A Hierarchical Routing Based Novel Network Lifetime Increment and Energy Competent Protocol for WSN

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Abstract: WSN has been recognized as one of the emerging technologies in the field of wireless communication which contains a large number of sensor nodes. As sensor nodes have limited amount of energy, one of the major issues in wireless sensor networks is developing an energy-efficient routing protocol which has a significant impact on the overall lifetime of the sensor network. This paper proposes a clustering technique based protocol which shows energy efficiency and also increases the lifetime of the network. Our technique forms clusters and selects cluster head within each cluster with highest residual energy in each communication round of transmission and also takes into account, the shortest distance to the base station from the cluster heads.

Keyword: Wireless Sensor Network, Hierarchical Routing, Clustering, Energy Efficiency, Network Lifetime.

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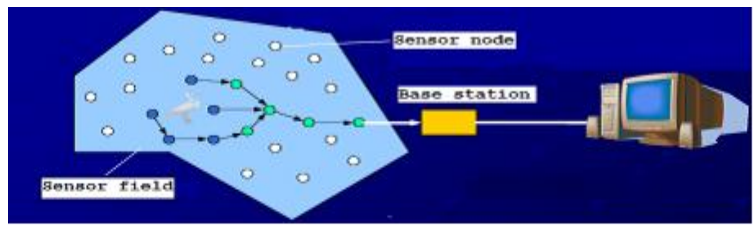
1. INTRODUCTION

1.1 Introduction to WSN

WSN has been recognized as one of the emerging technologies in the field of wireless communication. They promise a lot of potential in monitoring physical phenomena. Today, wireless sensor networks are widely used in the commercial and industrial areas such as for e.g. environmental monitoring, habitat monitoring, healthcare, process monitoring and surveillance. WSN consist of small devices, which collect information by cooperating with each other. These small sensing devices are called nodes. A typical sensor node is made of four building blocks: power unit, communication unit, processing unit and sensing unit. The sensing component in a node measures certain physical characteristic like temperature or detects soil moisture of a location in which it is placed. The processing component is responsible for collection and processing captured data from its surrounding. The wireless communication component of a sensor node is responsible for transmission or reception of captured data from one sensor node to another node or to an end user through the cluster head to the base station (BS). The sensor node, its processing and communication component requires energy to function as expected, and the power component, which is of limited amount, is solely responsible for provision of energy to the three other components. Based on application, the monitored event can either be dynamic or static in its operation. WSNs are usually deployed in an environment to monitor static or dynamic events.



Basic architecture of a wireless sensor network

1.2 Objectives of study

Sensor nodes which are battery operated are used for detecting and collecting information from the areas where there is very little scope for manual handling to recharge or change batteries. These sensing nodes collect the information and pass them on to the network towards the sink for further actions. For a better functioning and a longer lifetime for a sensing node within the network, we need to consider its energy consumption as a major factor of concern. So the main objective of the research is to improve the lifetime by reducing energy consumption in Wireless Sensor Network using the clustering technique.

2. NETWORK AND RADIO MODELS

2.1 The Network Model and Architecture

This research work lies in the realization that the base station is a high-energy node with a large amount of energy supply. Thus, we utilize the base station to control the coordinated sensing task performed by the sensor nodes. In this article we assume a sensor network model, with the following properties:

• A fixed base station is located at the origin.

• The sensor nodes are energy constrained with a uniform initial energy allocation.

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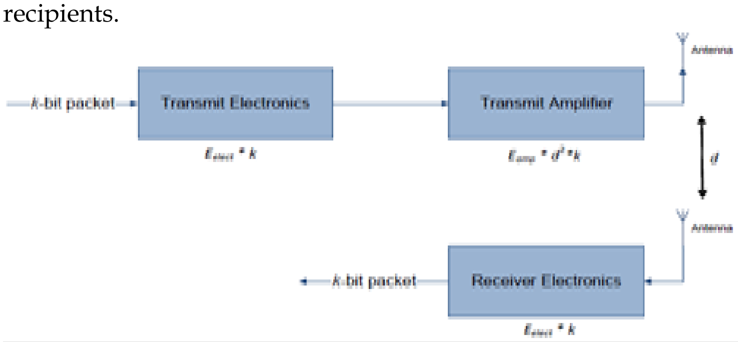
• The nodes are equipped with power control capabilities to vary their transmitted power.
• Each node senses the environment at a fixed rate and always has data to send to the base station.
• All sensor nodes are immobile.

The two key elements considered in this work are the sensor nodes and base station. The sensor nodes are geographically grouped into clusters and capable of operating in two basic modes:
• The cluster head mode
• The sensing mode
In the sensing mode, the nodes perform sensing tasks and transmit the sensed data to the cluster head. In cluster head mode, a node gathers data from the other nodes within its cluster, performs data fusion, and routes the data to the base station through other cluster head nodes. The base station in turn performs the key tasks of cluster formation, cluster head selection, and routing path construction.

2.2 First order radio model

This energy model offers an evaluation of energy consumed when transmission or reception is made by a sensor node at each cycle. The radio has a power control to expend minimum energy required to reach the intended recipients.



The first order radio model

Mathematically, when a k-bit message is transmitted through a distance, d, required energy can be expressed as stated in the equation:

$$ETx = Eelect . k + Eamp . d2.k$$

Likewise, the energy consumed at the reception is illustrated as shown in the equation:

$$ERx = Eelect . k$$

Where
ETx- energy dissipated per bit at transmitter.
ERx--energy dissipated per bit at receiver.
Eamp - amplification factor.
Eelect - 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.

The first order free space radio equation was used to verify the operation of our proposed protocol, assuming that the radio channel being symmetric such that equal energy is used up when a node A transmits to node B and when a node B transmits to node A with a given signal to noise ratio.

3. THE PROPOSED ROUTING PROTOCOL

In this proposed work we are dividing the whole available sensor area space into clusters of equal sizes by equally dividing nodes to the clusters. Instead of using the whole area space as one we divide it into two or three equal parts forming two clusters or three clusters. The two or three cluster formation is also known as first level and second level hierarchy respectively. After the cluster formation phase is over we reach cluster head selection phase, were we select a cluster head in each cluster.

This protocol aims at choosing cluster heads that ensures both the intra-cluster data transmission and inter-cluster data transmission are energy efficient. Cluster heads are the local centers in their own clusters. They perform many energy consuming tasks such as collecting data from member nodes and forwarding processed data to the BS. Thus the number of neighboring nodes, the distance between cluster heads and member nodes and the distances between cluster heads and the base station are all crucial issues when choosing cluster heads. In addition, in order to choose nodes with more energy to be the cluster heads, residual energy of the nodes is considered for cluster head selection in the protocol.

Here in the proposed work we make use of first order radio model to make some of the calculations. Here we first calculate the residue energy of the nodes of each cluster. Then the energy of the nodes are compared to each other, now in order to do maximum transmission node with maximum energy in the clusters are selected as cluster heads. In order to use the network for long time and more transmission we rotate cluster head in each cluster after each transmission. For this after each transmission the residual energy of the nodes is calculated and then again comparing the nodes energy and selecting the node with maximum energy as the cluster head. By doing this we equally divide the burden of transmission among all nodes and by doing this the energy of each node can be properly used and we can prevent more nodes from dying as they contain some energy at the end of the transmission.

To get better output and to get more residual energy and lifetime we use minimum distance concept during transmission. Here we calculate the distance between each nodes and nodes to the base station and selecting the minimum distance path for that transmission so that less energy is wasted in transmitting data when other paths are selected. This procedure is repeated after each transmission so that better results can be obtained for all rounds. Once the cluster head with shortest path is selected the data to be transmitted is aggregated and then transmitted through the CH following shortest path.

By following this procedure of selecting cluster head on the basis of energy, more residual energy is left at the end of the transmission and so more number of nodes remain in alive state and so network lifetime also increases.

3.1 THE PROPOSED ROUTING PROTOCOL ALGORITM

The proposed hierarchical routing technique algorithm consists of following main stages:

- ✓ Firstly, formation of cluster is done by dividing provided sensor area into parts.
- ✓ After the cluster is formed next step is the selection of cluster head in each cluster which is responsible for performing all the tasks of the cluster.
- ✓ Shortest distance between the nodes and nodes to the BS is measured.
- ✓ Then the data aggregation phase comes where cluster head collects data from all the nodes of the cluster.
- ✓ Then the data transmission phase comes where data collected in data aggregation phase is transmitted from the nearby cluster head to the base station.

The algorithm for the CH selection in the proposed hierarchical routing technique is as follows:

- ✓ The energy Ein(n) is the initial energy present at each node of the WSN.
- ✓ Then the distance of each node to the base station and to the other nodes is measured by $\sqrt{(Xa - Xb)2 - (Ya - Yb)2}$.
- ✓ Then we compare the measured distances and select the minimum distance for transmission in that round.
- ✓ Then we calculate the energy required by each node for the transmission of data within the cluster or to the higher level cluster head using the formula
  Eelect . k + Eamp . d2k.
- ✓ Then the residual energy after each round of transmission can be calculated from the formula Ein(n)- (Eelect . k + Eamp . d2k).
- ✓ Then the CH selection is carried out by selecting node with maximum energy in the cluster. These steps are repeated after each round.

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

- ✓ The nodes and clusters are considered to be static that means they are not moving.
- ✓ All the nodes are considered to be of same type that means they are homogeneous in nature.
- ✓ The location of the base station is considered to be situated at the origin (0,0) of the network area space.
- ✓ All the nodes of the area have the same initial energy.
- ✓ During the transmission cluster head uses multi-hop routing to transmit data to the next cluster head or to the base station.
- ✓ Nodes within a cluster transmit data directly to their respective cluster heads.

We had taken some of the parameter values for calculation like we have considered the nodes initial as 250 joules and transmitting the data packet (k) of size 100 kbytes. The coordinate of the base station is considered to be at the origin (0,0) and the cost of circuit energy (Eelec) when transmitting or receiving one bit of data is taken as 50 nano joules per byte and the amplifier coefficient (Eamp) is considered taken as 100 pico joules per bit.

4. RESULT

To implement our work we have used MATLAB software. Here we have considered a total of 300 nodes which are randomly placed throughout the network area. We have considered a network area of 300 x 300 m and we used the radio model equation in predicting minimal transmission energy level for cluster head selection, data aggregation and transmission phase for 500 rounds. The simulation results shown below gives us the output showing firstly, the nodes in a non-hierarchical formation, its network lifetime and the residual energy and secondly, the first level and second level hierarchical formation of the nodes along with the network lifetime and its residual energy.

From the network lifetime graphs shown in fig 2 we observe that the network lifetime for non-hierarchical formation lasts for nearly 164 rounds that means the network can work only for 164 rounds and after that no transmission can be done through this network. Whereas by observing network lifetime graph from fig5 for First level Hierarchical approach we find that it lasts for nearly 307 rounds that means now the transmission can be done for 307 rounds which is much more better than non-hierarchical approach, as the network remains in the alive state for more time so more transmission can be done.

When we observe network lifetime graph for second level of hierarchy we find that it lasts for 500 rounds that means the network remains in alive state for 500 rounds so more and more transmission can be done. Now when we compare this output with the network lifetime output of non-hierarchical formation and First level Hierarchical approach we find that much better output is obtained each time we divide the network into clusters. So as the number of clusters increases in the network more better lifetime time can be obtained.

Figure 3 shows the residual energy of nodes for non-hierarchical formation after 500 rounds of transmission, by observing this graph we find that the mean residual energy of nodes is 9.8 joules. Now observing figure 6 which gives the residual energy of nodes for first level of hierarchy after 500 rounds, we find that the mean residual energy of nodes is 14.56 joules which is better than the residual energy of non-hierarchical formation. So we can say that cluster formation is more energy competent than non-hierarchical formation.

Now when we observe the residual energy for second level of hierarchy from figure 9 after 500 rounds of transmission we find that the residue energy is nearly 143.79 joules. Now comparing this residue energy with that of non-hierarchical routing and first level of hierarchy we find that residue energy has increased to a great extent, resulting better performance. We see that when two clusters were formed then energy level increases to some extent but when three clusters are formed then it gives much better output so we can say that energy value of all the sensor nodes of our proposed method is higher than the non-hierarchical method which is a further indication of an improved network lifetime.

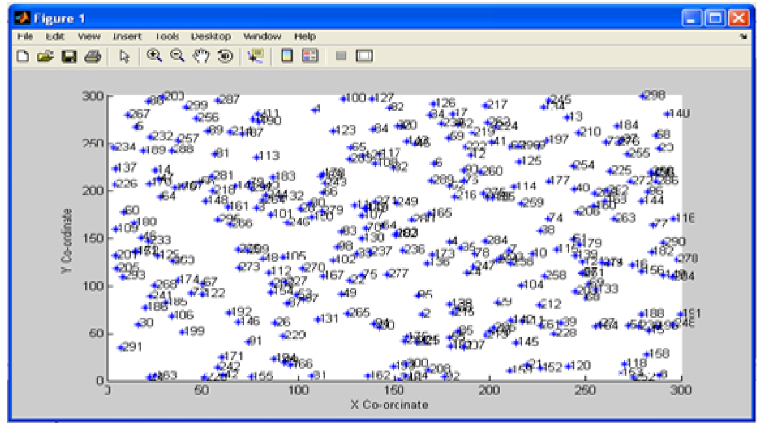


Fig.1. non-hierarchical formation

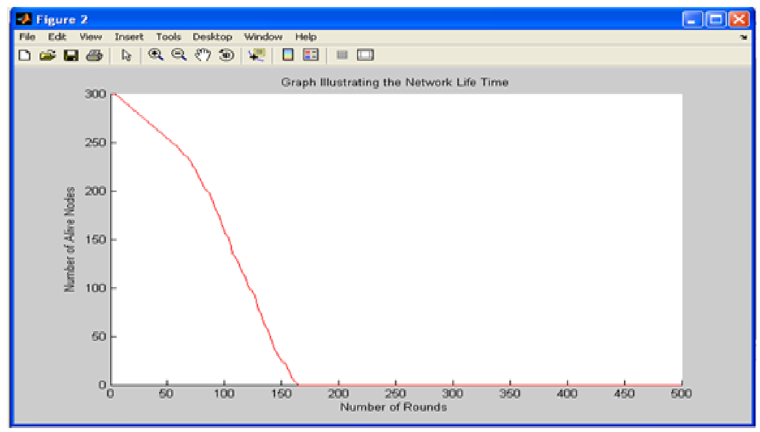


Fig.2.Network lifetime graph (number of alive nodes for non-hierarchical routing)

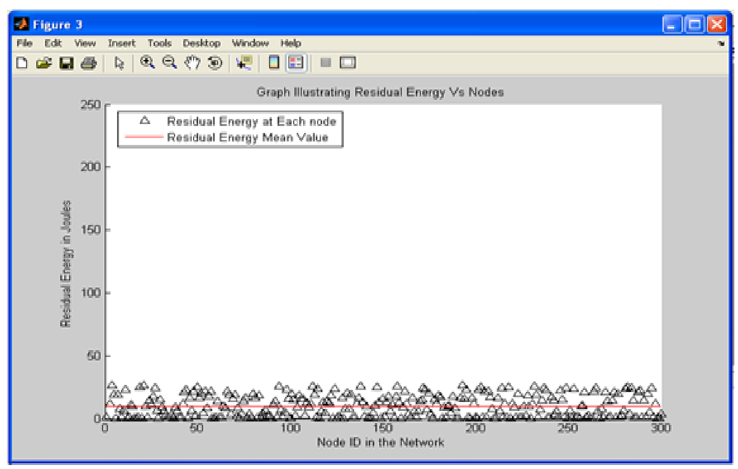


Fig.3. Nodes residue energy in non-hierarchical technique after 500 rounds of simulation

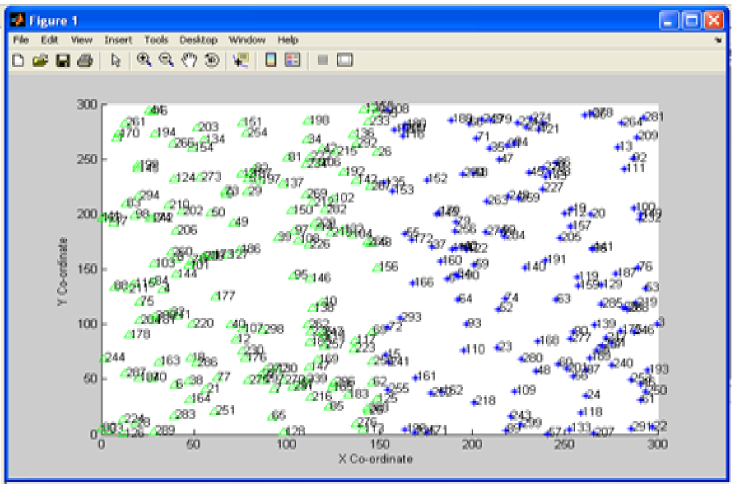


Fig.4. First level hierarchical formation.

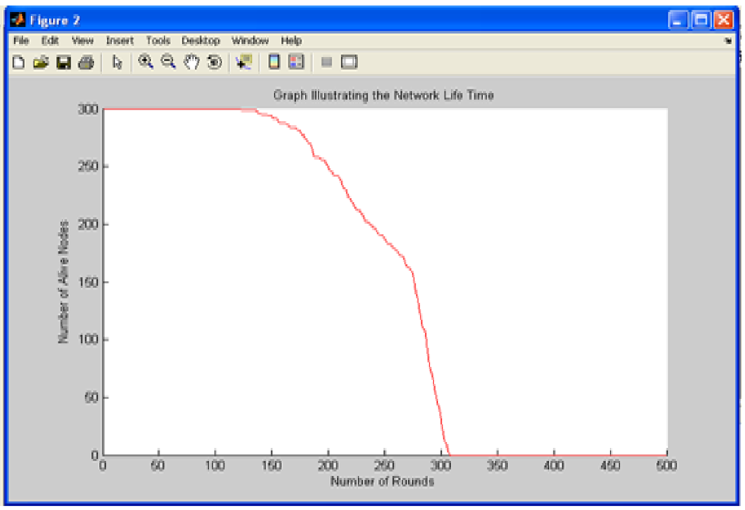


Fig.5. Network lifetime graph (number of alive nodes for first level hierarchical routing)

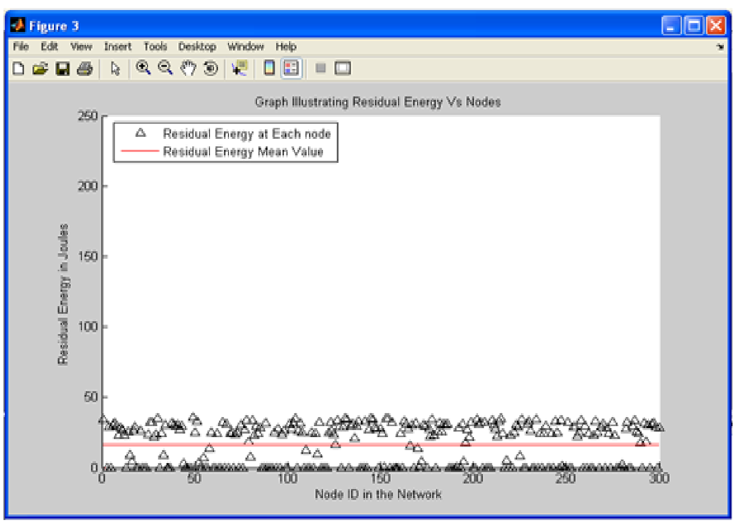


Fig.6. Nodes residue energy in first level hierarchical technique for 500 rounds of simulation

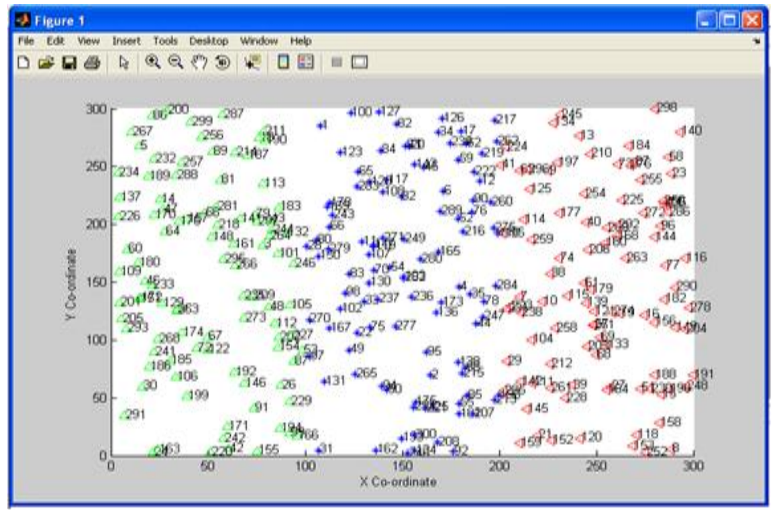


Fig.7. Second level hierarchical formations.

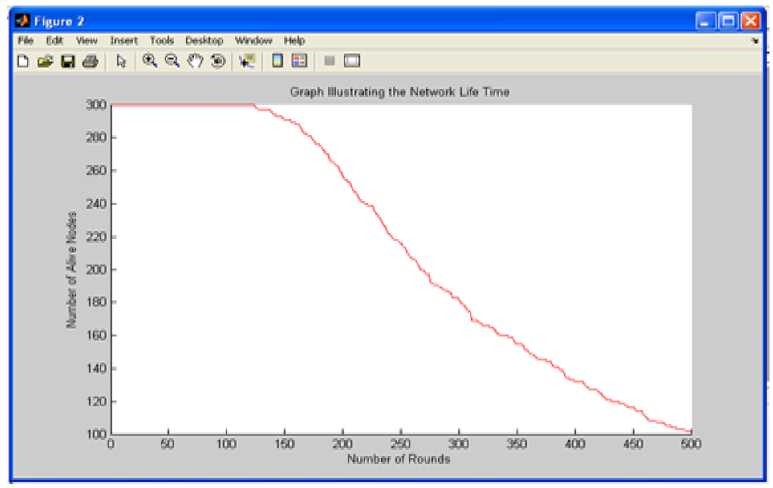


Fig.8. Network lifetime graph (number of alive nodes for second level hierarchical routing)

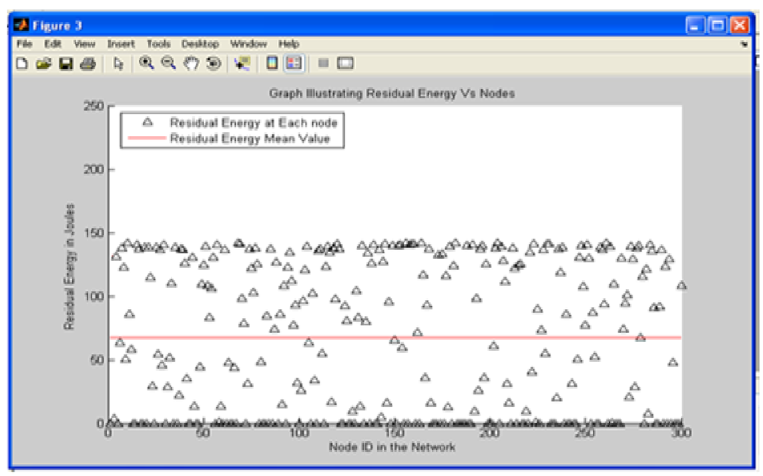


Fig.9. Nodes residue energy in second level hierarchical technique for 500 rounds of simulation.

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4. CONCLUSION

By observing the results of non hierarchical routing, first level of hierarchy and the second level of hierarchy we observe that the network lifetime and residual energy has increased to a great extent as we have increased the number of clusters in the network. The results shows that network remains in the alive state for a longer time and more residue energy is obtained so more transmission can be done when clustering scheme is adopted as compared to that of non hierarchical routing scheme. The proposed scheme makes better utilization of the energy of the nodes which is available in a limited amount.

5. REFERENCES

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