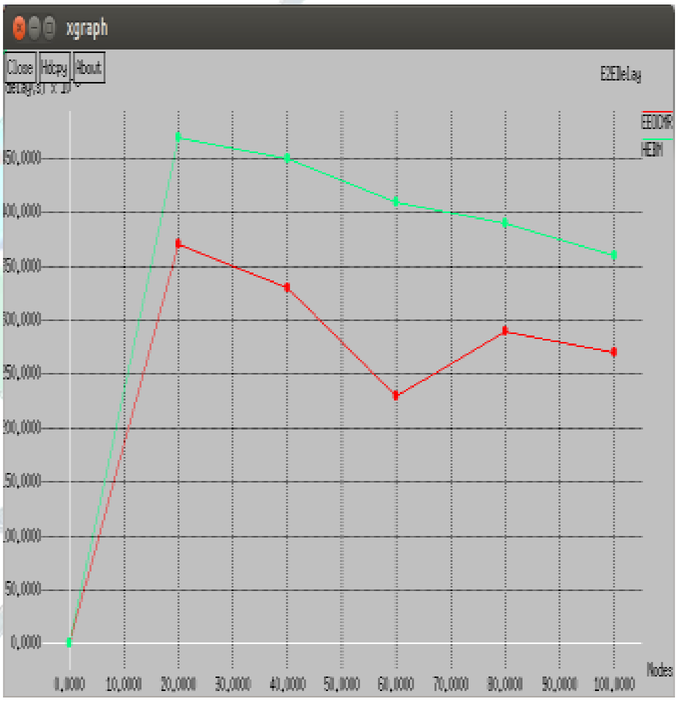

Fig 5: Nodes Vs Delay

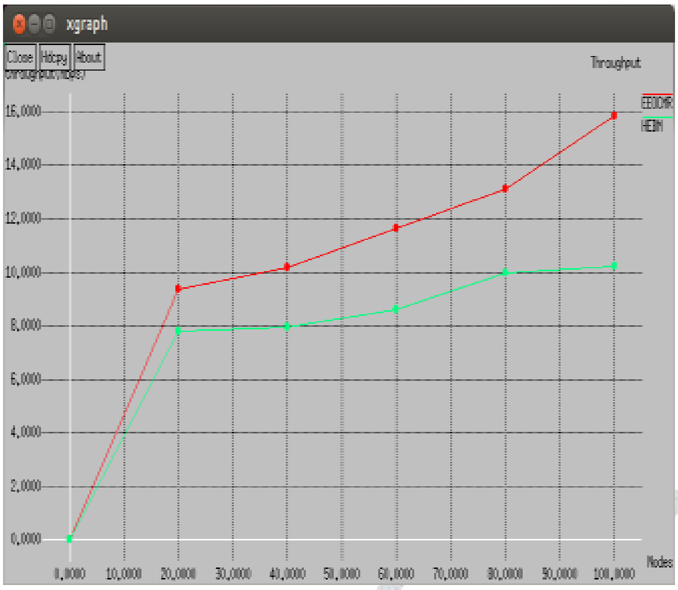

Fig 6: Nodes Vs Throughput

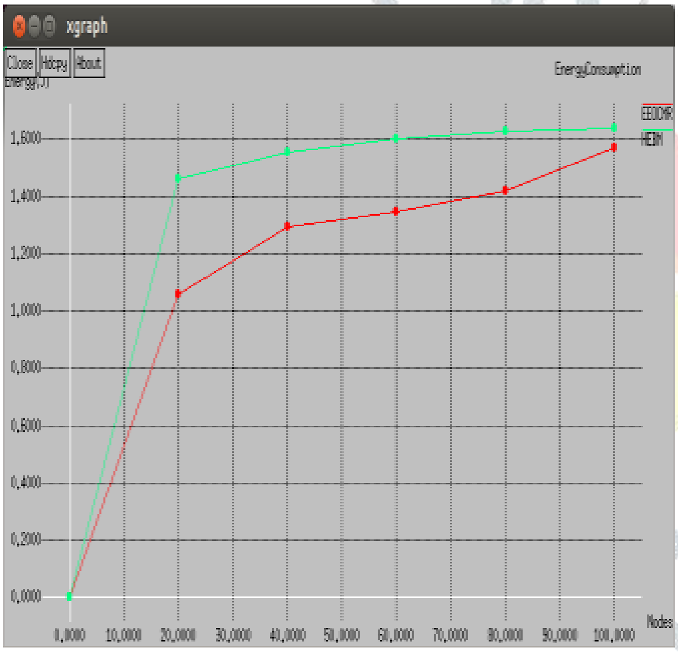

Fig 7: Nodes Vs Energy

From figure 4, we can see that the delivery ratio of our proposed EEOCMR is higher than the existing PDORP technique.

From figure 5, we can see that the delay of our proposed EEOCMR is less than the existing HEBM technique.

From figure 6, we can see that the throughput ratio of our proposed EEOCMR is higher than the existing HEBM technique.

From figure 7, we can see that the energy consumption of our proposed EEOCMR is less than the existing HEBM technique.

6. Conclusion

In this paper, we have proposed a clustered based multi-hop routing protocol for WSN. Initially the nodes deployed in the network are analysed for identifying the suitable cluster head based on the node characteristics table data. If the probability rate of node is greater than the predicted threshold, the node is considered as cluster head node. A cluster is formed in each zone, and a cluster head is selected. EEOCMR creates a route using these cluster heads. EEOCMR can manage the network size without affecting the route formation structure. It balances the load among the sensor nodes which increases the network lifetime. Simulation results showed that EEOCMR outperformed HEBM in terms of energy consumption, end-to-end delay, and data delivery ratio. By simulation results, we have shown that the proposed technique is more energy efficient. In future work, we extend this research study to increase energy efficiency by configuring mobile sink, where this can reduce the load during data gathering at each sensor

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