Energy Efficient Clustering based Bio-Inspired MST Routing Protocol (EECMSTR)

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Abstract

In wireless sensor network (WSN), Energy consumption in network is highly immerses area for the researcher. For monitoring and communication in network require the power and entire sensors node operated through battery. Number of research carried out for designing energy efficient protocol for wsn. Our proposed protocols also reduce the power consumption in network through three different levels. First one is forming the highly correlated sensor node forms a cluster than second is selection of cluster head through multi-criteria decision making approach and third is intra and inter-cluster communication of data routing through minimum spanning tree. In this paper, we implemented proposed Energy efficient clustering based bio-inspired MST routing protocol in MATLAB simulator. The simulation carried out with certain parameters like network size, no of nodes, no of cluster, packet size and many more. We also implemented proposed protocol through hardware. The simulation result shows that the proposed protocol (EECMSTR) performed batter than traditional protocols like LEACH, HEED and EECRP in terms of energy consumption, throughput, network lifetime, packet delivery ratio, end to end delay, bit error rate and jitter.

Keyword

WSN, Power consumption, k-mean Clustering, Minimum spanning tree, EECMSTR

I. INTRODUCTION

Wireless sensor network consist numbers of sensors node for monitoring or observing the environment. The environment conditions looks hazard, forest, harsh or some time underwater. The sensor node measures the conditions of environment such as water level, humidity, distance, temperature and many more. The sensor nodes collect the information from the environment and store at the central place. The role of sensor node in WSN is for the monitoring as well the communication.So In sensor industry the main approach for sensor design are less cost, low power consumption and small size use in various wsn applications. The sensors are capable for data receiving, transmitting and processing. The sensors collected the data or packets from the environment are transmitted to the base station or sink node. A sensor node is consists the sensor, micro-controller and battery. Major drawback of the sensor node is the power consumption. When the sensor node transmitting data and communicating with other nodes it use the energy from their battery.However the clustering process, cluster head selection and data routing are consider the most promising area [1,2] So Motive behind the research is reducing the energy consumption throughout the whole communication.

Initially all nodes are deployed in environment in random order. The cluster formation, cluster head selection and data routing are main steps for the creating energy efficient protocols. Clustering is technique for divided group of sensors node. The group is form of nodes depending on the residual energy or Euclidian distance. Using the clustering we can maintain the bandwidth in network as well reduce the communication cost through intra and inter cluster communication. So managing the whole network is difficult rather managing the cluster node. One sensor node representing the whole cluster is called cluster head. The selection process of cluster head in many ways. We use multi criteria decision making approach for cluster head selection. There are various applications of WSN used in our life in different aspact like healthcare, agriculture, security and military many more [3]

Using the cluster head we can reduce the cluster overhead. In cluster one is head and other node act as member node. All the members node communicate or send data to the cluster head and cluster head is responsible for the further sink node communication so with this approach we can optimize the energy level and enhance the life of network. In addition with the clustering technique data routing among the intra cluster and inter cluster communication play major role for enhance the battery life and energy consumption [4, 5]. Many challenge or parameters effected while implementing routing technique in protocol like energy consumption during the communication, node structure, data/packet aggregation, throughput and delay etc [3]. Considering above all the issues and challenges for designing cluster based routing protocol for wsn.

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Considering all the aspect of clustering, cluster head selection and routing technique for design energy efficient cluster based routing through MST. This paper is prepared in following sequence. Section II offers the literature review regarding clustering method, cluster head selection method and some routing technique. In section III we define the objective of this research paper. In section IV offer the proposed system outlook with well define technique. In section V and VI in this paper we have simulating the proposed system with properly defined simulating parameters and simulation result. In section VII refer the hardware implementation of proposed system. In next section VIII conclusion of this research work.

II. LITTERATURE REVIEW

Wendi B. has proposed LEACH [6] protocol first time, Data transmitting among sensors to base station is key task in WSN. In LEACH protocol use the concept of data transfer in terms of round, In Every round of transmission it divide two major roles like set up and run phase. In the first phase of every round, Every node check the probability to become the cluster head node or not based on residual energy. The selection of the cluster head is depending the random function of probability value that might be in between 0 to 1. The value is set from the below equation.

$$T(n) = \begin{cases} \dfrac{P}{1 - P * \left(rmod \dfrac{1}{P} \right)}, & \text{if } n \in G. \\ 0, & \text{otherwise.} \end{cases}$$

P is the probability parameter; R is executed round number,

In the phase of set-up, once the cluster head is elected based on the probability number, It notify the message to every members of the same cluster through broadcast, In run phase, Every members or node is going to send the data to the cluster head based on the slot allocation. In LEACH [6], cluster head use the concept of TDMA for assign the time slot in network. Every cluster head is responsible to transmit the data to the base station, Every members of cluster is send to the cluster head and cluster head will communicate to the sink node. The main advantage of the LEACH is elect the every node as cluster head in random manner with that achieve very low power consumption as well longer network life.

The authors of first implemented the HEED [7] protocol; It is also known as distributed clustering protocol. Which holds an energy-efficient routing algorithm with less energy consumption throughout the network in reference of others protocols like LEACH [6]? The cluster formation is based on the nearest nodes are together and form the cluster. The process of the selection of the cluster head is randomly, It selected the cluster head hybrid of the node residual energy and second parameter is the number of neighbors node, the process of the HEED is divide in to two phases one is calculate the residual energy of the node's and second is to calculate the communication cost in between cluster. In HEED the cluster head energy is comparatively higher than the others sensors node, due the unique way of cluster selection approach HEED is enhance the network life, efficiency, scalability and data aggregation.

Shen*et al.* [8]have proposed a new energy efficient centroid-based routing protocol (EECRP) for WSNassisted IoT to improve the performance of the network. The proposed EECRP includes three key parts: a new distributed cluster formation technique that enables the self-organization of local nodes, a new series of algorithms for adapting clusters and rotating the cluster head (CH) based on the centroid position to evenly distribute the energy load among all sensor nodes, and a new mechanism to reduce the energy consumption for long-distance communications. In particular, the residual energy of nodes is considered in EECRP for calculating the centroids position. The simulation results indicated that EECRP performs better than LEACH[6], LEACH-C[9] and GEEC[8]. In addition, EECRP is suitable for networks that require a long lifetime and whose base station (BS) is located in the network.

III. OBJECTIVE

To study and analyze the state-of-the-art wireless sensor network based IoT routing challenges¬ and propose an energy efficient cross layer routing protocol by introducing a new clustering and routing techniques. Development of Energy efficient Cluster formation and Cluster Head election and utilization of¬ Compressive Sensing scheme for inter cluster transmission. Energy-efficient cross layer routing protocol (CLRP) design: The main idea of CLRP is to send¬ SYN, DATA and ACK frames that are required with appropriate transmission power levels instead of maximum.

IV. PROPOSED SYSTEM

In this research we have proposed the energy efficient protocol with the combination of three different following levels

1. Cluster formation
2. Cluster head selection
3. Intra and Inter cluster data routing

We developed Energy efficient clustering based bio-inspired minimum spanning tree based routing (EECMSTR) with the combination of above all three levels. Using modified k-mean clustering approach for the cluster formation in sensor network. For cluster head selection we use multi-criteria decision making approach to select the best node work as cluster head through following criteria we keep during selection like node location, energy status and QoS impact.

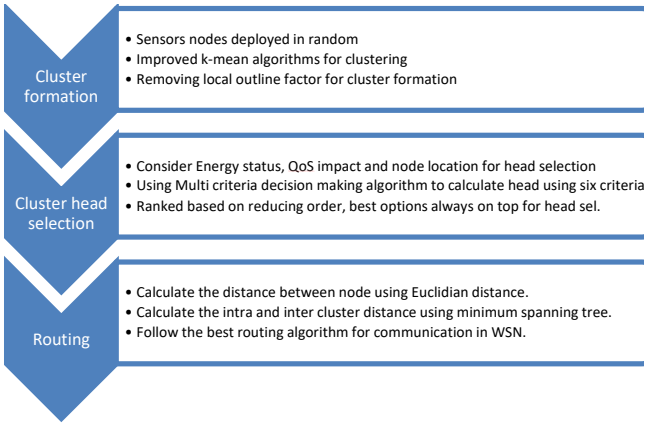

Fig. 1 Flow of the proposed system

4.1 Improved K-means based Clustering[11]

In view existing simple K-Means clustering algorithm [10], this paper presents an advance like improved K-means algorithm for clustering. Using outlier detection method, we do pre-process and clustered of the node. i.e. LOF (Local Outlier Factor) the outliers are removed. LOF is an extra parameter for measure to generate more stable outcome within clusters. The clustering process is given below.

Step 1: Compute LOF of point *P*, *LOF(P)*

$$LOF(P) = \frac{\sum_{i=1}^{m} \frac{LRD(i)}{LRD(P)}}{m} \qquad (1)$$

If the LOF(P) isgreater than 1 then the isolated point P should be excluded from P otherwise the new data set N is provided.

Step 2: Compute new data set (N) mean value;

$$Mean = \frac{1}{n}\sum_{i=1}^{n} z_i \qquad (2)$$

Step 3: Calculate the cluster center also distance from the center node to remaining point of cluster.

$$L_n = \sum_{j=1}^{K} \max\left(d_{m-1}^{j} - \left\|z_n - z_j\right\|^2, 0\right) \qquad (3)$$

where, sample pointz_n is created whose L_n is largest as the next starting cluster center.

Step 4: Compute the mean of the cluster sensor nodes know as new cluster center for each cluster.

Step 5: Repeat 3) 4) before convergence of criterion function E, return *(m1, m2. . . m_k)*. Algorithm terminates.

Pseudo code for Improved K-Means Clustering Algorithm
Input: Data set *M* {x_1, $x_{2,\ldots}x_m$} to be clustered, the number of clusters *m*; **Output:***m* clusters and the sensor nodes nearest cluster center is the smallest. **Begin** Compute LOF of point *P*, *LOF(P)* using eqn (1) Compute new data set (N) mean value by eqn (2) Find the next center of cluster and compute the distance between the remaining points and the cluster center using eqn (3) Calculate the mean of sensor nodes in each cluster as a new cluster center Repeat the step of 2 and 4 **End**

4.2 Cluster-head selection process

In this paper, Cluster head selection we use three main criteria and two sub criteria of each. In this case,We consider the residual energy, restart number, node location, number of neighbor node, communication cost and link quality for the CH calculation.

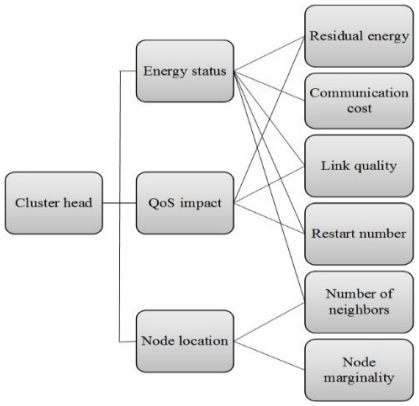

Figure 2: Decision making criteria for cluster head selection[11]

- **Node energy**

As the right-wing candidate for the choice of the CH, the proposed algorithm uses the highest energy node. As a CH has an additional responsibility in the management of the cluster and in the collection of information rather than a CM, it has the high energy profile to promote the comfort of the power consumption in the network.

$$Minimize \quad Node_E = \sum_{i=1}^{n} \frac{1}{E_{CH_i}}$$

Here E_{CH_i} is residual energy of the i^{th} CH and n is number of CHs.

- **Node Degree**

It is defined as the number of sensor nodes that can be reached from a CH.

$$Minimize \quad Node_D = \sum_{i=1}^{n} | CM_i |$$

Here CM_i is the number of members of the cluster i^{th} CH.

- **Intra-cluster distance**

This parameter ensures cluster reliability and maximizes the connection value between the CH and the CMs. It is defined as the average intra-cluster distance of the cluster from its CDs.

$$Minimize \quad IC_D = \sum_{j=1}^{n} \left[\frac{\sum_{i=1}^{|CM_j|} d(CH_j, CM_i)}{| CM_j |} \right]$$

Here $d(CH_j, CM_i)$ is the Euclidean distance between j^{th} CH and the i^{th} CM.

- **Communication cost between a node and its neighbors**

It requires more energy to send a message, which is located close to a distance square between the candidates ' nodes and the initial node known as the origin[16].

$$Cc = \frac{D_{avg}^2}{D_0^2}$$

Where D_{avg} This represents the normal distance between the node and the neighboring node and D_0 is the spread of the node.

- **Number of neighbors**

The immediate neighbors are main concern that are closest to the methodology the optimal number. The largest possibility of a node will be chosen as a CH. The number of neighbors computed as:

$$N = \frac{|N_i - N_0|}{N_0}$$

Here, N_i refers to the next node number and N_0 is the neighbors ' optimal value.

- **Restart number**

The system can be used to restart the PC to ensure that the node continues to function. Therefore, a day summary may consume spare energy. The restart number can be checked using the following expression. Node is an invalid structure. Sometimes the system has to be damaged by software and hardware components.

$$R = 1 - \frac{R_0 - R_{\min}}{R_{\max} - R_{\min}}$$

where the value of $R_{\max}$ and $R_{\min}$ are received from the nearest node. and R_0 is indicate the total restart number after network deployed.

Table 1: Fuzzy relationship values

Scale	Relationship values
Lowest Rank (VLR)	(0.00, 0.06, 0.14, 0.22, 0.30, 0.38)
Low Rank (LR)	(0.20, 0.26, 0.34, 0.37, 0.42, 0.45)
Medium Rank (MR)	(0.40, 0.46, 0.51, 0.58, 0.65, 0.66)
High Rank(HR)	(0.60, 0.63, 0.70, 0.74, 0.81, 0.84)
HighestRank(VHR)	(0.80, 0.86, 0.92, 0.97, 0.98, 1.0)

4.3 Multi Criteria decision making algorithm: TOPSIS[12]

After determining weights, the cycle of TOPSIS[12] proceeds to choose a cluster face. The ideal choice must be the lower distance from the ideal positive solution, and the shortest distance from the ideal negative solution in TOPSIS strategy[11].

Step 1: Formation of the decision or choice matrix

The matrix of choice is shown in the following

$$D = \begin{pmatrix} l_{11} & l_{12} & \dots & \dots & l_{1m} \\ l_{21} & l_{22} & \dots & \dots & l_{2m} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ l_{n1} & l_{n2} & \dots & \dots & l_{nm} \end{pmatrix}$$

where l_{ij} is the assessment of the alternative A_i with respect to the criterion C_j

Step 2:Standardize the selection choice.

Each element is achieved with Euclidean normalization by the decision matrix standardization process.

$$r_{ij} = \frac{l_{ij}}{\sqrt{\sum_{i=1}^{n} l_{ij}^2}}, \quad i = 1,...,n, \ j = 1,...,m.$$

***Step 3*:** Construct the weighted normalized decision matrix

The weighted normalized decision matrix v_{ij} is computed as

$$v_{ij} = W_j * r_{ij} \quad \text{where} \sum_{j=1}^{m} W_j = 1$$

Step 4: Determine the positive ideal and negative ideal solutions, respectively,

$$A^+ = \left[V_1^+,...,V_m^+\right] = \left[\left(\max_i v_{ij} \mid i = 1,...,n\right), j = 1,...,m\right]$$

$$A^- = \left[V_1^-,...,V_m^-\right] = \left[\left(\min_i v_{ij} \mid i = 1,...,n\right), j = 1,...,m\right]$$

Step 5: Calculate the distance of each alternative from A^+ and A^-.

$$Z_i^+ = \sqrt{\sum_{j=1}^{m} (v_{ij} - V_j^+)^2}, \ i = 1,...,n$$

$$Z_i^- = \sqrt{\sum_{j=1}^{m} (v_{ij} - V_j^-)^2}, \ i = 1,...,n$$

Step 6:Calculate the comparative closeness to the ideal solution.

$$C_i^* = \frac{Z_i^-}{Z_i^+ + Z_i^-}, \quad i = 1,...,n$$

The set of alternatives can be ranked based on reducing order of C_i^*. The highest value of node C_i^* will be elected as the cluster head in network.

4.4 Minimum spanning tree-based Routing

In wireless senor network converted in form of graph like each sensor node act as vertices of a graph and the path exist between two sensors node is called edges, In this proposed system, we calculate the distance from two node using ecludian distance formula, Once graph has been formed, We have G:<*V,E*> with the positive distance between node d_i by the creating MST is nothing but we can travers all the vertices means nodes from the graph effectively travers the data from that node to sink via multiple nodes, Generally we have to form the undirected-connected graph from the sensor node, For creating MST we can used Kruskal [13] and Prim's algorithm[14]. In our proposed system we used Kruskal for creating MST. The Pseudo code of Kruskal is illustrated below.

Pseudo code for Minimum spanning tree

Initialize the parameters for sensor nodes
Initialize nodes position P_i randomly
Calculating distance from the node using Euclidian distance
Function MinimumSpanningTree(G = (N, A))
Sort A by increasing length
p ← the number of nodes in N
NT ← Ø {edges of the minimum spanning tree}
Define p sets, containing a different element of set N
repeat
s ← {a, b} //s is the shortest edge not yet considered
ucomp ← find(a)
bcomp ← find(b)
if ucomp ≠ vcomp then merge(ucomp, vcomp)
NT ← NT U {s}
until NT contains n - 1 edges
return NT

V. SIMULATING PROPOSED SYSTEM

5.1 Simulation Environment

In this paper, We used Matlab as simulating software was used for the cluster based routing protocols and comparison with the LEACH, HEED, EECRP protocols with the different efficiency criteria like energy consumption, throughput, network life time, error rate, jitter and packet delivery ration. All others simulation parameters like number of nodes, packet size and network size given in the below table.

Table 2: Name and value of simulation parameters

Parameter	Value
Network size	100 x 100 m

Number of nodes	500
Number of clusters	Maximum 0 4
Base station position	(x,y)
Data packet size	256 bits
Transmitting energy consumption	50 nJ/bit
Initial energy of node	2 J
Transmission type	Constant
Simulation time	500 s

Our proposed protocols has been compared with other famous protocols like Low Energy Adaptive Clustering Hierarchy Protocol (LEACH), Hybrid Energy-Efficient distributed Algorithm (HEED) and Energy efficient clustering based routing protocol (EECRP).

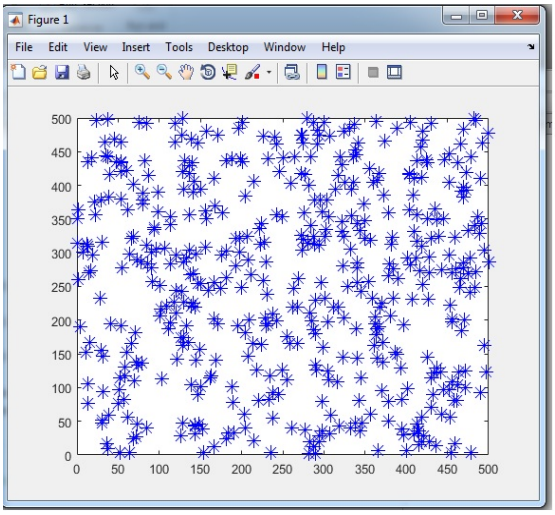

Fig 3 Sensors node deployment

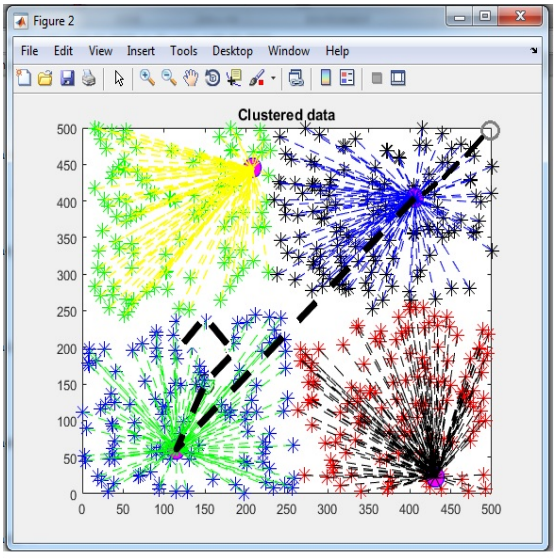

Fig 4 Data routing in sensor network

As shown in fig. we deployed 500 numbers of nodes in network size of 500 X 500 m, this all nodes deployed randomly in network. We divided four different clusters among the whole network using the improved k-mean algorithm with removing local outlier. The cluster formation is needed in very large network for communication with the base station, there are four cluster head in different cluster, The selection process of the cluster head is based on the multi criteria decision making approach. For the selection we used six different criteria based on energy, node location and QoS. All the members' node has been shared the information or data to the head and cluster head is responsible for sending to the base station. For communication of the network we used the minimum spanning tree approach for the data routing.

5.2 Quality of services criteria in proposed method

We want to show the Energy efficient cluster based bio-inspired MST routing protocol's performance , we consider the following performance measuring parameters like Energy consumption, Throughput, Packet delivery ratio, Network life time, End to end delay, Bit error rate and jitter. The metrics of all parameters described as below.

- Energy Consumption: Energy consumption is defined as the total energy consume or used by any node in network. Generally energy used for communication or data transmission by any node is considered as energy consumption.
- Throughput: Number of packet transmitted or delivers successfully over the communication channel. Throughput is measured in bits/sec.
- Packet delivery ratio: It can be measured as ratio of the total number of packet deliver from source to destination and total number of packet sent.
- Network life time: It is define like, the running time between when network has been started and first node is dead, this also called network full active period. Network life time can be measure trough round.
- End to end delay: It refer the time taken from generating the packet from the source node and receiving at destination node or sink node. Generally difference between the time from sending to receiving. It can be measure by mSec.
- Bit error rate: It can be define the ratio of the number of wrong bit deliver over the total

number of bit transmitted in network. It can be measure through bits.

- Jitter: It can be define like the variation in delay of the receiving packet transmitted from source node is called jitter. It can measure through msec. Higher jitter means higher variation delay in packet and lower jitter means low variation delay in packet.

VI. REAL-TIME EXPERMENT SCENARIO

In our real time experiment, We have created live wireless sensor network using the arduinouno low power controller, We have used for communication in network using Zigbee. For the live experiment we have deployed four sensors node in WSN, Every node define like Arduino board as controller using power beg as power supply, ultrasonic sensor for the data collection, USB cable for connection with power supply and cables for sensor connection. For the limited sensors node we have implemented the code of routing only in Arduino studio.

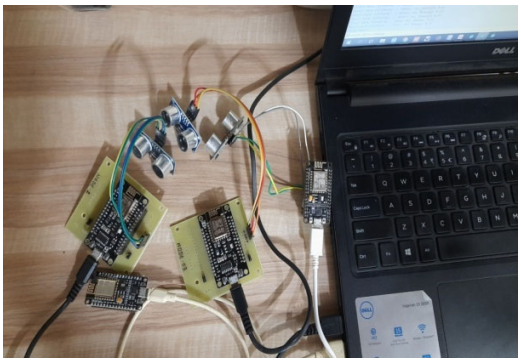

Fig 5 Real time node deployment

We have only four sensors node so no need of the cluster formation as well cluster head selection process for the EECMSTR. For the Routing we use krushkal minimum spanning tree algorithm[13]. All four sensors collect the data from the network and act as the cluster head and send the data to sink node in two different ways one is directly from the cluster head and another it routing from nearest sensor node and delivered at sink node. Implemented scenario, Intra cluster and Inter cluster communication through ESP8266 with four nodes. The data sent to the server and displayed in webpage as well database. Fig 6 shows the data in table format. The table contain the log time, which node sent the packet, sensor data, network path and energy consume by node. The performance result we have displayed in website refer the below image for performance and efficiency parameter calculation.

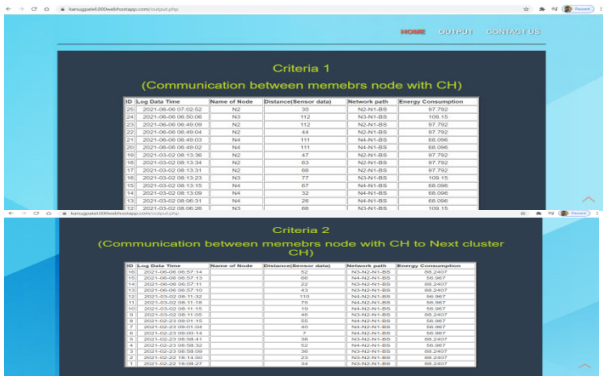

Fig 6 Real time data on server side of both criteria

VII. SIMULATION RESULT

The simulation preformed on MATLAB software, we have deployed 500 nodes in random order in 100x100 m simulation size. In this paper we have compared our proposed protocol with Low Energy Adaptive Clustering Hierarchy Protocol (LEACH), Hybrid Energy-Efficient distributed Algorithm (HEED) and Energy efficient clustering based routing protocol (EECRP) protocols with different parameters like energy consumption, Throughput, Packet delivery ratio, Network life time, End to end delay, Bit error rate and jitter.

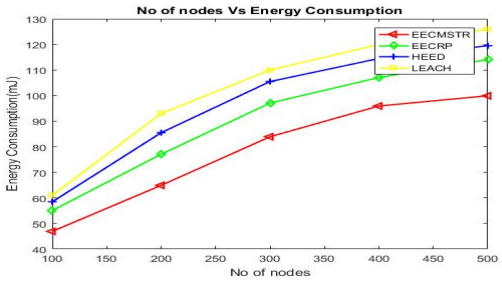

Fig 7 No of nodes vs Energy consumption

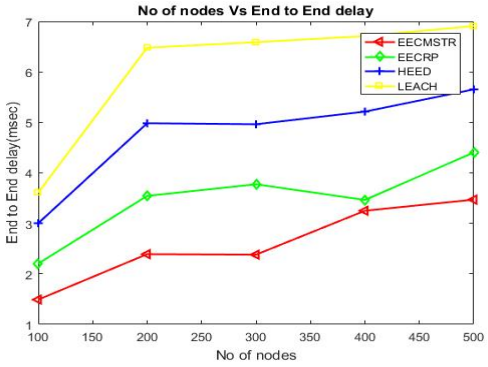

Fig 11 No of nodes vs End to end delay

In Fig. The vertical axis indicates the energy consumption in (mJ) and horizontal axis indicate no of nodes. The comparison made among the four protocols based on 200,300,400 and 500 different nodes used in network. Among the four LEACH has highest energy consumption comparing HEED, EECRP and EECMSTR. Our proposed protocol EECMSTR has required very less energy consumption. When number of nodes increasing same time the energy consumption by EECMSTR used less energy. In Fig. Measuring the throughput of all four protocols with different no of nodes. The vertical axis indicates the throughput in Mbps and horizontal axis indicates the no of nodes. Our proposed protocols is highly throughput comparing LEACH,HEED and EECRP.

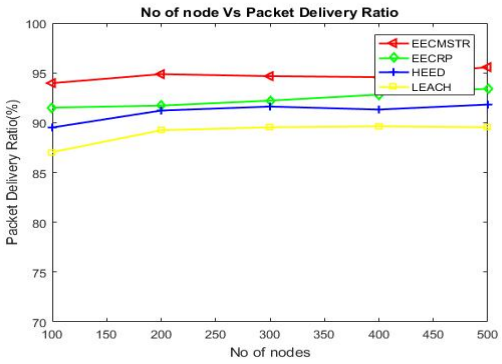

Fig 9 No of nodes vs Packet delivery ratio

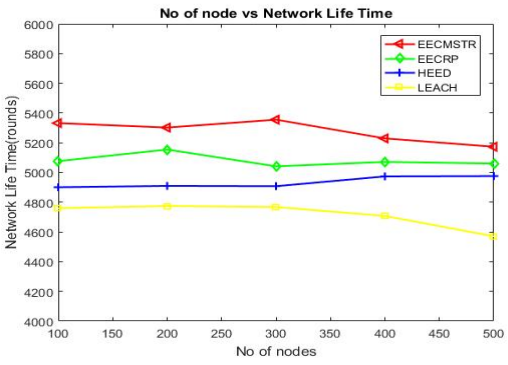

Fig 10 No of nodes vs network lifetime

In fig shown the No of nodes vs Packet delivery ratio. The vertical axis indicates the packet delivery ration measure in percentage (%) and horizontal axis indicate the no of nodes. LEACH and HEED packet delivery ration around 87-90%. EECRP has very good compare to LEACH and HEED is around 92-94. Our proposed protocol is good compare to all others is almost 94-95% from 100 nodes to 500 nodes. In fig indicate the no of nodes vs network life time. As our proposed protocol has high throughput compare to remaining three protocols like LEACH,HEED and EECRP. So We used highly effective approach for the cluster formation, cluster head selection and routing so our network life is increase drastically comparing LEACH, HEED and EECRP. It can be measure in rounds so EECMSTR has failed after 5380 rounds in initial 100 nodes and when nodes increase the no of round decreasevery less.

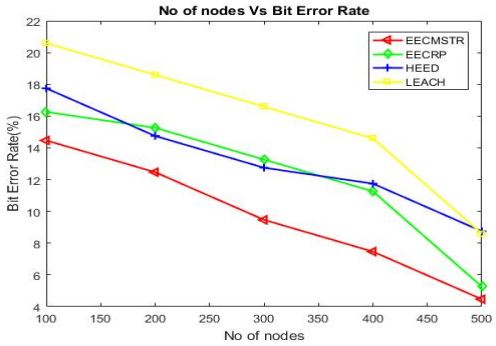

Fig 13 No of nodes vs Bit error rate

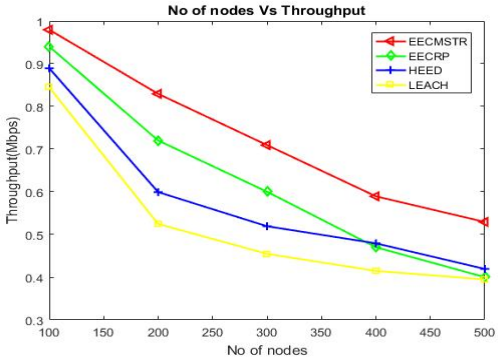

Fig 8 No of nodes vs throughput

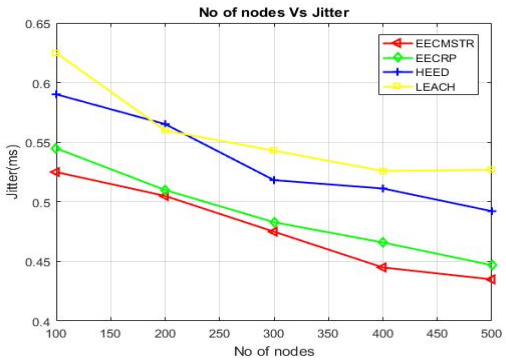

Fig 14 No of nodes vs jitter

The fig. indicates the end to end delay vs no of nodes. The vertical axis indicates the end to end delays measure in msec and horizontal axis indicate the no of nodes varies from 100 to 500. When we transfer the packet from the member node to sink node almost around 3-4 different nodes might be use as intermediate node. The

proposed protocols take very less delay like 1-3 msec for packet transmitting from source to sink node. In fig. indicate the no nodes vs jitter. The vertical axis indicates the jitter in ms and horizontal axis indicates no of nodes. The variation delay of the receiving packet transmitted from the source node very less like 0.5 to 0.42 in EECMSTR compare to LEACH, HEED and EECRP.

In fig. indicates the no of nodes vs bit error rate. The vertical axis indicates the bit error rate in percentage (%) and horizontal axis indicates no of nodes. EECMSTR has used intra and inter cluster communication for packet routing. It has been very less rate of wrongly packet transmitted throughout the network compare to LEACH and HEED. EECRP used same mechanism along with packet verification mechanism so at 500 nodes network EECRP is better than our proposed protocol.

VIII. CONCLUSION

In this research work, A new energy efficient cluster based bio-inspired routing protocols name as EECMSTR was proposed. The EECMSTR cover up all aspect of like clustering, cluster head election and routing in efficient way. The proposed protocol employ cluster head selection process from the suitable nodes on the basis of important criteria of energy status, QoS impact and node location while each criteria contains some sub-criteria. The detailed description of the proposed protocols were discussed and given. The protocol finds the best way of the network communication to minimize the energy utilization and achieve the longer the network life. In this paper, the simulation was implemented in MATLAB software. The hardware based EECMSTR implemented and shown the output shown in webpage. The EECMSTR protocols compared with the different well known protocols like LEACH, HEED and EECRP with different parameters. The performance is evaluated and good compared with the existing protocols such as LEACH, HEED and EECRP with respects to the energy consumption and Quality of services parameters such as packet loss, bit rate, throughput, transmission delay, and jitter.

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