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Energy Efficient data collection through Double Cluster Heads in Wireless Sensor Network

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Abstract-Wireless sensor network is the revolution in the sensors applicability in the modern era. Almost every sector is influenced by the wireless sensor networks. The one of the major constraint in the WSN is the limited battery resources. The efficient routing techniques have to be developed to take concern of the network lifetime. There have been various routing strategies aiming to enhance network lifetime. In this paper, we have proposed the two levels of Cluster Heads (CHs) in each cluster to make the data forwarding much efficient towards the Base Station (BS). By employing two cluster heads, the load of single CH is distributed with the other one. Main CH (MCH) will collect the data from the assistant CH (ACH) and then it will be forwarded to the BS or to the other MCH. Results in MATLAB shows that the proposed protocol has given the much enlarged network lifetime.

Keywords: *Double Cluster Heads, Clustering, Wireless sensor network, routing protocols*

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1. Introduction

Wireless Sensor Network is defined as a network of various numbers of sensor nodes which are deployed in a sensor field and these sensor nodes sense their surrounding or the environmental conditions such as temperature, air pressure, humidity, light, motion or vibration, and so on. The sensor nodes are used to gather the data from their surrounding and then transmit the sensed value or data to the base station at regular intervals. A sensor node is comprised of four fundamental segments, as appeared in Figure 1; sensor unit, a processing unit, a transceiver unit, and a power unit. Sensor units are typically made out of two subunits:
a. Sensors
b. Analog to Digital converters (ADCs).

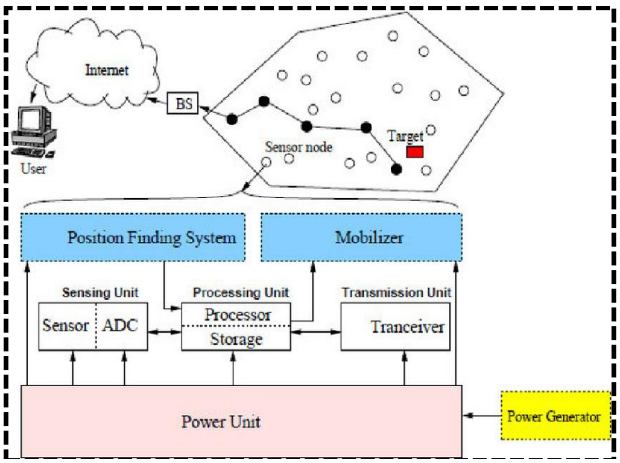

Figure 1. The components of a sensor node

The sensor units are required to sense the various physical parameters like moisture of soil, vibrations, pressure, humidity etc many more parameters of the environment and their surrounding and the sensed values or the analog signals generated by the sensors based on the observed phenomenon are converted to digital signals by the ADC, and then fed into the processing unit. In the processing unit, local computation can be performed on the sensed data.

The transmission unit of sensor node is responsible for message exchange or transmitting and receiving the data from one sensor node then onto the next node or to an end client through the cluster head to the base station (BS).

The power unit is used to supplies the power to various components i.e. sensor unit, processing unit and transmission unit for their proper functioning. There are additionally different subunits that are application-subordinate which are location finding system and Mobilizer. A large portion of the sensor system steering methods and detecting undertakings require information of area with high exactness. In this manner, it is regular that a sensor node has an area discovering framework or location finding system. A mobilizer may here and there be expected to move sensor nodes when it is required to do the appointed tasks.

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WSNs are widely used for different applications like Biomedical Signal Monitoring, Smart Parking, Structural Health Monitoring, Greenhouse Monitoring, Habitat Surveillance and many more [8].

Paper organization: The rest of the paper is organized as follows: Section 2 presents an overview of clustering in WSN. Section 3 presents earlier works on uneven energy efficient clustering algorithms. Section 4 presents the problem definition. Section 5 explores the detailed description of the proposed algorithm. Section 6 presents the simulation results and discussions, and Section 7 concludes the work.

2. Clustering in WSN

Clustering scheme can be used by the hierarchical energy efficient routing protocols. Clustering in WSN helps in achieving the scalability to the network and also enhances the lifetime of a network. In the clustering process, sensor nodes are grouped into the clusters, a node is chosen as the cluster head (CH) of a cluster and all other alternate nodes are called as cluster members (CMs). Every node in the cluster gathers neighborhood data from the environment intermittently and sends it to its cluster head. After collecting all the data from the CMs, the CH aggregates the collected data and sends it to the base station by using single-hop path or by multi-hop way.

2.1 Equal and Unequal clustering

In equal clustering, the same sizes of clusters are formed in a network. It groups the nodes into clusters of equal sizes.
In unequal clustering, the different sizes of clusters are formed in a network. It groups the nodes into clusters of unequal sizes. Cluster heads closer to the base station have smaller cluster sizes than those farther from the base station, thus they can preserve some energy for forwarding the inter-cluster data.

2.2 Single hop and Multi hop communication

In Single-hop communication, the cluster head of clusters in a network directly sends their data to the base station. The CHs farther away from the BS need to transmit data to a long distance which can cause more utilization of vitality. So the vitality of CHs which are located at a longer distance from the BS should be larger than the CHs closer to the BS. Otherwise the CH which located far away from base station have to transmit data to a long distance and it will die very early compared to CH located near to base station.

In Multi-hop communication, the cluster head located near to base station have a heavy relay traffic load compared to those located far away from base station. This will cause the premature dying of CHs located near to the base station. This phenomenon is known as energy hole or hot spot problem. To solve the above problem the energy efficient unequal clustering algorithms are proposed.

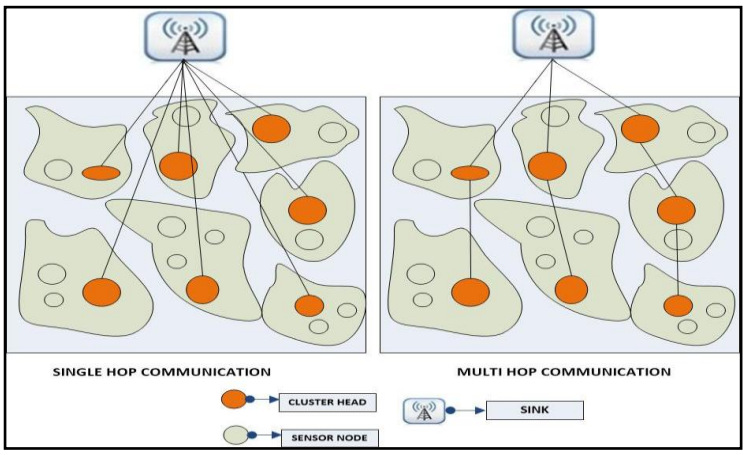

Figure 2. Single hop v/s Multi-hop communication

3. Related works

In the previous years, various algorithms or protocols have been proposed in the area of energy-efficient clustering for WSNs. In this section the various hierarchical unequal clustering based routing protocols are discussed.
LEACH [1] is the first energy efficient hierarchical clustering algorithm for WSNs proposed by Heinzelman et. al. and has become the most popular in hierarchical clustering by reducing power consumption. LEACH distributes the energy load evenly among all sensor nodes in a network by dividing the network into a several clusters and selecting cluster head from each cluster randomly. In LEACH cluster head responsibility is randomly rotated among all the sensors such that all the nodes drain its battery equally. Cluster head aggregate (or Fusion) the original data into the smaller size of data that carry only meaningful information from the cluster to the base station which also helps to prolong network lifetime.

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In HUCL [2], the network is divided into layers and clusters of various sizes. The cluster heads are selected based on available energy, the distance to the sink and the number of neighbors. Once the cluster is formed, the same structure is maintained for a few rounds. The data are forwarded to the sink through a multi-hop layer-based communication with an in-network data compression algorithm. In comparison with the existing protocols, the HUCL balances energy and achieves a good distribution of clusters, extends the lifetime of the network and avoid the energy hole problem.

In ECDC [3], the authors introduced the coverage importance (CI) metrics for area coverage and point coverage. They induced these metrics in the waiting time calculation and to find a data forwarding path to the sink to increase the network lifetime.
In [5], the unequal cluster versions of HEED were proposed as UHEED. The unequal size clusters are created based on the distance of the CH from the sink. The competition radius calculation is the same as EEUC; UHEED creates a smaller cluster closer to the sink.

In UCR Protocol [6], it groups the nodes into clusters of unequal sizes. Cluster heads closer to the base station have smaller cluster sizes than those farther from the base station, thus they can preserve some energy for forwarding the inter-cluster data. To mitigate the hot spot problem and introduced a novel unequal clustering protocol called UCR. The selection and rotation of CHs are based on residual energy. The model increases the network lifetime by decreasing the number of nodes in clusters with higher relay loads near the sink.
In [7], the authors addressed the ‘‘isolation point’’ and the hot spot problems. Each node collects its neighbor information for computing the average energy and assigns the waiting time for each node based on residual energy. After the waiting time expires, the node itself assumed as the CH and sends the CH announcement message within its competition radius. For inter-cluster communication, it uses a multi-hop communication pattern.

4. Problem Definition

Clustering in WSN helps in achieving the scalability to the network. However, there is still huge gap of improvement that is to fulfill. The cluster head selection is an important issue to handle the data collection. Employing single cluster head in each cluster would burden the Cluster head for the task it has to perform. So it is proposed to introduce the two cluster heads in each cluster. One with low selective index will be selected as Assistant Cluster Head and with maximum value will be selected as Master Cluster Head. It is expected to enhance the network lifetime by bringing energy balancing in the network.

5. Proposed Approach

In this paper, the protocol having two cluster heads is produced in each cluster. It helps in the load sharing of the data among the nodes. The farther placed nodes get benefitted from this at large level. In the Figure 3 it can be seen how the proposed protocol is implemented. MCH and ACH are being represented in the Figure by using an arrow. The red lines connecting to the BS from the MCH shows the direct connection of the CH nodes to the BS.
There are few network assumptions that have been considered in this paper. These assumptions give the real ground to the network model that has incorporated in the proposed protocol.

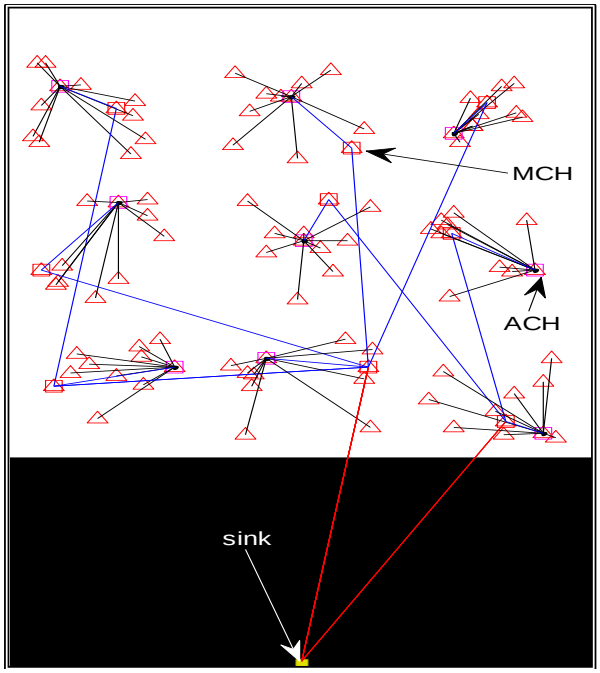

Figure 3. The proposed network scenario

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5.1 Network Model

A few assumptions are made about the sensor nodes and the network model:

a. There is 'N' no. of sensor nodes are distributed randomly in an M × M square field.
b. Each node has a unique identity id.
c. All the sensor nodes are homogeneous.
d. All the nodes and the BS are stationary after the deployment.
e. All nodes can adjust their transmission power according to the distance.
f. The elected cluster heads can communicate with the BS directly.
g. The BS is located outside of the sensor field. It can be reached by all sensors and has sufficient energy.
h. CH can perform data aggregation.

5.2 Simulation Scenario

The simulation scenario of the proposed protocol is being shown in the Table 1. There are different values for the different parameters. There are some universally constant values for the radio energy consumption model.

Table 1. Simulation parameters.

Parameter	Value
Sensor field	100 m × 100 m
BS location	(150, 50)
Number of nodes	100
Initial energy of nodes	2 J
Data packet size	1000 bytes
Packet header size	25 bytes
Control message size	50 bytes
RL_{max}	10–60 m
E_{elec}	50 nJ/bit
E_{fs}	10 pJ/(bit m^2)
E_{amp}	0.0013 pJ/(bit m^4)
E_{agg}	5 nJ/(bit signal)
E_{com}	2 nJ/(bit signal)
E_S	0.5 nJ/(bit signal)

5.3 Radio Energy Consumption

The energy required for receiving the data also depends on the number of bits being received. The energy required for transmitting and receiving the data can be outlined as in below equations.

$$E_{tx}(l, d) = lE_{elc} + lE_{efs}\, d^2 \quad \text{for } d<d_o \tag{1}$$

$$E_{tx}(l, d) = lE_{elc} + lE_{efs}\, d^4 \quad \text{for } d>d_o \tag{2}$$

$$E_{rx}(l) = lE_{elec} \tag{3}$$

The process of data aggregation also consumes some energy given by equation (4).

$$E_{dx}(l) = mlE_{da} \tag{4}$$

Where E_{elec} is the energy being dissipated to run the transmitter, E_{amp} is the energy dissipation of the transmission amplifier; K is the length of the message in bits, d is the distance between transmitter and receiver.

5.4 Cluster attributes

The cluster formation is random in nature and it is unequal in case. However clustering is uniform but it follows the random topology. Nodes which are closer to each other they form clusters. The role of CH is rotated within the cluster. The fundamental of cluster employs only single CH, but here the two level Cluster Head is incorporated in the network. It consists of Main Cluster Head selection and Assistant Cluster Head selection. The Main Cluster Head selection follows the three parameters i.e. Energy, distance and node density.

The selection of MCH is done by ranking the nodes with highest values of these two parameters and lowest value for the distance. So the selection index is computed. The node with highest value of selection index, is termed as MCH and node with second highest will be considered as ACH.

The whole process of data transmission is performed as shown in the flow chart.

6. Results and Discussion

There are various performance metrics which evaluate the performance of proposed protocol. These are given below:

(i) Stability Period
(ii) Network Remaining Energy
(iii) Graph of Alive Nodes vs Rounds
(iv) Graph of Dead Nodes vs Rounds
(v)Throughput of Network

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It can be seen that the proposed protocol has given the stability period of 1683 rounds. The load balancing is observed at different value of rounds with the dead nodes. 20% nodes are dead at 1686 rounds. As the data transmission proceeds, the half of the network is found dead at 1693 rounds. Similarly, 80% nodes are dead at 1705 rounds. The whole network is found dead at 1977 rounds.
The network remaining energy is shown in Figure 4. The graph of alive nodes vs rounds is shown in Figure 5.

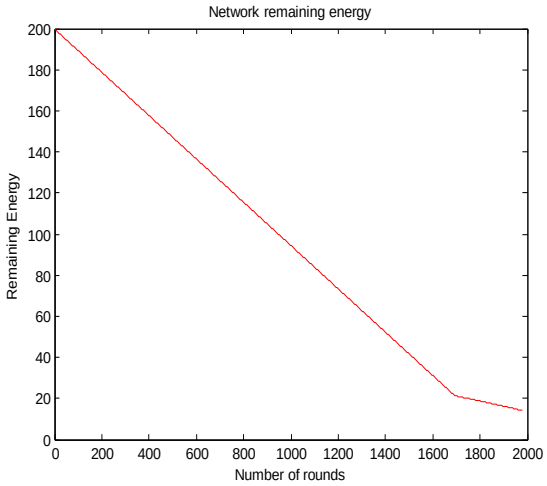

Figure 4. Network Remaining Energy

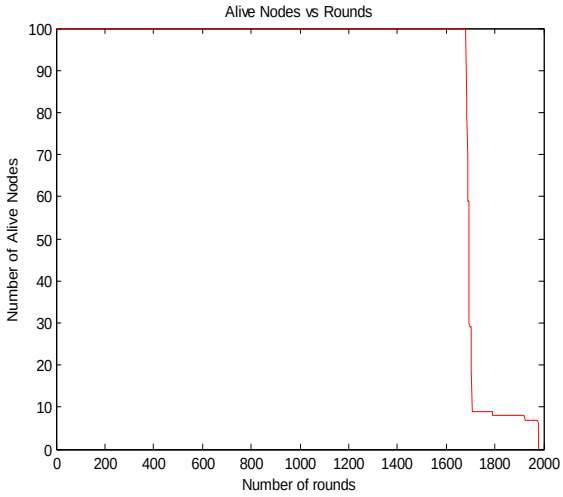

Figure 5. Graph of Alive Nodes v/s Rounds

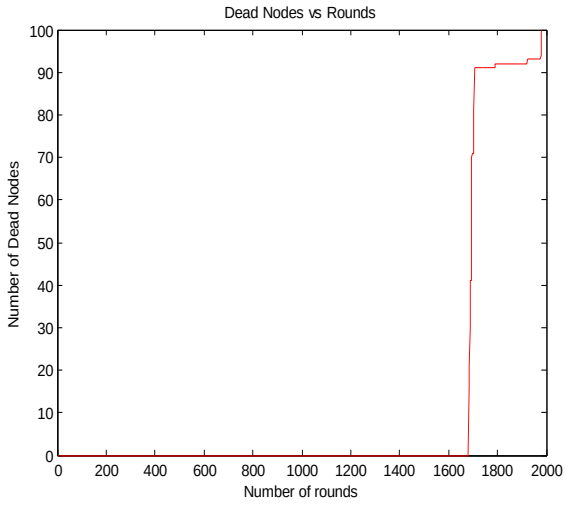

Figure 6. Graph of dead Nodes v/s rounds

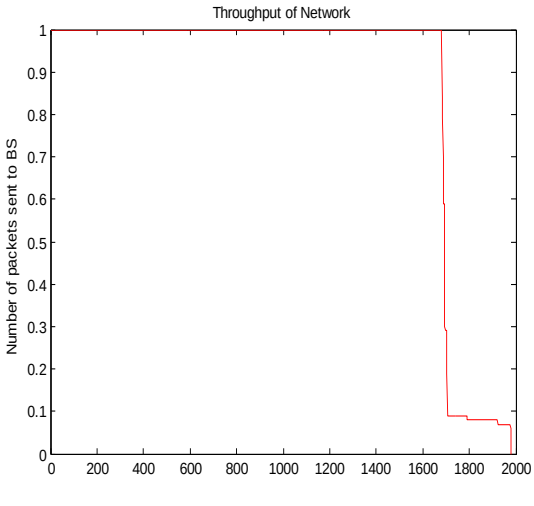

Figure 7. The Throughput of Network

The graph of dead nodes vs rounds is being shown in Figure 6. It shows the steeper graph which balances the load distribution in the network. The throughput of the network is being shown in Figure 7. The high throughput is achieved due to the dual cluster heads approach in the network.

The flow chart shown in the Figure 8 gives the description of the network, the way it incorporates the data transmission among the nodes and CH. Flow chart explains about the data transmission in the network, as well as it also presents the way the CHs are selected in the network.

When the energy of node is equivalent to zero, the network checks for all the nodes in the network, whether all the nodes are dead, thereafter the network stops functioning.

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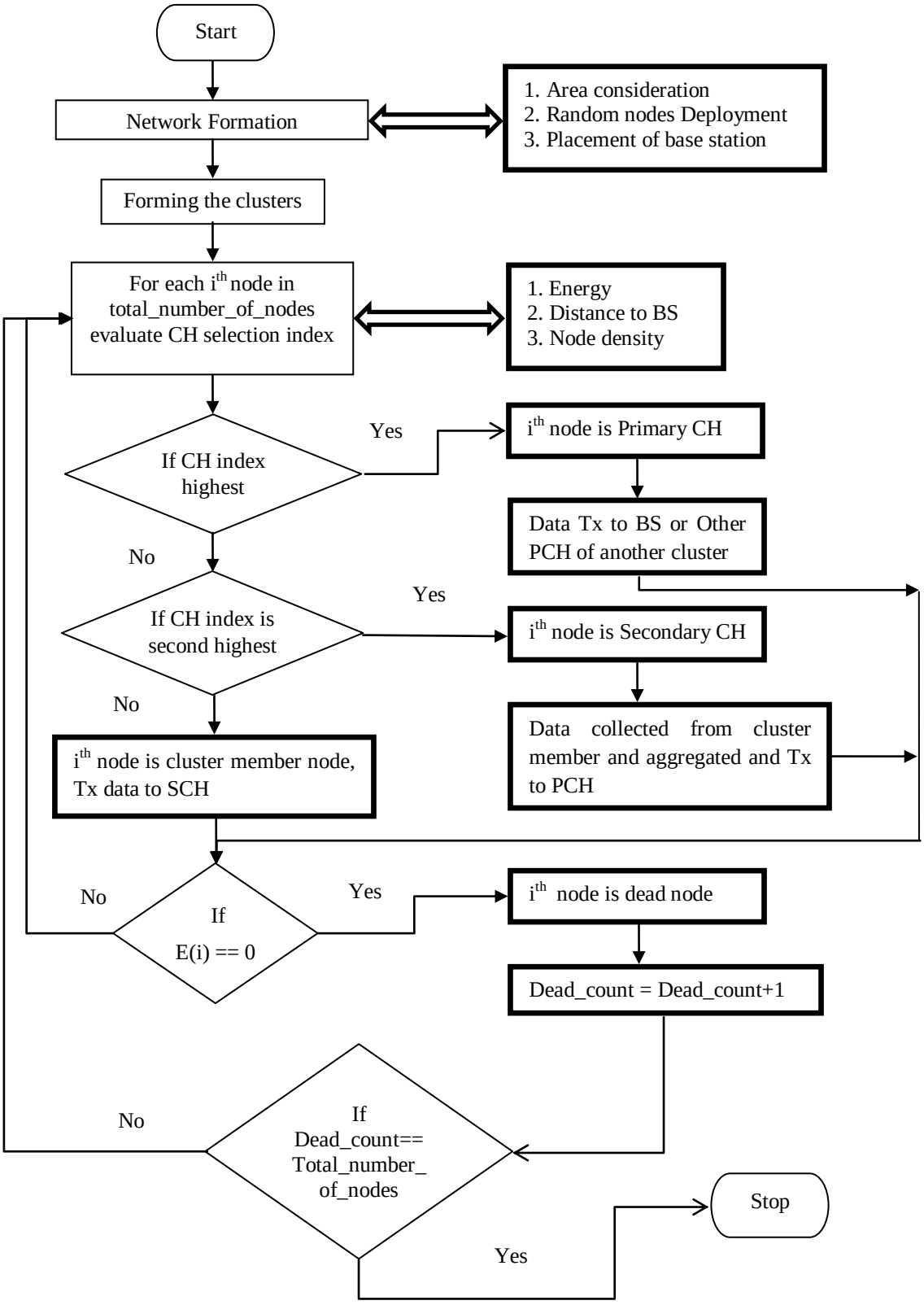

Figure 8. Flow chart for the proposed methodology

7. Conclusion

Wireless sensor network has its major constraints on its functioning due to the limited battery resources. The main focus of the research in WSN has been aiming to achieve the enhanced network lifetime by proposing various routing strategies. In this

proposed paper, the routing technique with two level of cluster heads; MCH and ACH is proposed. MCH and ACH are involved in the data transmission in a way that they tend to share the load of CH in the cluster. In large scale network where the unequal clustering is employed, MCH and ACH make a huge impact.

It is seen high number of rounds around more than 1600 is achieved with the first node dead. It is seen that load balancing is achieved at much higher side.

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