AN ENERGY-EFFICIENT CLUSTERING ALGORITHM BASED ON NODE DEGREE AND DISTANCE FROM BASE STATION FOR WIRELESS SENSOR NETWORKS

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Abstract: The Wireless sensor network (WSN) consisting of a large No. of sensors are effective for gathering data in a variety of environments. Since the sensors operate on battery of limited power, it is a great challenging aim to design an energy efficient algorithm which can minimize the energy consumption by sensor nodes while offering high energy efficiency and long span of network lifetime. To support high scalability and better data aggregation, sensor nodes are often grouped into disjoint, non-overlapping subsets called clusters. Clusters create hierarchical WSNs which incorporate efficient utilization of limited resources of sensor nodes and thus extends network lifetime. We proposed an algorithm for better cluster head selection based on node degree and distance from base station to reduce No. of transmissions and reduce energy consumption by sensor nodes. The proposed algorithm is compared with the HEED algorithm in terms of No. of clusters and energy consumption. Simulation results using MATLAB shows that the proposed algorithm significantly reduces energy consumption and thereby increases in the total lifetime of the wireless sensor network compared to the HEED algorithm.

***Index Terms* - Battery Content, Cluster head, Distance from base station, Node Degree.**

I. INTRODUCTION

A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants. Sensors are built by recent advances in micro electro mechanical systems (MEMS) technology. WSN's consists of many sub nodes for data dissemination and data gathering on information. Sensory data comes from multiple sensors of different modalities in distributed locations. Wireless Sensor Networks, which are responsible for sensing as well as for the first stages of the processing hierarchy [1].

The challenges in the hierarchy of: detecting the relevant quantities, monitoring and collecting the data, assessing and evaluating the information, formulating meaningful user displays, and performing decision-making and alarm functions are enormous. The information needed by smart environments is provided by Distributed Wireless Sensor Networks, which are responsible for sensing as well as for the first stages of the processing hierarchy. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance and is now used in many industrial and civilian application areas, including industrial process monitoring and control machines, health monitoring, environment and habitat monitoring, healthcare applications, home automation, and traffic control [2].

Each node in a sensor network is typically equipped with a radio transceiver or other wireless communications device, a small microcontroller, and an energy source, usually a battery. A sensor network normally constitutes a wireless ad-hoc network, meaning that each sensor supports a multi-hop routing algorithm where nodes function as forwarders, relaying data packets to a Base Station.

A key feature of any wireless sensing node is to minimize the power consumed by the system. Generally, the radio subsystem requires the largest amount of power. Therefore, it is advantageous to send data over the radio network only when required [3]. This sensor event-driven data collection model requires an algorithm to be loaded into the node to determine when to send data based on the sensed event. Additionally, it is important to minimize the power consumed by the sensor itself. Therefore, the hardware should be designed to allow the microprocessor to judiciously control power to the radio, sensor, and sensor signal conditioner [4].

The major issues that affect the design and performance of a wireless sensor networks are hardware and operating system for WSN, wireless radio communication characteristics, medium access schemes, deployment, localization, synchronisation, Clustering, calibration, data aggregation and dissemination, database centric and querying, architecture, programming models for sensor networks, quality of service and security. Recent advances in miniaturization and low-power design have led to the development of small-sized battery-operated sensors that are capable of detecting ambient conditions such as temperature and sound [5].

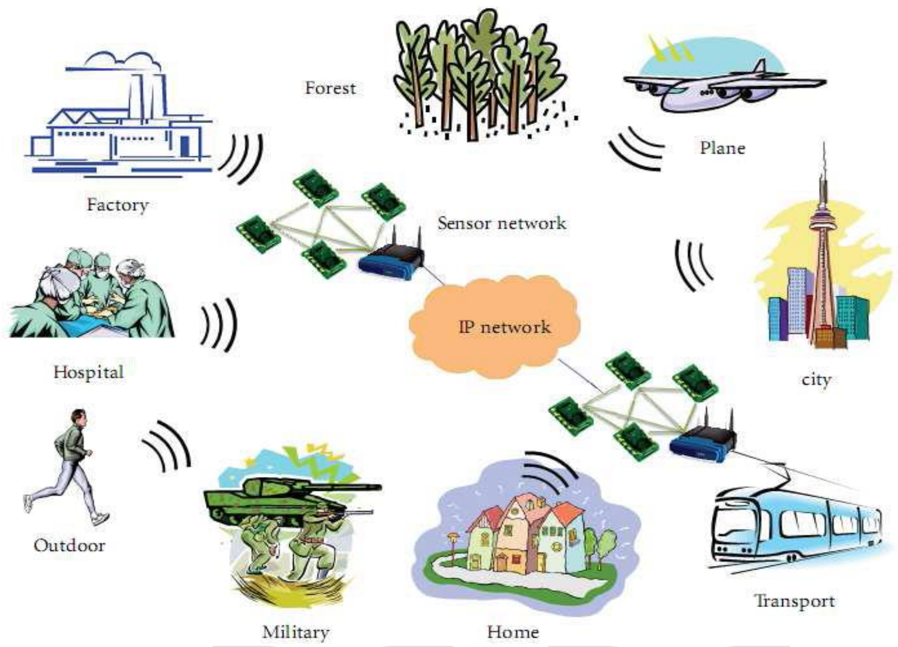

Figure 1.2: Wireless sensor networks with different applications

Clustering is a process of connecting nodes using a specific topology to perform certain tasks as per the requirements. The algorithm used for wireless sensor networks finds a set of distinguished nodes to construct the appropriate topology of the network. The concept of Clusters in wireless sensor networks was first proposed in the packet radio network, which was mainly used for hierarchical routing. With the continuous deepening of the study, to date, for constructing and maintaining the sub-Cluster network structure, we had proposed a large number of Clustering algorithms. Clustering-based network can reduce the cost of routing algorithm and the flooding broadcast. So, we can easy to manage mobile nodes and control the channel access, and can improve the efficiency of network resources [6].

Grouping sensor nodes into Clusters has been widely pursued by the research community in order to achieve the network scalability objective. Every Cluster would have a leader, often referred to as the Cluster-head (CH). Although many Clustering algorithms have been proposed in the literature for ad-hoc networks, the objective was mainly to generate stable Clusters in environments with mobile nodes. Many of such techniques care mostly about node reach ability and route stability, without much concern about critical design goals of WSNs such as network longevity and coverage [7].

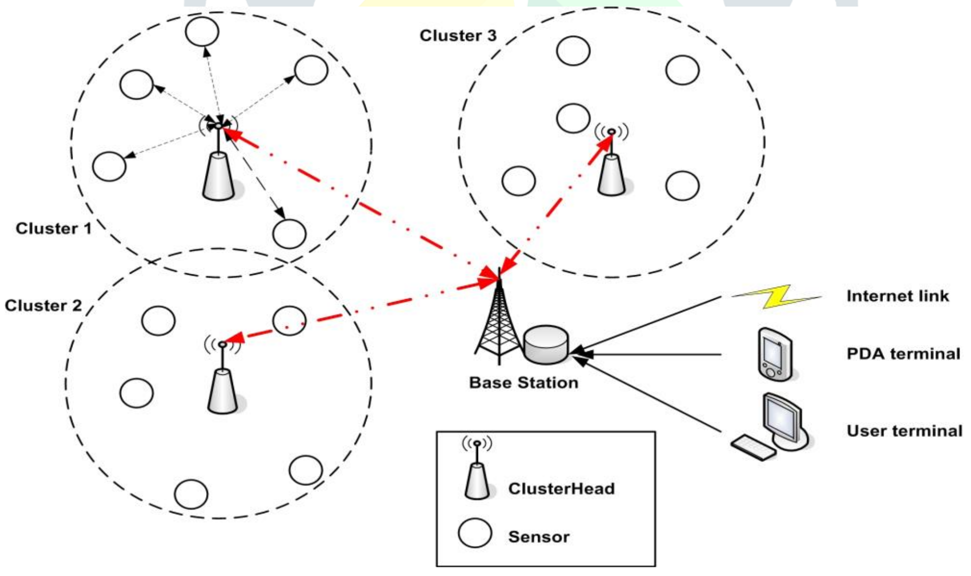

Figure 1.4: General Sensor Network Architecture with Clusters

Another challenge of wireless sensor networks is how to allocate resources efficiently and thus can order the bandwidth by the way of quantitative or statistical. In cellular networks the resources allocation is relatively easy to be achieved, directly or through other communication nodes in the Base Station, each mobile node can obtain the bandwidth requirements, that is, it can carry out resource allocation through the Base Station. However, if the network is divided into the hierarchical structure which is based on the Clusters, then it will extend the method of the cellular networks to the wireless sensor network. Within each Cluster, the first Cluster node can control business requirements and rational allocation of the bandwidth [8].

II. Related work

Recently, a number of Clustering algorithms have been specifically designed for WSNs.Clustering algorithms can be based on criteria such as energy level of nodes, their position, degree, speed and direction. Probably the most crucial point when dealing with clustering is the criterion how to choose the CH. The number of CHs strongly influences the communication overhead, latency, inter- and intra-cluster communication design as well as the update policy [9]. A CH may be elected by the sensors in a Cluster or pre-assigned by the network designer. A CH may also be just one of the sensors or a node that is richer in resources. The Cluster membership may be fixed or variable. Here the related work to our project work is analysed. The cluster head process and clusters formation process are studied for various clustering algorithms [10].

The author proposed Fuzzy logic approach to cluster head selection. The sensor is selected by the base station after sensors transmit the selection parameters to it. The selection parameters are node concentration, current residual energy, node centrality with respect to entire cluster. These parameters are also refereed as fuzzy descriptors. This technique uses a central control algorithm to select the cluster head. The model of fuzzy logic control consists of fuzzifier, fuzzy rules, fuzzy inference engine and a defuzzifier. It uses the most commonly used fuzzy inference engine called Mamdani Method. The process is performed is four steps: Fuzzification of input variables, rule evaluation, aggregation of rule outputs and defuzzification [11].

In the proposed the HEED protocol initially distributes the sensors in different clusters using a distributed clustering algorithm. For intra cluster energy efficiency it uses energy consumption as a parameter to decide the cluster head. The energy consumption is determined by the average energy it takes for a sensor to transmit a unit of data to the cluster head [12]. For a given sensor's transmission range, the probability of CH selection can be determined using the residual energy of the sensor node, is given by CHprob = Cprob * Eresidual/Emax

In the current method uses a deterministic cluster head selection technique. LEACH uses randomized rotation of high energy cluster head positions among the sensors in the network. In this way load of the energy consumption is distributed among other nodes. The operation of LEACH is divided into rounds. Each round has two phases setup phase and steady phase. In the setup phase sensors are organized into clusters. In the steady phase, data transmission from the sensors to their respective cluster head begins. Since being cluster head is an energy consuming process each node takes turn to become cluster head. Each sensor elects itself as cluster head in the beginning by assigning itself a probabilistic value. This value is based on energy of the node, recently performed cluster head operation or not served as cluster head in a given round. Sensors with higher energy have a higher probabilistic value and sensors with lower energy have lower value. The LEACH scheme tries to balance the energy consumption of the sensor by rotating the duties of cluster head for a given list of sensors. This enables the sensors to serve as cluster head but also not sap their energy to below critical threshold [13].

The author proposed an Energy Efficient Unequal Clustering. This scheme is distance-based scheme similar to EECS and it also required that every node has global identification such as its locations and distances to the base station. Hotspot is the main problem in WSNs because of multi hopping that occurs when CHs closer to the sink tend to die faster compare to another node in the WSNS, because they relay much more traffic than remote nodes. These algorithms partition the all nodes into clusters of unequal size, and clusters closer to the sink have smaller sizes than those farther away from the sink. Thus, cluster heads (CHs) closer to the sink can conserved some energy for the inter cluster data forwarding. Energy consumed by cluster heads per round in EEUC much lower than that of LEACH standard but similar to HEED protocol [14].

In the proposed LEACH-Centralized uses a centralized clustering algorithm to form clusters and associate cluster heads for the sensors. First the sensors send their location information to the base station. Then the base station computes the average node energy and nodes which are below the average cannot be cluster head for the given round. Using the remaining nodes as possible cluster heads, the base station finds cluster using the simulated annealing algorithm [15]. This algorithm tries to minimize the amount of energy for the non-cluster head sensors to transmit their data to the cluster head. This is done by minimizing the distance between the cluster head and the non-cluster head nodes. The algorithm allows the sensors to disassociate themselves from earlier cluster head and scan the area for other cluster heads. If a sensor finds a cluster head closer to it, than the others it associates with the closer one. This process of dynamic association enables the sensor to make a decision in its best interest, by utilizing the least power to communicate with the cluster heads [16].

III. PROBLEM STATEMENT

Clustering is efficient scheme for data aggregation in the wireless sensor network. In which each sensor node sends data to the aggregator node means cluster head (CH) and then cluster head perform aggregation process on the received data and then send it to the base station (BS). Performing aggregation function over cluster-head still causes significant energy wastage. Since the sensors operate on battery of limited power, it is a great challenging aim to design an energy efficient algorithm to select better cluster head, which can minimize the energy consumption by sensor nodes while offering high energy efficiency and long span of network lifetime. Thus, in such a situation an energy efficient clustering algorithm must be implemented to reduce the number of transmissions there by to minimize the energy consumption by sensor nodes.

IV. PROPOSED METHODOLOGY

The proposed work will explore the use of an algorithm for better cluster head selection based on node degree and distance from the base station to reduce number of transmissions and reduce energy consumption by sensor nodes. The methodology mainly focuses on node degree of the node i.e. the number of nodes that come under the transmission range of each node to form a cluster, also it considers the Node's distance from the Base Station that as to become the Cluster Head because it is also an important characteristic that should be taken into account, apart from these two parameters it considers the amount of battery content of the node which is the source for transmission between inter-Cluster and intra-Cluster communication due to the difference of distance to the Base Station. In other words, the basic idea is that the minimum the number of left out nodes, the closer to the Base Station and higher the battery content results in a larger Cluster area. Therefore, each sensor node has the probability of becoming a Cluster Head which is determined by its Node Degree, distance to the Base Station and its residual energy. The method is compared with existing HEED algorithm in terms of number of clusters and energy consumption by sensor node.

The sensor node is selected as cluster head based on node degree, battery content of each sensor node and distance from the base station. If the probability of sensor node is less than average probability value it is selected as cluster head. This process takes place for all nodes and clusters are formed. The total number of clusters is determined for particular number of nodes. Each CH uses energy in receiving data signals from its members, aggregating the data and transmitting it to the BS. For each non-CH node, it only needs energy to transmit its data to the CH during cluster formation process. The energy used by CH node and non-CH node is calculated using first order radio energy model. The algorithm is compared with the existing clustering algorithm in terms of energy consumption, number of clusters to find the efficiency of proposed algorithm. The proposed methodology is shown in figure 4.1.

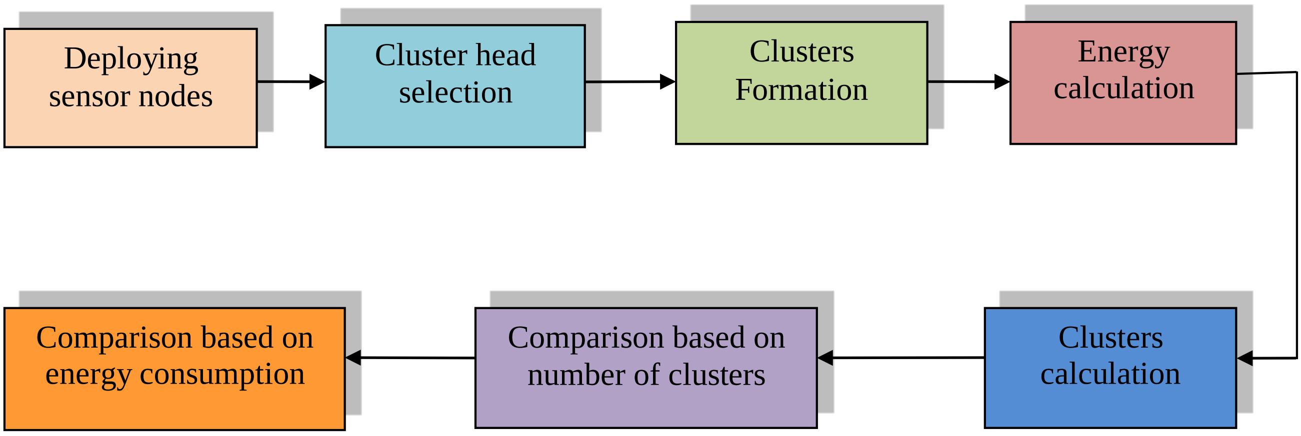

Figure 3.1: Project work flow diagram

The sensor node is selected as cluster head based on node degree, battery content of each sensor node and distance from the base station. If the probability of sensor node is less than average probability value it is selected as cluster head. This process takes place for all nodes and clusters are formed. The total number of clusters is determined for particular number of nodes. Each CH uses energy in receiving data signals from its members, aggregating the data and transmitting it to the BS. For each non-CH node, it only needs energy to transmit its data to the CH during cluster formation process. The energy used by CH node and non-CH node is calculated using first order radio energy model. The algorithm is compared with the existing clustering algorithm in terms of energy consumption, number of clusters to find the efficiency of proposed algorithm.

V. Implementation

The proposed methodology is implemented in 3 phases.
1.Initialization deployment and identification of sensors in WSN
2.Cluster Head Selection and formation of clusters
3.Energy Computation and Number of Clusters Computation

5.1 Initialization and Deployment of sensors in WSN

Initialization and deployment of sensors in WSN is explained in the following steps.

Step1: Specify the number of nodes.
Step2: Randomly generate Coordinate values (x, y) of defined number of nodes.
Step3: Define the communication range.
Step4: Identify the sensor nodes for cluster formation.
Step5: Node plot of WSN.
Step6: Filter the node having range more than communication range.

5.2 Cluster Head Selection and formation of Clusters

Selection of sensor node for Clustering with their Transmission range

Step1: Calculation of Probabilistic value

$$Pi = db / (Ni * bat)$$

Where, db = Distance from Base Station

$$= \sqrt{((Xb-Xi)2+(Yb-Yi)2)}$$

Ni = Node degree

Bat = Battery content

Step 2: Average of the Probabilistic values of all Nodes

$$Pavg = (P1 + P2 + P3 + \ldots\ldots + Pi)/n$$

Where, n = total number of nodes

Step 3: If Pi <= Pavg, it is selected as Cluster Head

Step 4: Sensor nodes present in CH's Transmission range will become its member nodes.

Step 5: Assigning of Cluster ID to each member node present in the corresponding cluster group

Step 6: Repeat from step 4 for the remaining nodes till all the nodes whose

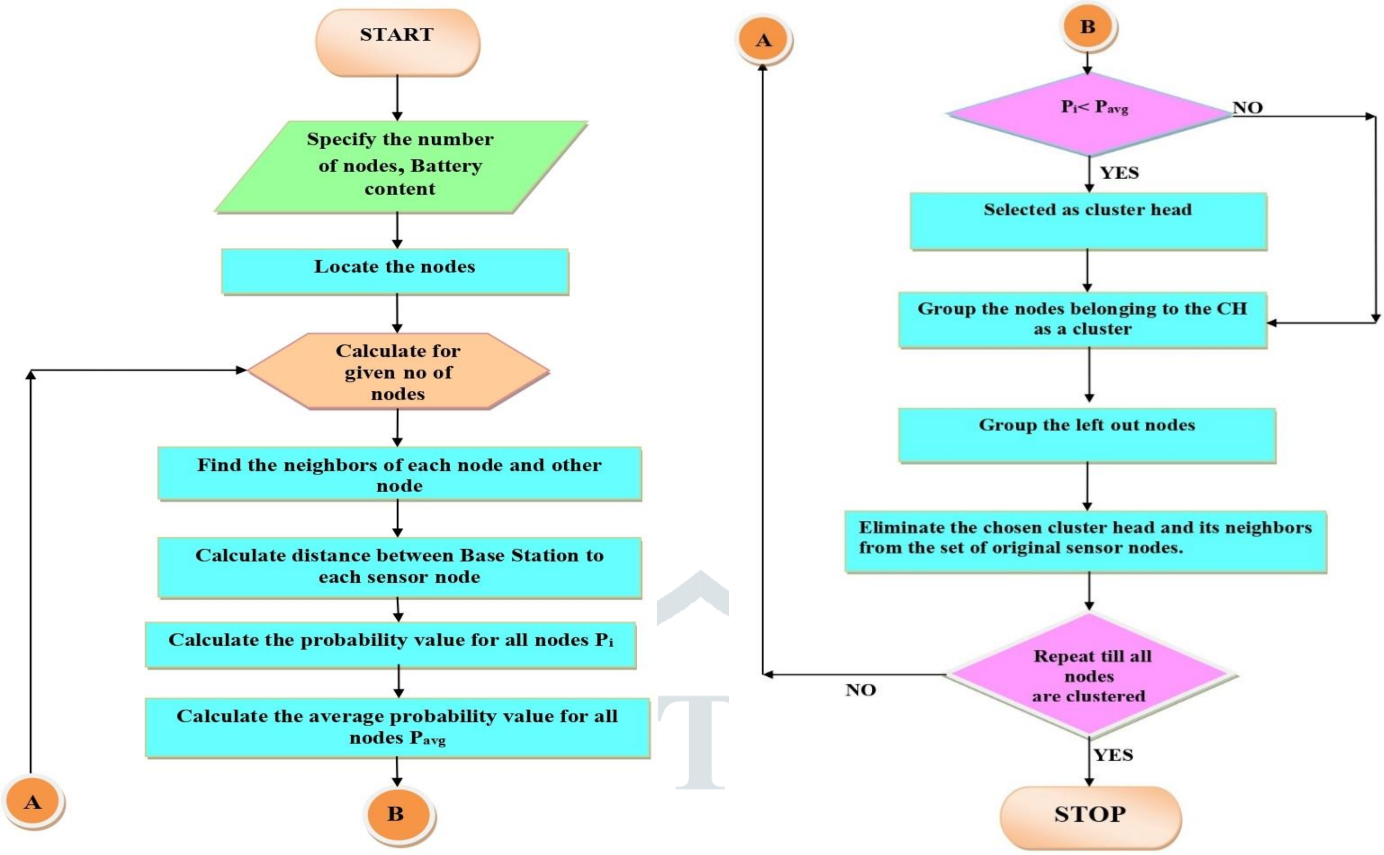

Figure 3.2: Cluster formation process flowchart

5.3 Energy Computation Algorithm

Initialize all the first order radio model parameters.

Step 1: Calculate the energy consumed by a sensor i in receiving a k-bit data.

Erx= (Eelect x k)

Step 2: Calculate the energy consumed in transmitting a data packet to sensor j

Step 3: Calculate the energy consumed in transmitting a data packet to sensor j

ETx=Eelect x k+ (Eamp xRtx2x k

Step 4: Calculate the energy consumed by CH node in receiving data signals from its members.

Ech= (Eelect X k X CHdegree+ EDAX k) + (EelectX k+ E amp X d2 tonextCH X k)

Step 5: Calculate the energy consumed by non-CH node to transmit data signals to the CH.

Enon-CH= (Eelect X k) + (E amp X Rtx2x k)

Step 6: Calculate the total energy consumed by CH node and non-CH node is given by

Etotal= Ech +Enon-CH

VI. RESULTS AND DISCUSSION

To validate the proposed clustering algorithm based on node degree and distance from the base station for cluster head selection, the performance of proposed method was compared with the existing clustering algorithm like HEED. Performance metrics are- total energy dissipation in node and Number of clusters was considered to evaluate the performance. Proposed algorithm and HEED simulation was carried out in MATLAB 7.0. First of all, 100 WSN nodes were randomly distributed in a spatial region of 100mx1000m network area. In HEED algorithm, 5% of the nodes have been taken as cluster-heads. Each node transmits 256 bits of information during transmission. For the better simulation the first order radio energy model parameters considered are Eelec=50 nJ/bit, Eamp=50 nJ/bit, EDA=5 NJ/bit and ERX=100nJ/bit.

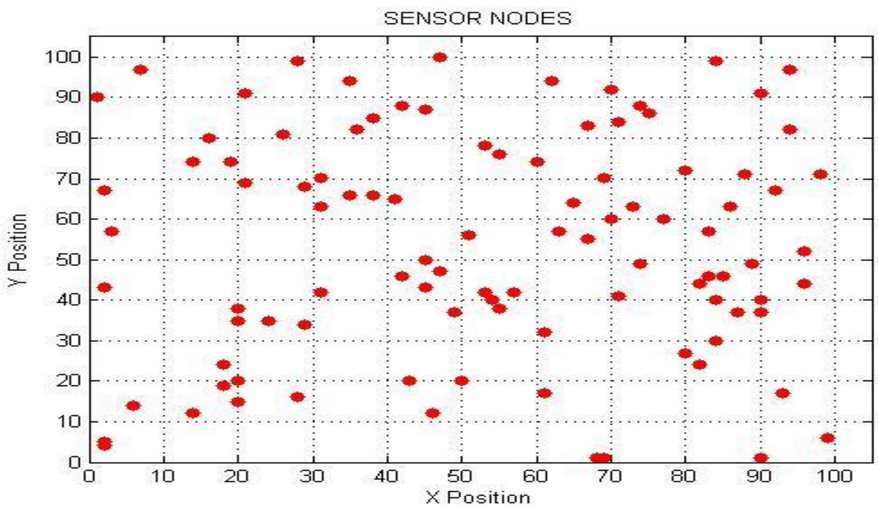

Figure 5.1: Distributed Sensor Nodes in the field (N=100)

Figure 5.1 shows the distribution of 100 nodes randomly in 100 X 100 areas. X-location and Y-location are the X-co-ordinate and Y-co-ordinate values of each sensor nodes.

The sensor nodes are uniquely represented by a number to identify during cluster head selection, calculation of number of clusters and during determination of energy consumption by sensor nodes in receiving data signals from its members, aggregating the data and transmitting it to the BS.

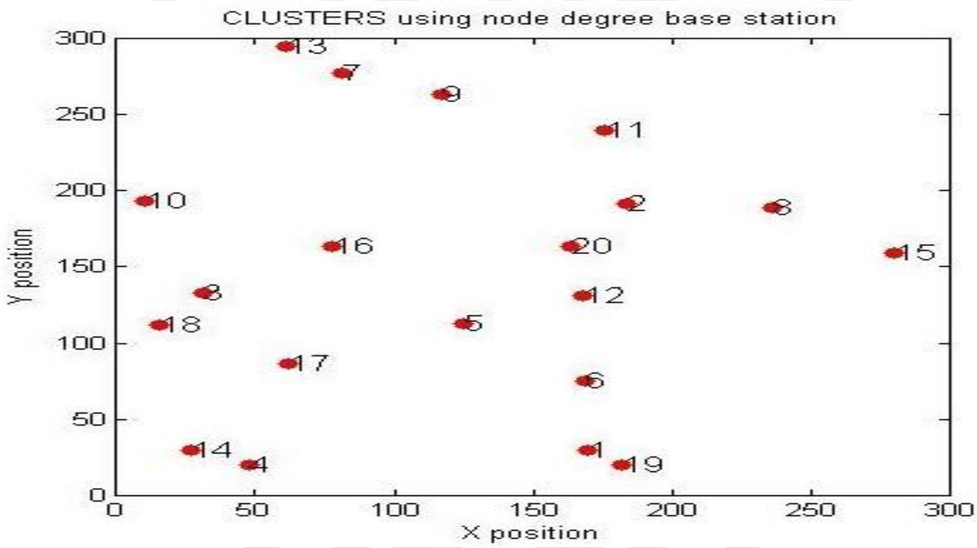

Figure 5.2: Sensor nodes with identification

Table 5.1: Simulation parameters

PARAMETERS	SYMBOL	VALUE
Nodes	N	5-100
Simulation area	X * Y	100X100
Transmission Range	R	5,10,15
Distance from base station	Db	dbi = √((Xb-Xi)2+(Yb-Yi)2)
Bits	K	256
Electronics energy	Eelec	50nJ/bit
Amplifier Energy	Eamp	100pJ/bit/m2
Energy for aggregation	Eda	5nJ/bit

Here the performance of proposed algorithm is validated for 100 nodes. The simulation results of clusters formation process, clusters calculation and energy consumption calculation is shown below. The performance metrics are considered for 3 different transmission range like 5, 10, 15. The proposed method is compared with HEED in terms of number of clusters and energy consumption by sensor nodes. The simulation results are shown below.

In this case totally 24 clusters are formed for 100 nodes. Here black points represent cluster heads (CH), red points represent member/follower nodes of respective cluster heads. Bigger black point represents position of base station (BS). Here we are considering base station location as (0, 0) which is exactly at center of 100 X 100 area. Here green line indicates cluster head to each of its follower connection (intra-cluster connection). Here pink line indicates base station to each cluster head connection.

The simulation results with cluster heads connected to the base station for data transmission are shown below in figure 5.3.

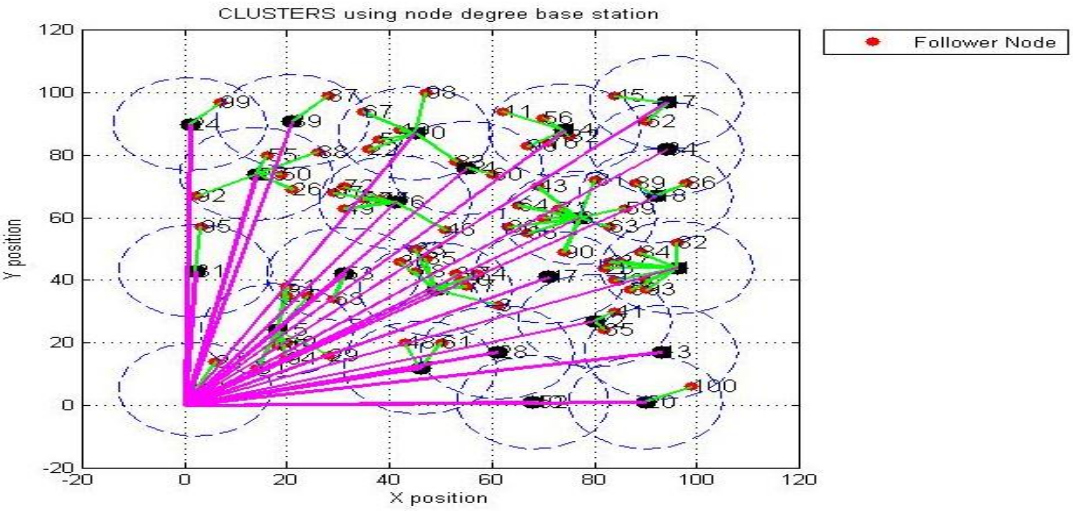

Figure 5.3: Clusters formation process for n=100

The number of clusters produced for each 5 nodes with transmission range r=5,10,15 for both proposed method and HEED algorithm is shown below in figure 5.4. The simulation results shows that clusters are reduced in the proposed method.

Number of nodes =100

No_of_clusters NBS=

5	10	15	19	23	26	29	33	36	40	44	47	51	55	58	59	62	67	71	74
4	9	14	18	22	24	27	29	30	31	33	33	33	35	35	33	34	36	40	42
3	7	10	14	16	18	21	23	22	23	24	25	25	25	24	25	25	25	24	25

No_of_clusters HEED =

5	10	15	19	23	26	29	33	36	40	44	47	51	55	58	59	63	68	71	74
4	9	14	18	22	24	27	29	31	33	35	35	35	37	37	37	38	39	41	43
3	7	10	14	16	18	22	24	24	24	25	25	25	25	25	25	25	25	25	25

Figure 5.4: Number of clusters for proposed method and HEED method

The simulation results that show the comparison of number of clusters for different transmission range r=5, 10, 15 with reference to number of nodes is shown below in figure 5.5

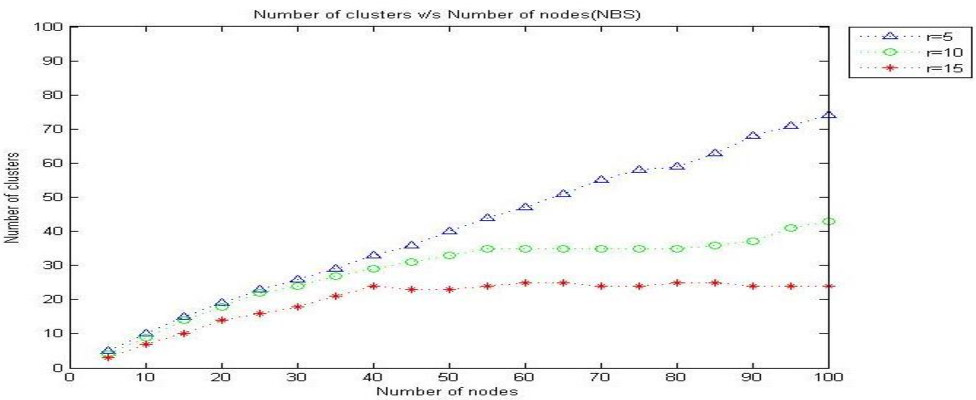

Figure 5.5: Number of clusters v/s Number of nodes (Tx_range=5, 10, and 15) for n=100

The number of clusters v/s number of nodes for transmission range r=5 is shown below.

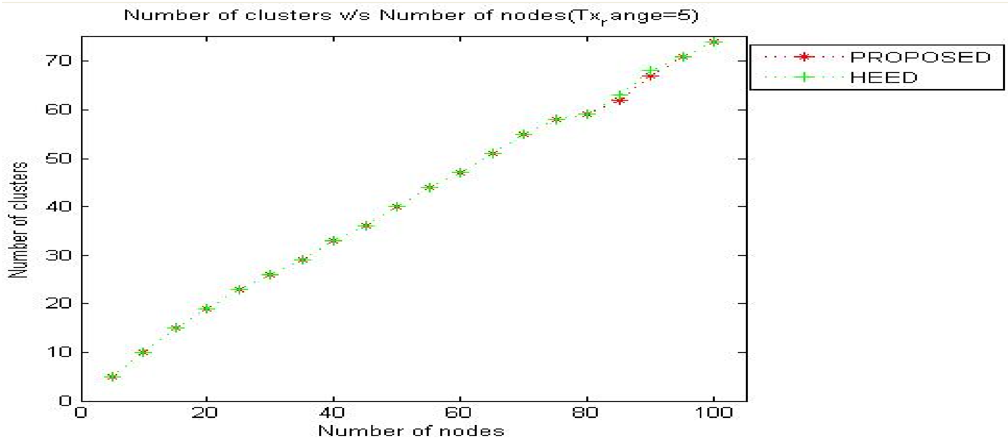

Figure 5.6: Number of clusters v/s Number of nodes (Tx_range=5) for n=100

Figure 5.6 shows number of clusters v/s number of nodes for transmission range 5m. In this case approximately both the algorithms giving same number of clusters for transmission range 5m. But for the nodes from 80 to 100 ranges, clusters number for proposed algorithm is slightly less compare to HEED. From this we can conclude that for nodes in the range 80 to 100 proposed algorithm giving good results compare to previous algorithm.

The number of clusters v/s number of nodes for transmission range r=10 is shown below.

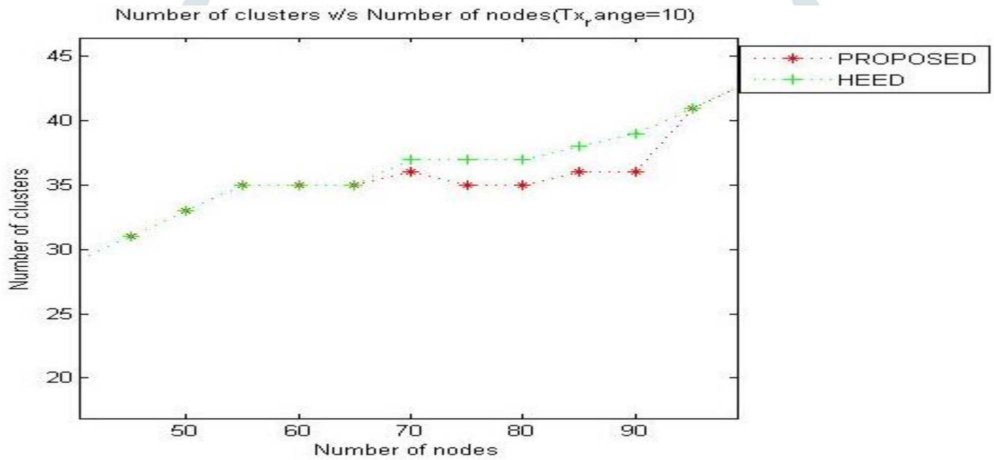

Figure 5.7: Number of clusters v/s Number of nodes (Tx_range=10) for n=100

Figure 5.7 shows number of clusters v/s number of nodes for transmission range 10m. In this case approximately both the algorithms giving same number of clusters for transmission range 10m for nodes 60. But for the nodes from 60 to 100 ranges, clusters number for proposed algorithm is slightly less compare to HEED. From this we can conclude that for nodes in the range 60 to 100 proposed algorithm giving good results compare to previous algorithm.

The number of clusters v/s number of nodes for transmission range r=15 is shown below.

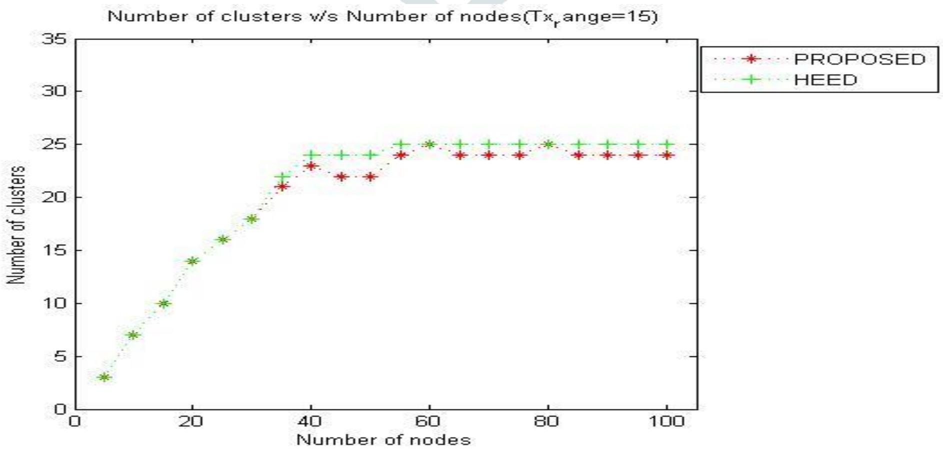

Figure 5.8: Number of clusters v/s Number of nodes (Tx_range=15) for n=100

Figure 5.8 shows number of clusters v/s number of nodes for transmission range 15m. In this case approximately both the algorithms giving same number of clusters for transmission range 15m for nodes 0 to 30. But for the nodes from 30 to 100 ranges, clusters number for proposed algorithm is slightly less compare to HEED. From this we can conclude that for nodes in the range 30 to 100 proposed algorithm giving good results compare to previous algorithm.

Energy Computation

The total energy consumed by both cluster head and non-cluster head during cluster formation process is shown below.

Etot_ch = 0.0022

Enon_ch = 2.3040e-005

Etot_nonch = 0.0018

ETOT =0.0039

The simulation result for the comparison of the energy consumption for different transmission range r=5, 10, 15 with reference to number of nodes is shown below in figure 5.9.

The energy consumption v/s Number of nodes for transmission range r=5, 10, 15.

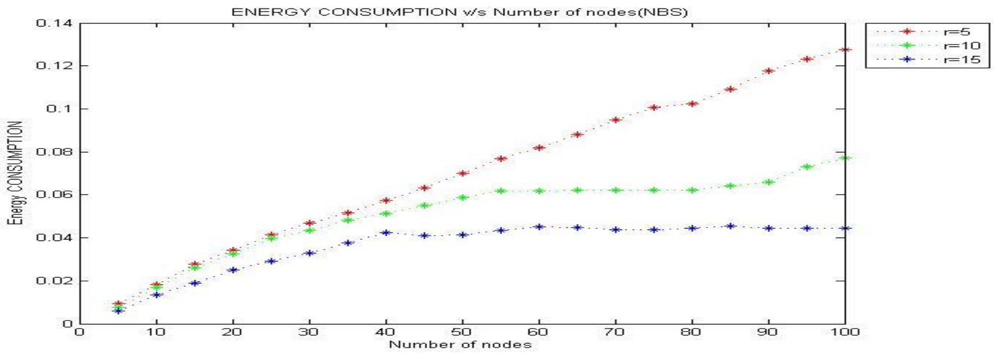

Figure 5.9: Energy consumption v/s Number of nodes (Tx_range=5, 10, and 15) for n=100

The energy consumption v/s Number of nodes for transmission range r=5 is shown below.

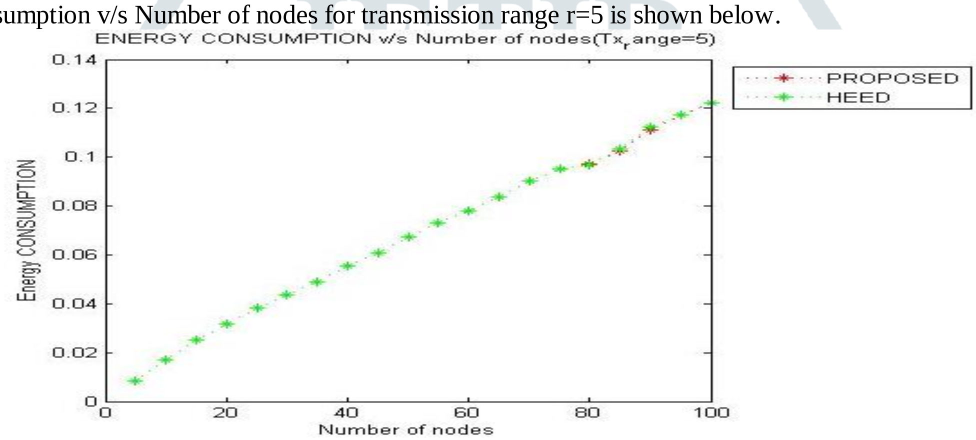

Figure 5.10: Energy consumption v/s Number of nodes (Tx_range=5)

Figure 5.10 shows Energy consumption v/s Number of nodes for transmission range 5m. From nodes 5 to 80 both algorithms merged on one another which results same energy consumption. But from nodes 80 onwards energy consumption for the proposed algorithm is slightly less than heed. From this we can conclude that for transmission range 5m, nodes in the range 80 to 100, proposed algorithm giving comparatively good results compare to previous algorithm.

The energy consumption v/s Number of nodes for transmission range r=10 is shown below

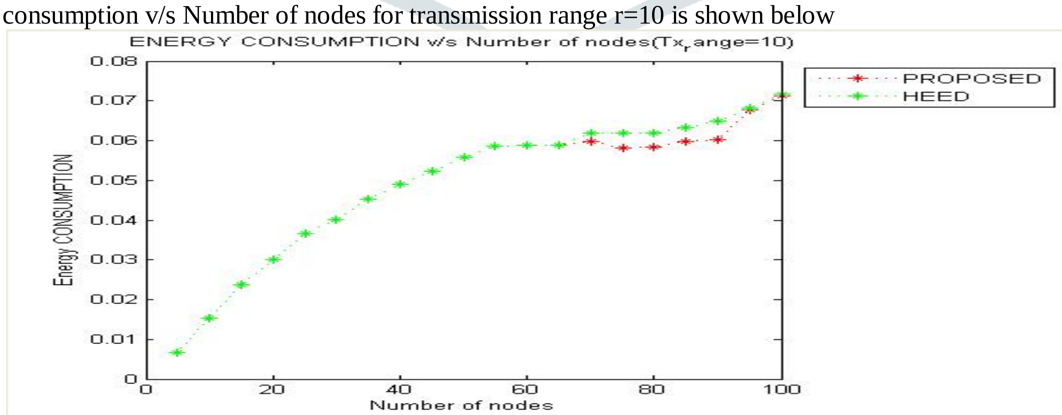

Figure 5.11: Energy consumption v/s Number of nodes (Tx_range=10)

Figure 5.11 shows Energy consumption v/s Number of nodes for transmission range 10m. From nodes 5 to 60 both algorithms merged on one another which results same energy consumption. But from nodes 80 onwards energy consumption for the proposed algorithm is slightly less than heed. From this we can conclude that for transmission range 10m, nodes in the range 60 to 100, proposed algorithm giving comparatively good results compare to previous algorithm.

The energy consumption v/s Number of nodes for transmission range r=15 is shown below .

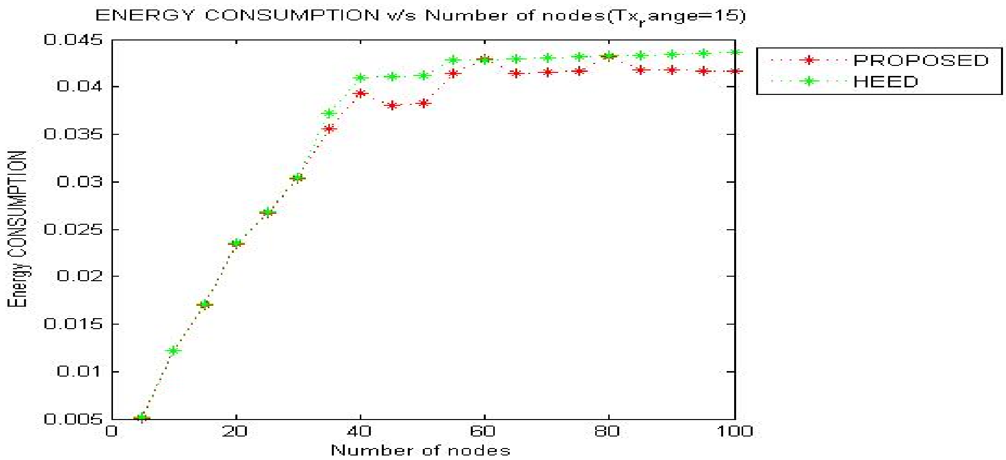

Figure 5.12: Energy consumption v/s Number of nodes (Tx_range=15)

Figure 5.12 shows Energy consumption v/s Number of nodes for transmission range 15m. From nodes 5 to 20 both algorithms merged on one another which results same energy consumption. But from nodes 80 onwards energy consumption for the proposed algorithm is slightly less than heed. From this we can conclude that for transmission range 15m, nodes in the range 20 to 100, proposed algorithm giving comparatively good results compare to previous algorithm. The simulation results show that compared to the HEED algorithm in our proposed algorithm number of clusters reduces for different transmission range. It also shows that energy consumption is decreased in the proposed method for the different transmission range.

VII. CONCLUSION

In wireless sensor networks, power consumption is an important factor for network lifetime. Hence, we have developed a new algorithm for clustering of wireless sensor network. The method is for better cluster head selection based on node degree and distance from base station to reduce energy consumption by sensor nodes, and to reduce number of clusters which will prolong the network lifetime. The proposed algorithm is compared with the HEED algorithm in terms of number of clusters and energy consumption. Simulation results using MATLAB shows that the proposed algorithm significantly reduces number of clusters and reduces energy consumption and thereby increase in the total lifetime of the wireless sensor network compared to the HEED algorithm.

VIII. ACKNOWLEDGMENT

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