Hierarchical Routing Technique for Prolonging the Lifetime of Wireless Sensor Networks

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Abstract

Wireless sensor networks (WSNs) usually consists of a large number of nodes called sensor node that bring themselves together to form a wireless network. However, the major fact that sensor nodes run out of energy quickly has been an issue and many power efficient routing protocols have been proposed to solve this problem and seniority of the network. This is the reason why routing techniques in wireless sensor network focus mainly on the accomplishment of power conservation. In this paper we intend to proposes the algorithms for cluster formation and cluster head (CH) selection for prolongs the network lifetime. This algorithm selects CH with highest residual energy in each communication round of transmission and also takes into account, the shortest distance to the base station from the CH. In our approach, the cluster formation is done geographically.

Keywords: *Base station, Clustering, Cluster head, Residual Energy, Routing protocols, Wireless sensor networks.*

1. Introduction

Generally, routing protocols on the basis of network structure are divided in to three main groups as Flat routing, Hierarchical routing, Location based routing. Due to the nature of the WSN, sensor nodes are normally powered by the use of batteries and thereby having a very constrained budget in terms of energy [1]. To effectively maintain the network sensors to have longer lifetimes, all areas of the network should be carefully designed to be energy efficient. Among many methods, clustering the sensor nodes into groups, so that sensors send information to only the cluster heads (CH) and then the CH communicate the aggregated information to the base stations, may be a good method to minimize energy consumption in WSN. This data aggregation in the head nodes greatly reduces energy consumption in the network by minimizing the total data messages to be sent to BS. The less the energy consumption, the more the network life time. The main idea of developing cluster-based routing protocols is to reduce the network traffic toward the sink. This method of clustering may introduce overhead due to the cluster configuration and maintenance, but it has been demonstrated that cluster-based protocols exhibit better energy consumption and performance when compared to flat network topologies for large-scale WSNs [2]. A survey of the routing technique in wireless sensor network and mentioned that hierarchical routing technique has the advantages related to scalability and efficient communication [9].

In WSN various algorithms have been developed for Cluster formation and CH selection such as LEACH, PEGASIS,TEEN etc. In this paper have to proposes the Hierarchical routing algorithm which is used for prolongs the lifetime of the wireless sensor networks uses hierarchical routing technique includes cluster formation and CH selection. Simulation results show that proposed technique is better than the non-hierarchical routing technique. Also it is power efficient and prolongs the lifetime of WSN.

The paper is organized in the following way. Having section 1 which introduces the paper in brief, section 2 explains related work, section 3 introduces the energy model employed and proposed hierarchical routing technique . Section 4 gives simulation setup and its validation. Also shows the the simulation of non-Hierarchical and Hierarchical cluster formation and how it is being implemented in MATLAB. Section 5 conclude the paper and also mentioned the scope of future design .

2.Related Works

The various power efficient Hierarchical routing protocols have been proposed for minimizing energy consumption and to increase the network life time in WSN such as by Heinemann et al. [3], who described the LEACH protocol , is a kind of cluster-based routing protocols, which includes distributed cluster formation. LEACH randomly selects a few sensor nodes as cluster heads (CHs) and rotates this role to evenly distribute the energy load among the sensors in the network. LEACH uses time division multiple access (TDMA), to transmit data from the sensor nodes to the cluster head. Then CH aggregates the data and transmits it to the base station for processing. One of the features of LEACH is it rotates the cluster heads in a randomized fashion to achieve balanced energy consumption.

In [4] Lindsey et al. who describe PEGASIS protocol , it is an enhancement over the LEACH protocol and it is a near optimal chain-based protocol. The basic idea of the protocol is that in order to extend network lifetime, nodes need only communicate with their closest neighbours, and they take turns in communicating with the BS. It eliminates the overhead of dynamic cluster formation created by LEACH. In this protocol, the nodes transmit to the CH and transmission of data is done by the cluster head, which is selected in a rotational manner, to the BS. PEGASIS protocol is found to save more energy and is more robust in node failure when compared to LEACH.

In [5] A. Manjeshwar et al who describe TEEN, which is a hybrid of hierarchical clustering and data-centric protocols, which groups sensors into clusters with each led by a CH. TEEN uses LEACH's strategy to form cluster. First level CHs are formed away from the BS and second level cluster heads are formed near to the BS.

Muruganathan et al. [6] developed a protocol that creates clusters of the similar size and uses multi-hop routing between CH and the BS. The cluster head which forward the last hop is selected randomly from the sets of cluster heads to minimize the load of cluster head which are located nearest to the base station.

Wei Cheng et al. [7] proposed a novel adaptive, distributed, energy efficient clustering algorithm, AEEC for wireless sensor network. Their approach selects cluster heads based on the node energy related to that of the whole network which can bring about efficiency in heterogonous networks.

3. Proposed Technique

The Hierarchical routing algorithms have been designed mainly for to reduce the power consumption in wireless sensor networks during communication rounds and increase the lifetime of networks .Thus, the research question is: How can we improve the lifetime by reducing energy consumption in Wireless Sensor Network using the hierarchical routing technique?

For the solution of this question we designed new algorithm for cluster formation and cluster head selection .To reduce energy consumption in WSN, we have proposed an approach whose principle of cluster head selection is based on the highest predicted residual energy after the following round and the shortest distance via the closest neighbouring cluster head to the base station. In our approach, the cluster formation is done geographically.

3.1 First Order Radio Model for System

Currently, there is a great deal of research in the area of low-energy radios. Different assumptions about the radio characteristics, including energy dissipation in the transmit and receive modes, will change the advantages of different protocols [8] . In our work, we assume a simple model where the radio dissipates E_{elec}=50 nJ/bit to run the transmitter or receiver circuitry and ε_{amp}=100 pJ/bit/m2 for the transmit amplifier. These parameters are slightly better than the current state-of-the-art in radio design.

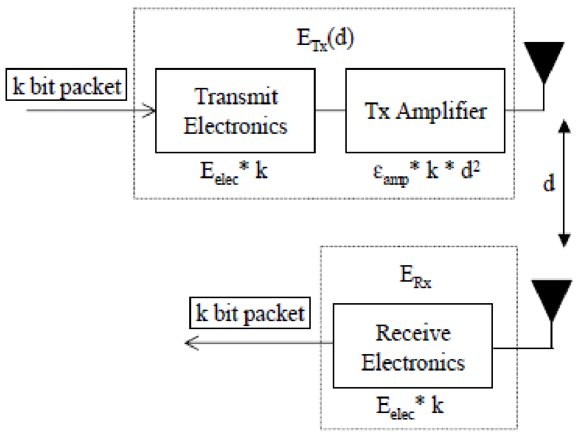

Figure1.First Order Radio Model For the system

We also assume an r^2 energy loss due to channel transmission. Thus, to transmit a *k*-bit message a distance *d* using our radio model, the required energy is given as in equation (1):

$E_{Tx}(k, d) = E_{Tx\text{-}elec}(k) + E_{Tx\text{-}amp}(k, d)$

$E_{Tx}(k, d) = E_{elec} * k + \varepsilon_{amp} * k * d^2$ ...... (1)

And the energy consumed to receive this message at receiver is given as in equation (2):

$E_{Rx}(k) = E_{Rx\text{-}elec}(k)$

$E_{Rx}(k) = E_{elec} * k$ ......(2)

Where

$E_{Tx\text{-}elec}$ -energy dissipated per bit at transmitter
$E_{Rx\text{-}elec}$ - energy dissipated per bit at receiver
ε_{amp} -amplification factor
E_{elec} - cost of circuit energy when transmitting or receiving one bit of data
k- a number of transmitted data bits
d - distance between a sensor node and its respective cluster head or between a CH to another cluster head nearer to the BS or between CH and BS.

For these parameter values, receiving a message is not a low cost operation; the protocols should thus try to minimize not only the transmit distances but also the number of transmit and receive operations for each message. We make the assumption that the radio channel is symmetric such that the energy required to transmit a message from node A to node B is the same as the energy required to transmit a message from node B to node A for a given SNR. For our experiments, we also assume that all sensors are sensing the environment at a fixed rate and thus always have data to send to the end-user.

3.2 The Proposed Routing Algorithm

The proposed hierarchical routing protocol is based on the principle of clustering algorithm. With data transmission at the network layer being the core area of interest, we have modified the LEACH protocol in terms of hierarchical data transfer with the employment of energy prediction technique for selection of CH via any shortest path to the BS. In the proposed model, clusters are formed geographically. Geographical formation of cluster sizes is based on equal segmentation of area space, depending on the case being considered. Apart from the one cluster formation which makes use of the entire sensors area space, other formation such as two clusters formation and three clusters formation involves equal segregation of area space. The CH election phase proceeds after the cluster formation phase. The selection of CH(s) within each cluster formed is carried out by electing a node that require less transmission energy (to BS or to the next hop CH nearer to the BS) to be the CH for a particular transmission round. Due to draining activities being constraint on a cluster head during data aggregation and transfer phase, the cluster head is rotated among the sensor nodes of each cluster at every transmission round. A completely new estimation of energy is carried out at the beginning of every transmission round to elect a new CH for the cluster and thereby energy wastage is being reduce to its minimum, and utilization of each nodes energy is being maximized to ensure a prolong network lifetime.

The proposed hierarchical routing technique consists of four main stages

- Geographical formation of cluster.
- Selection of cluster heads in each cluster formed.
- Data aggregation phase which involves the gathering of collected data by the cluster head from the sensor nodes within its cluster.
- Data transmission phase which involves the transfer of all data from the nearest cluster head(s) to the BS.

Also, the CH selection in the proposed hierarchical routing technique can be explained also in four main stages:-

- The initial energy $E_{in}(n)$ of node is measured

- The distance d(n) from each node to the base station or to the corresponding higher level cluster head is measured.
- Estimation of the energy required by each node for transmission within the cluster not to BS or to higher level CH for two and three cluster formation within a cluster is carried out using the formula: $(\varepsilon_{amp} * k * d^2)$
- The maximum energy after the subsequent transmission round for each node is estimated and selection of CH is done using the formula: max $(E_{in}(n) - \varepsilon_{amp} * k * d^2)$, then after the CH selection is carried out, the next cluster head selection will take place after the current round is completed.

4. Simulation Setup and Validation

In previous section we proposed a hierarchical–based routing protocol that improves the network lifetime of the system. In this section, we show how the protocol performs better in terms of power efficiency by improving the lifetime of WSN. In this simulation, a total number of 250 nodes were randomly deployed within a space region on 300 m x 300 m.The parameters used in the simulation are listed in Table 1.

Table1. Parameter Values

Conditions	Values
Simulation Area	300m X 300m
Total number of nodes, (N)	250
Initial energy per node E_{in} (n)	200 J
Packet size (k) in bytes	100 bytes
E_{elec}	50 nJ/byte
Amplifier coefficient (ε_{amp})	100 pJ/bit
Base Station Location	(0,0)

Proposed Routing Technique:

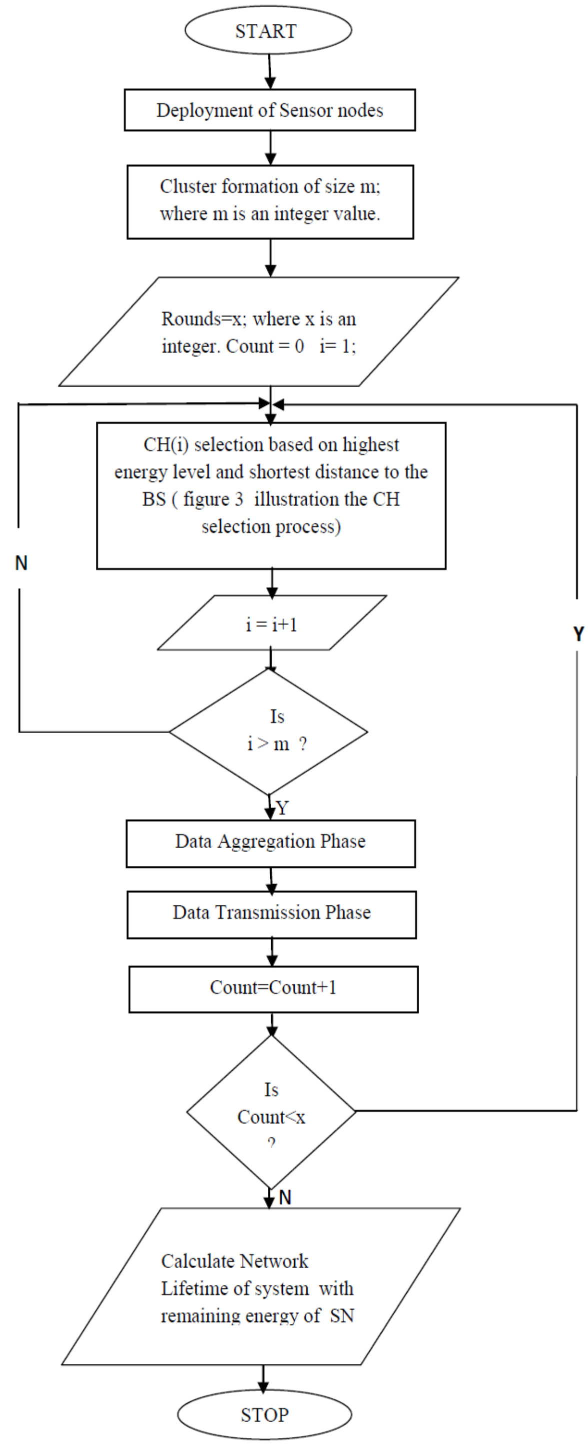

Figure 2. Flowchart of the proposed hierarchical routing technique.

Cluster Head (CH) Selection:

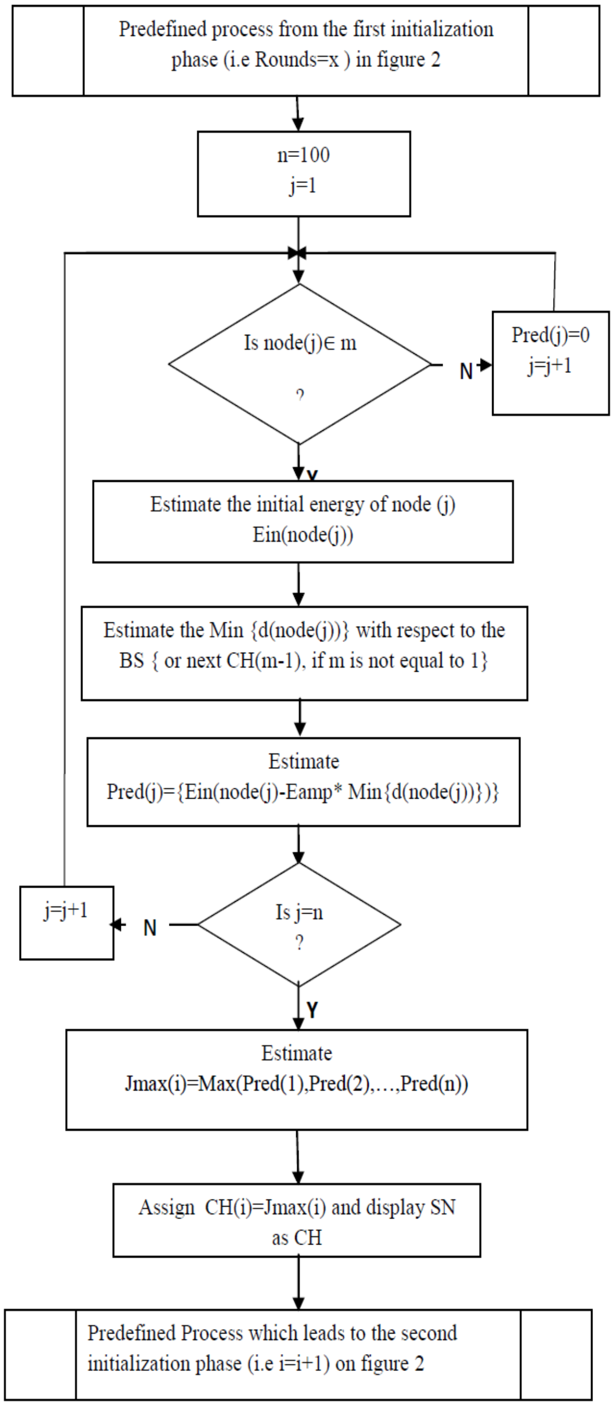

Figure3. Flowchart of Cluster Head selections.

With the nodes being deployed, some assumptions were made concerning the node features and these are as follows:

- All nodes are homogeneous in nature;
- All nodes starts with the same initial energy;
- The base station is situated at the (0,0) origin of the area space;
- Clusters and nodes are static;
- Normal nodes transmit directly to their respective cluster heads within a particular cluster;
- Cluster heads use multi-hop routing to relay data to the data sink;

5.1 Simulation Results

5.1.1.Cluster formation with CH election with routing.

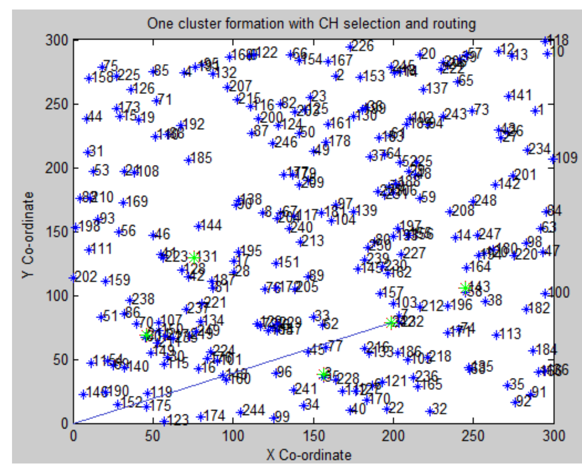

Figure 4. One cluster formation with CH selection and routing.

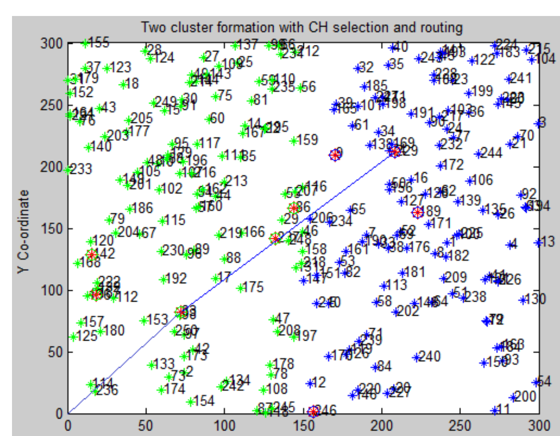

Figure 5. Two cluster formation with CH selection and routing.

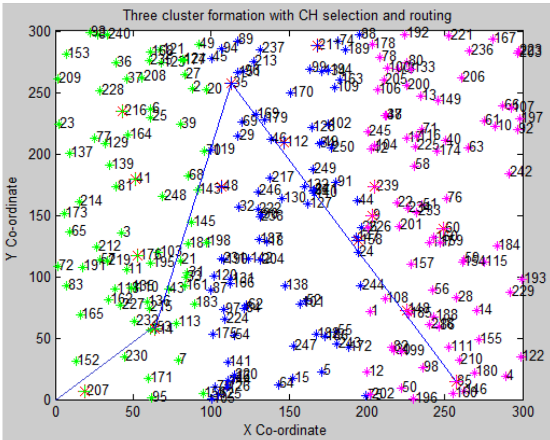

Figure 6. Two cluster formation with CH selection and routing.

5.1.2. Network lifetime Graph.

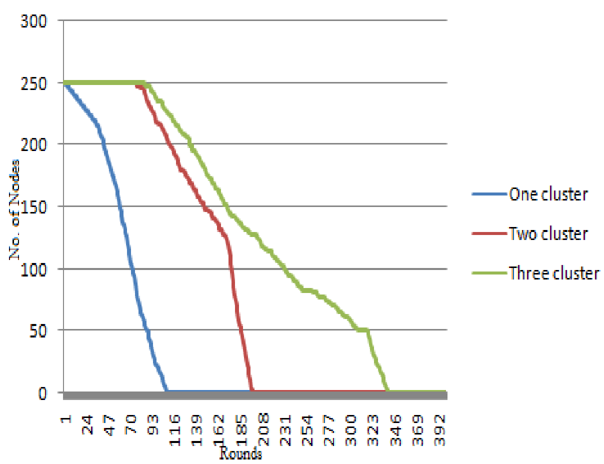

Figure 7. Network Lifetime

Table 2. Comparison of Network Lifetime

Cluster size	First node dies	Network lifetime
One	3	110
Two	78	200
Three	87	342

Table3. Comparison of Mean and variance

No. Of Cluster	Mean value	Variance
One	7.3410	6.7818
Two	13.0593	10.9153
Three	46.1048	44.0060

5.1.3. Residual energy at node and mean value

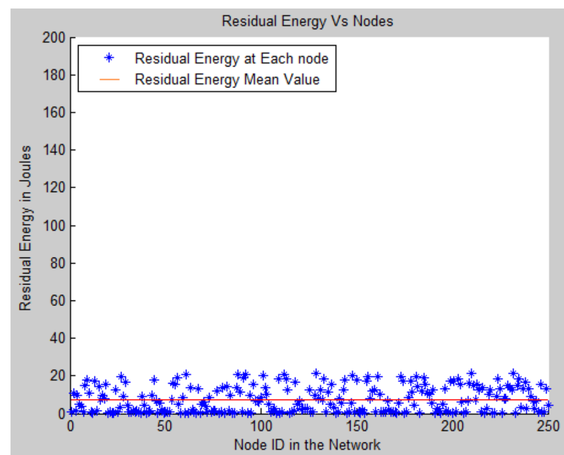

Figure 8. Residual energy at each node and mean value in one cluster formation

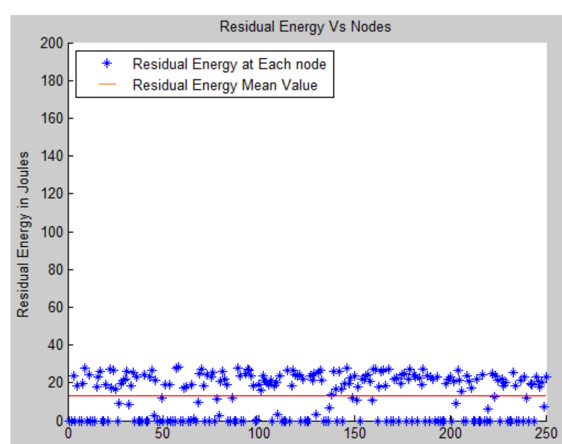

Figure 9. Residual energy at each node and mean value in two cluster formation

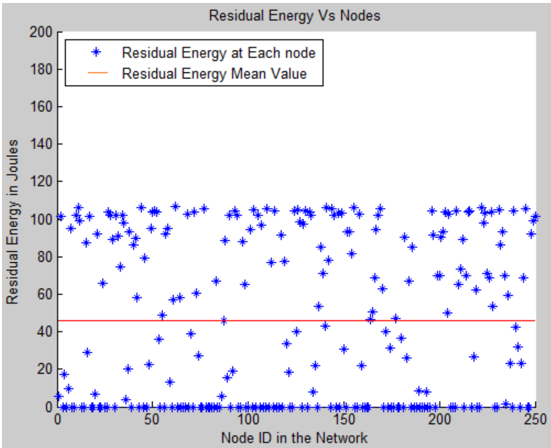

Figure 10. Residual energy at each node and mean value in three cluster formation.

Discussion

1) Using our technique we formed one, two and three cluster formation with CH selection and its routing as shown in fig.(4), fig.(5) and fig.(6). We also plot the network lifetime graph for observation of their lifetime as shown in fig.(7).
2) It is observed in fig.(7) that the first node dies faster in the one cluster formation because all nodes tend to send captured data via one randomly selected cluster head per round to the BS. The constrained load on the elected cluster heads during the entire communication round of simulation drastically reduced the CHs' energy over a short period.
3) It is also observed that the proposed technique offers a better life span for each nodes and even the entire network. Our proposed technique uses optimal energy to extends the lifetime of networks to an impressive range as compared to one cluster formation. The impressive increment in life span of the network from our proposed hierarchical technique is seen as a result of efficient routing decision and optimization of energy in CH selection of each cluster formed.
4) Since the sensor nodes in each cluster send data to the cluster head within its cluster range and then the aggregated data is sent to the cluster head closer to the base station, which further aggregates data of its own cluster and that of the incoming data, from cluster head whose distance is farther to the BS, before sending the data to the base station. Thus, a considerable amount of energy is saved which indicate improved network lifetime in the case of two cluster formation when compared to one cluster formation technique.
5) Furthermore, we also observed in Fig. (7) that the network lifetime increased to a certain length in the three cluster formation scenario. With this increase, the WSN's lifetime was further prolonged when compare to the two cluster formation and the non hierarchical technique. The table 2. indicate when was first node died and total lifetime of the network in case of one , two and three cluster formation scenarios.
6) Our proposed technique is also proved by evaluating the residual energy in each node for a particular rounds of simulation. The results in Fig. (8), (9) and (10) show that the mean residual energy value of all the sensor nodes of proposed method is higher than the non hierarchical method which is a further indication of an improved network lifetime when our proposed technique is being implemented.
7) The Table 3. Shows the mean value and variances of the residual energy after 400 rounds simulations for the hierarchical routing technique used. The mean value of the residual energy increases in each round of simulation as the hierarchical structure increases .This implies better network performance since the nodes has more energy in the latter level of hierarchy.
8) It is also observed in the Table 3. that one cluster formation has the lowest variance and the three cluster formation has highest standard deviation value. The highest value implies the residual energy values after those rounds of simulation are spread out over a large range. It is also observed that a larger variance value indicate how dispersed the residual energy of all node is from the mean value after the entire simulation rounds. It is also noticed that as the value of the variance gets closer to the mean value, it implies a better performance of network since most of the node will die almost at the same time in the end of the simulation. The Figure 4.9, Figure 4.10 and Figure 4.11 show the plot of the histogram of the histogram of the residual energy after 400 rounds of simulation.

6. Conclusion

In this paper, we propose an hierarchical routing technique in which is used for prolonging the lifetime of sensor networks in which cluster heads are elected based on the prediction of transmission energy via a shortest distance to the base station. The important features which includes cluster formation and rotation, cluster head election and rotation, and cluster optimization of our proposed hierarchical routing technique in transmitting data to the base station was analyzed and emphasized. Our proposed hierarchical technique, which uses the predict of smallest transmission energy via the shortest path possible to send data to the BS proved that it offers more reduced energy consumption and also increase the lifetime of the WSN.

In future work, the number of clusters increases to four, five, six and so on, can be investigated. Therefore, this can show how the lifetime in the network would be affected and the optimal cluster size would also be known in case the lifetime is reduced at a certain level of hierarchy. Quality of services (QoS) related to video and imaging sensors, factors affecting cluster formation and the communication between CHs or CH to BS are open issues for future research.

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