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Energy Efficient Clustering for Lifetime Maximization and Routing in WSN

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Abstract

Wireless Sensor network (WSN) is a quickly rising area for research and development. WSN can be seen in various fields like environmental monitoring, battle field surveillance, border security surveillance, motion tracking etc. A main issue of research in WSN is to arrange the sensors with different capabilities like power, sensing range, communication range in wireless network and route the sensed data from the sensors to a sink with dynamism. Clustering is a key technique used to lengthen the network lifetime by decreasing the energy utilization. In clustered WSN, Routing the sensory data to the sink without obstacle is impossible. So eliminating the obstacle in the routing area is essential. In this paper, grouping the sensors into clusters by energy efficient heterogeneous clustering, that often selects the cluster head from the cluster. Cluster head is selected with respect to the nodes residual energy and other parameters like transmission range and number of transmissions. In this work the connectivity is concentrated by Route identification technique with the help of shortest path algorithm to reach the sink among obstacles. Connectivity is considered as a measure of Quality of Service. We show that the proposed system reduces the energy utilization, average hop count and packet delay of heterogeneous WSN.

Keywords: Clustering, Connectivity, Routing, Wireless Sensor network, Energy, Network Lifetime.

INTRODUCTION

Wireless Sensor Networks consist of many tiny sensor nodes capable of sensing and wireless communication. Sensor nodes are distributed and autonomous used for various applications like environmental monitoring, human motion tracking, medical science and military etc.The region will be distributed with autonomous sensors.Each sensor will be capable of sensing and transmitting. Sensor node senses the environment and transfers the data to the sink node. Coverage depends on the sensing range and Connectivity of the node to reach sink depends on the communication range. Connectivity can be defined as an ability of the sensor node to sense the environment and transfer the information through the network to reach the data sink (FIGURE 1).

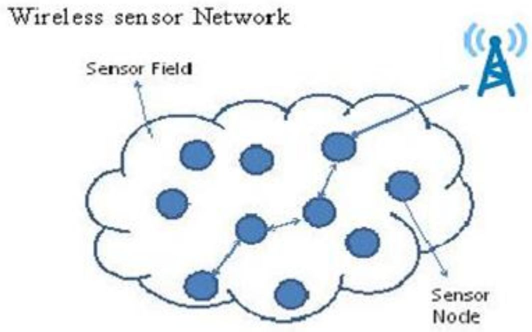

Figure 1. Wireless Sensor Network (WSN)

Heterogeneous wireless sensor network consists of many sensor nodes with different energy, communication range and sensing range. Each sensor nodes are battery powered (energy). Energy is being a most important one because the battery present in the sensor node cannot be replaced often. The node has a non-rechargeable battery or impossible to replace batteries in most sensor fields. To lengthen the lifetime of the WSN, clustering is the key technique. Clustering will dynamically re-assign the member nodes in the cluster. So the network disconnection due to energy drain out nodes can be avoided. Energy consumption of the sensor node is reduced to increase the lifetime of the network.Only few works focus on lifetime maximization in heterogeneous WSN. The paper is organized as follows: In chapter I, addressed about the introduction and issues in WSN. In Chapter II, Related work, Observations made and issues. In Chapter III, discussed about the proposed system. In Chapter IV, deals with the methodologies used to maximize network lifetime. In Chapter V, Results and Discussion. In Chapter VI, Performance Evaluation. Finally in Chapter VII, conclusion of the paper. At the end is the list of references.

RELATED WORK AND OBSERVATIONS

Clustering is a technique used to extend the lifetime of a sensor network by reducing energy consumption. Connectivity is very essential for data transmission. Clustering can also increase network scalability. Researchers in all fields of wireless sensor network believe that nodes are homogeneous, but some nodes may be of different energy to prolong the lifetime of a WSN and its reliability. A distributed approach to determine if a sensor in WSN is a cluster head to meet the preferred connectivity requirements [1]. Cluster based routing in WSN is used to reach network scalability and maximize lifetime [2]. The existing methods for prolonging the lifetime of WSNs focus on the issues of device placements [3], data processing [4], routing [5] and topological management [6]. In[7]Energy aware algorithm for the selection of sensor and to identify the relay node. Shortest path algorithm is used for choosing the path. In [8] ABC Based Sensor Deployment. Schedule the sensor nodes to achieve network lifetime. Target coverage is provided. Maximized coverage not provided for heterogeneous type of network.On observing the existing work, most of the techniques are applied only in the homogeneous type of WSN and not in the heterogeneous network.

PROPOSED WORK

In the proposed work, to reduce the energy consumption and to maximize the network lifetime an Energy efficient Heterogeneous Clustering (EHC) technique and a Route identification technique in clustered WSN among obstacles are used. Sensor network are often deployed in remote areas. As the energy capability of the nodes is restricted and battery powered, some method should be introduced to preserve energy to avoid node failure. Clustering is one of the key concepts for energy consumption and to increase the lifetime of a sensor node in a network. After deploying the sensor nodes randomly in the region of interest, each sensor nodes in the field try to form as a cluster. Each node only interacts with a small set of sensor nodes within the transmission range. At the beginning all the nodes are not clustered. Each node in the clustering process use different types of messages like Broadcast message, State message and Join message.

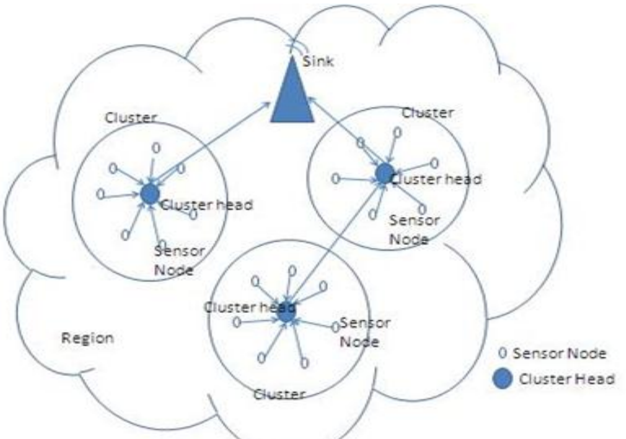

Figure 2. Clustered Networks

Each node broadcasts a message to all its neighbors. According to the number of received messages and with respect to the residual energy and delay the node will decide by itself to be a cluster head. The node with high residual energy will have less delay. Once the delay expires the node will give a state message to its neighbors as a cluster head. All other nodes will give a join message and form as a cluster (FIGURE 2). Each cluster head can form a connected network. Cluster head will communicate with sink node and transfers data. Energy efficient heterogeneous clustering is the proposed technique which works with the heterogeneous type of sensor nodes. Here heterogeneity means the nodes with different energy level, transmission range, sensing range etc. are grouped as a cluster. EHC form a clustered WSN. It performs the cluster formation and the cluster head identification in a distributed manner. Route identification technique with shortest path algorithm which avoids obstacles is used to identify the shortest route to reach the sink node for communication (FIGURE 3). After routing path has been established by cluster heads it will form a connected network. The cluster head identification should be changed time to time dynamically to increase the network lifetime. This dynamic cluster formation will reduce the energy consumption and increase the network lifetime.

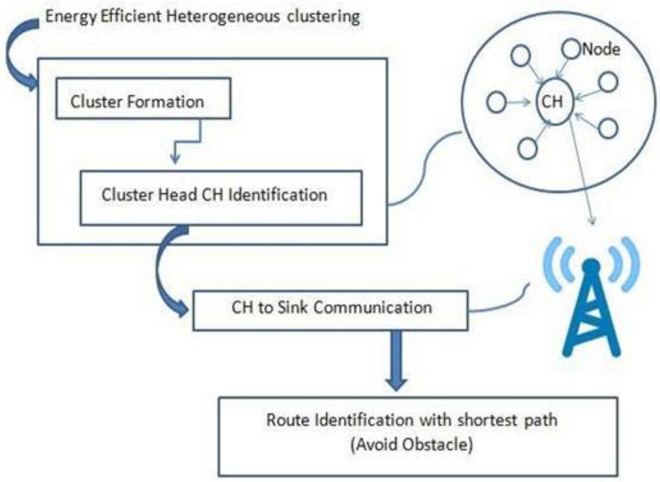

Figure 3. System Architecture

In this paper, the lifetime of the network is the time from the start of the network operation till the death of the first sensor node in the network. The lifetime of the WSN is divided into trips to balance the energy usage among sensor nodes. At the start of the trip, each sensor involves in the cluster formation and cluster head election using EHC. Each sensor sense the data and forwards it to the cluster heads, which routes the data to the sink node using route identification technique.

METHODOLOGY

Energy efficient Heterogeneous Clustering

The sensor nodes are distributed randomly on the sensing field. Energy efficient Heterogeneous Clustering (EHC) will form the cluster and cluster head identification in a distributed approach.

Cluster Formation: After deploying the sensor node n in the region of interest. The node in the region will makes decision independently. Clustering is a key technique toform cluster and is completely distributed. The nodes in the field are formed as a small region called cluster. And each cluster will elect a node as a cluster head. Steps to form a cluster and cluster head identification is discussed in the cluster head identification phase.

Cluster Head CH identification: In this work, n nodes are randomly deployed in the network. Each nodehas initial energy E(i), transmission power P(Tx) and other required parameters by the time they are deployed. The main purpose of the cluster head CH selection is to determine the normal nodes and the cluster head in the network. Every cluster head should be connected with the sink node directly or through some another CH. Now the competition is set among each node that is qualified to be a CH. Node can be identified as a CH only when it has a high residual energy E(r) and with less delay D.Initially each node is given with E(i) and P(Tx) as input. Process each node separately in each trip.

Step 1: For current node C(n), in the current trip C(r) calculate the number of transmissions n(Tx) while sending the broadcast message to all the neighbor nodes. This broadcast message is given to say the neighbor about the survival of the node. The n(Tx) can be calculated as the number of node count each node receives.

Step 2: For the current node C(n) calculate the residual energy E(r) with E(i), P(Tx) and n(Tx) as input with the following formula.

$$E(r) = E(i) - [P(Tx) * n(Tx)]$$

Step 3: Calculate the Energy Consumption Rate ECR for C(n) with E(i), E(r) and the Current Trip CR as input.

$$ECR = \frac{E(i) - E(r)}{CR - 1}$$

Step 4: Calculate the Delay D for C(n) with E(i), E(r), random number x which can be 0 or 1 and the Round Trip Delay RTD.

$$D = \left(\left(\frac{E(i) - E(r)}{E(i)}\right) + x\right) * RTD$$

Step 5: Repeat the steps for all the nodes. By doing this the node with high residual energy and with less delay will be identified easily.

```
Identify the Cluster Head CH (Broadcast Message)
Input Initial Energy E(i), Transmission Power P(Tx)
Begin
for each node (Current node C(n))
 {
  for each round(Current trip C(r))
   {
     Calculate Number of Transmissions n(Tx);
     Calculate the Residual Energy E(r) with E(i), P(Tx) ,n(Tx);
     Calculate Energy Consumption Rate for C(n);
     Calculate Delay D for C(n);
   }
 }
Pick Random Number x in(0,1);
Assume P(D), Q(D) as Delay of First node, Second node;
Process all the nodes;
for each node
 {
   Compare P and Q and capture the less D node;
   if (P(D)<Q(D) && high E(r))
    {
     P(D) with less D;
     Node announces itself as CH to nearest nodes;
    }
   Else
    {
     P(D) with high D;
     Will act as normal node;
    }
 }
End;
```

Figure 4. Identification of the Cluster head

Consider two nodes for assumption P, Q. Let P(D) and Q(D) be the delay of first node and the second node. If P(D) is less than Q(D) then P will announce itself as CH to Q. Else the delay is higher and P will act as a normal node in the cluster (FIGURE 4). The node with higher E(r) will have less delay. So the higher E(r) nodes delay will expires soon and it will give the state message as CH to the neighboring nodes. Now the other nodes will give a join message to the CH andacts as a normal node. Thus the cluster is formed and the CH is identified.After sometime, CH will be re-elected with respect to a threshold value THv. This is done dynamically time to time.So that the nodes will not drain its energy so soon and go under death. This will increase the network lifetime and reduce the energy utilization.

Route Identification Technique

Cluster head is identified and it is allowed to communicate with the Sink S to form a connected network.

Network Connectivity: Connectivity is considered as a measure of quality of service. In order to avoid disconnection during data transfer, the node has to maintain its connection with the nearest nodes. The connectivity depends on the communication range and should identify the shortest path to reach the sink.

Route Identification: For identifying the shortest route to reach the sink, initially input the clustered WSN. Consider n is a node, for each n with the help of the graph method send data to the CH. If n is a cluster head send data to the sink S. If the CH does not has the nearest node as the sink node then send the data to the nearest CH to reach S. If n is an obstacle, avoid the obstacle and apply the shortest pathalgorithm (Dijkstra) to reach the sink node with shortest path.Consider the clustered network as a Graph G and take a node as Source src. Assume the node as the vertex v. For each vertex in G, assign the distance as infinity, distance to src as zero and the current cost to be infinity. Starting nodes distance is permanent and for all other nodes it's temporary. U is the node with smallest distance. Q is the set of all nodes in the graph G. If a calculated distance of a node is smaller as the current one, update the distance and set the current node as previous node. Set the node with minimum temporary distance as active. Set its distance as permanent. Repeat the process to identify the shortest route to the sink node from each CH (FIGURE 5).

```
Route Identification Technique
Input clustered WSN
for each node
 {
  if (n is a node)
    {
     send data to cluster head CH;
    }
  else if (n is a CH)
    {
     send data to nearest CH or Sink S;
    }
    if (n is an obstacle)
     {
      Apply SPA on vertex v;
      function Dijkstra (Graph G, Source src)
      for each v in G
          distance(v)=8 ;
          previous(v)=undefined;
          distance(src)=0;
          Q=all nodes in G;
           while (Q is not empty)
             {
              u=node in Q with smallest distance(u);
              remove u from Q;
              for each nearest node v of u
                {
                 a=distance(u) + distancebetween(u,v);
                 if (a < distance(v))
                  {
                   distance(v)=a;
                   previous(v)=u;
                   return previous();
                  }
                }
             }
    else
     {
      send data to nearest CH or Sink S;
     }
  else
   {
    identify n;
   }
}
```

Figure 5. Route Identification.

Route identification technique will attain a path from the CH to the sink node with minimum cost. Shortest path here is considered as a hop count among obstacles. This will also achieve the connectivity in the WSN. Each node is connected with neighbours. Coverage without connectivity is meaningless. So connectivity is an important measure.

RESULTS AND DISCUSSIONS

An Energy efficient heterogeneous clustering technique is proposed in WSN that selects the cluster head to create a connected network. In this technique sensors make local decisions on whether to join the network as a cluster head or as a member node of a cluster. The decision of the each node is based on the residual energy and an estimate of how many of its neighboring CH will benefit from it being a cluster head. It is a distributed technique where cluster head can be changed with time to increase the lifetime of the sensor nodes present in the network. The proposed work is implemented using NS2 simulator. Network simulator produces one or more text-based output files that contain detailed simulation data, if specified to do so in the input script. The data can be used for simulation analysis or as an input to a graphical simulation display tool called NAM.

Table I. Simulation Parameters

Parameters	Value
Network Size	500m x 500m
Nodes location	Random
Initial energy	0.5J
Number of nodes	100
Transmission power	100W

Node Creation: Sensor nodes are randomly distributed in the sensing field (FIGURE 6). In this network, the nodes are static and fixed. The sensor nodes sense the information and then send to the server. If the source node sends the packet, it will send through the intermediate node. The node communicates only within the communication range. So the node's communication range has to be identified.

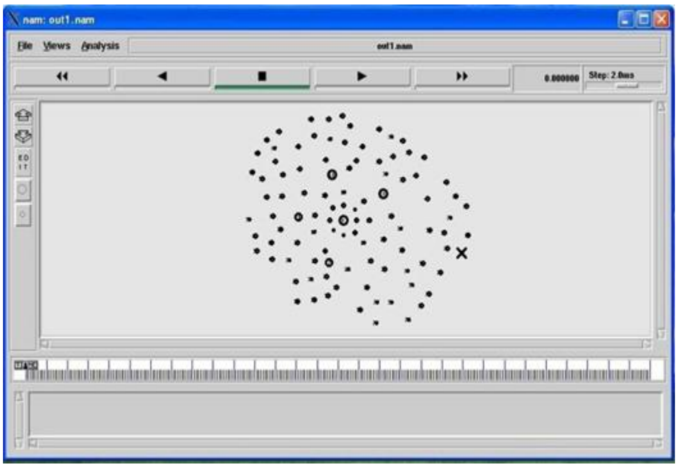

Figure 6. Node Creation

Cluster Formation: Sensor nodes in WSN are divided into clusters (FIGURE 7). Number of clusters in a network region is based on number of nodes and their distribution. Each cluster is a subset of nodes that can communicate with CH. After the cluster formation, node sensors directly communicate with its CH sensor. Each cluster has its ownCH. All the cluster member nodes transmit the data to its own CH. The CH of each cluster communicates with the sink node. The direct communication between the cluster members and base station is restricted because of its maximum power consumption during data communication.

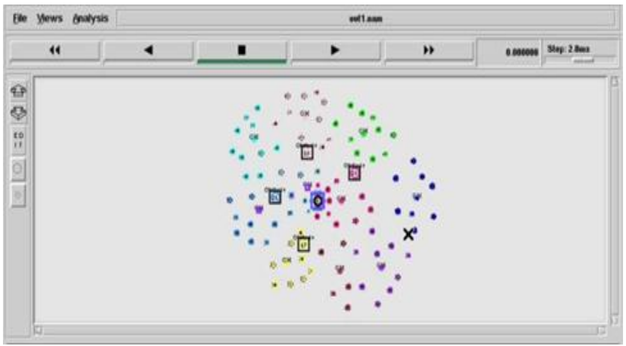

Figure 7. Cluster Formations

Cluster Head Identification: A cluster head is selected based on residual energy level and secondary parameters such as the utility of the sensor to its neighbors. In this way, the selected cluster heads have number of neighbors and residual energy (FIGURE 8). Cluster members transmit the data to the cluster head and the cluster head in turn forwarded to the Sink.

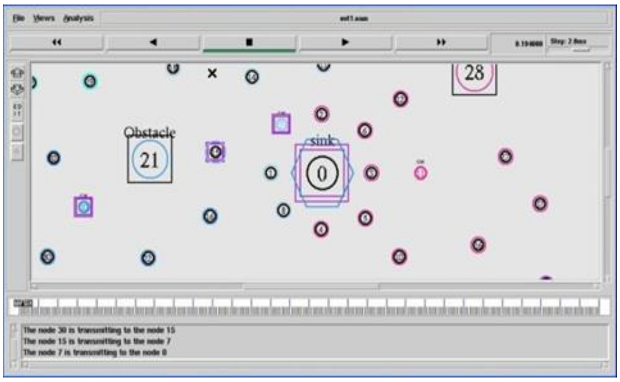

Figure 8. Cluster Head Identification

Route Identification and Data transfer: Route identification technique forms an energy efficient path between the CH and the sink. Route identification technique uses Dijkstra's shortest path algorithm. What attracts us is that in the work, the forwarding strategy of existing routing is not changed. The goal of a route identification technique is to achieve a path from the source to the sink as well as to achieve the goal at a minimum cost. In the proposed work, route identification technique in clustered WSNs that optimizes the path length during data transmission without any extra overhead (FIGURE 9). Some malicious node does not give proper signal strength as the energy level of the node has gone down. These cluster members are considered to be the obstacles.

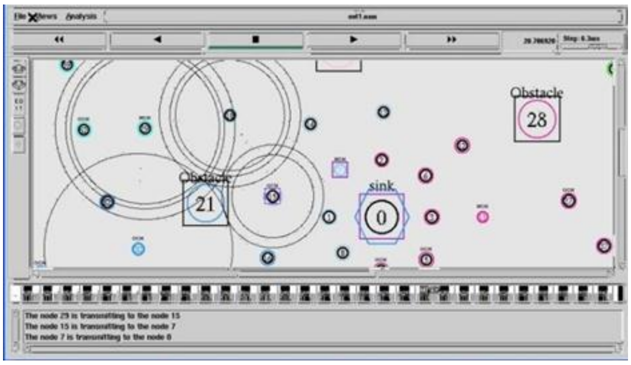

Figure 9. Route identification and Packet transmission over obstacles

Cluster Head Change: After a time if the CH reaches a threshold value level then the cluster head should be re-elected (FIGURE 10).

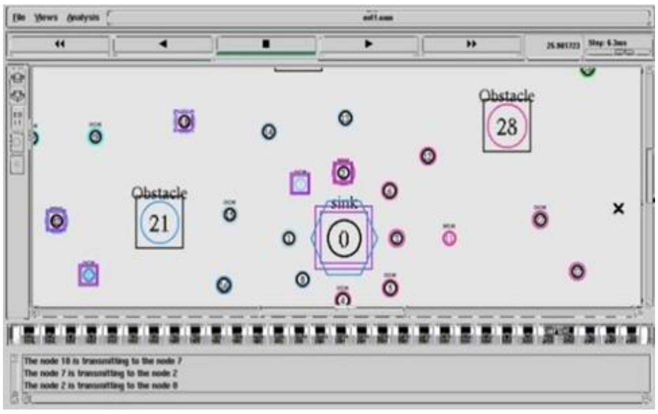

Figure 10. Cluster Head change

Data Transfer: All the active nodes transfers the data to the cluster head. And each cluster head transfers the data to the sink through the shortest path (FIGURE 11).

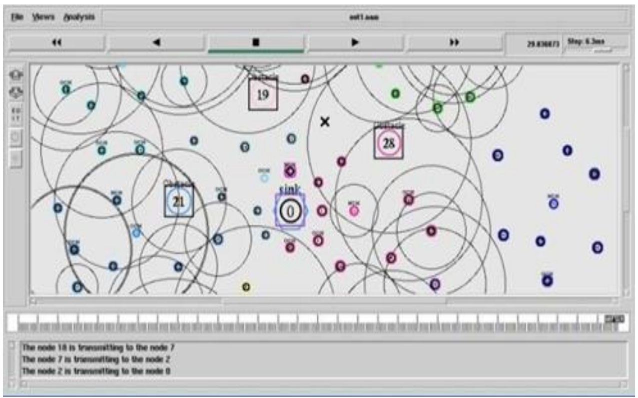

Figure 11. Data Transfer

Successful Transmission: Here the data are transmitted from the source to the sink successfully by overcoming the obstacle.

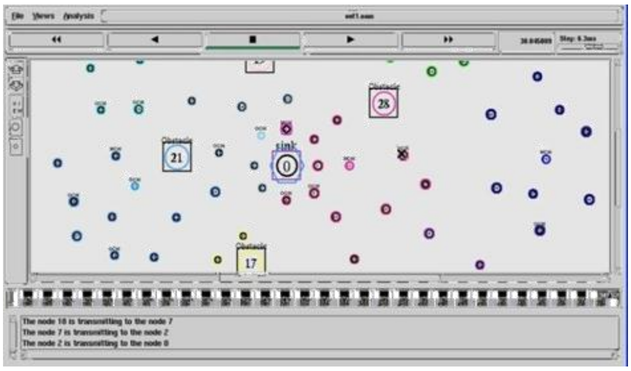

Figure 12. Successful Packet Transmission

Thus by the proposed work, the energy consumption is reduced. Packet delivery ratio is increased. Delay in packet delivery is reduced. Lifetime of the network is increased

PERFORMANCE EVALUATION

In the proposed work the performance is evaluated by simulation results. X graph is used for evaluating the performance. The analysis of Energy consumption, Packet delivery ratio, Delay and Lifetime are presented. Comparison of EHC and route identification technique with the already existing technique called Greedy Perimeter Stateless Routing (GPSR) is done.

Energy Consumption: Energy consumption is the core issue in wireless sensor networks (WSN). To generate a node energy model that can accurately reveal the energy consumption of sensor nodes is an important part of performance evaluation in WSN. It is considered as a performance measure. Energy consumed by the each node should be reduced. Energy consumed should be less to increase the lifetime of the nodes in the network.But its performance level should be increased (FIGURE 13).

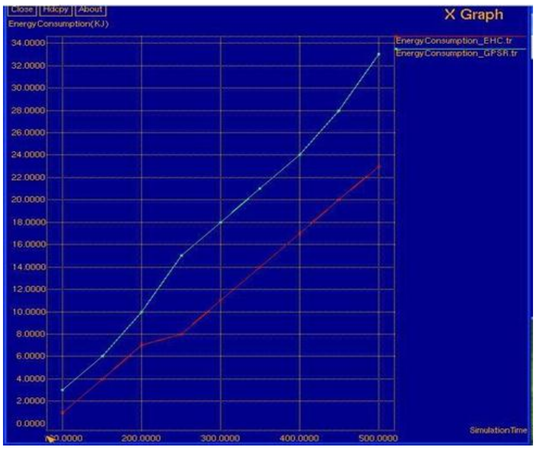

Figure 13. Comparison of energy consumption between EHC and GPSR

Packet Delivery Ratio: The ratio of the total number of packets received by the receiving node to the number of packet sent by the source (FIGURE 14). It is considered as an evaluation metric. It is the ratio of the number of packets that are received by the sink over packets submitted to the network by the source.

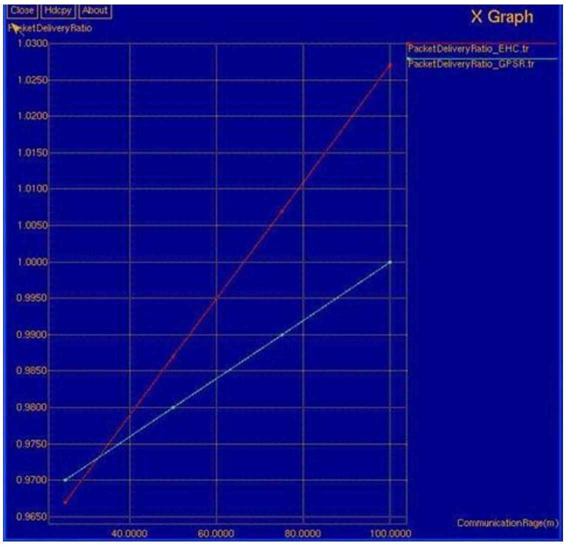

Figure 14. Packet delivery ratios between EHC and GPSR

Delay: The time taken by the packet to reach the destination from the source (FIGURE 15). Delay is the measurement of the time for the packet to reach its destination beyond the described time.

Figure 15. Comparison of Delay between EHC and GPSR

Lifetime: It is the time interval of the sensor network until the death of the first active node. Power consumption should be minimized since it determine the lifetime of network (FIGURE 16).

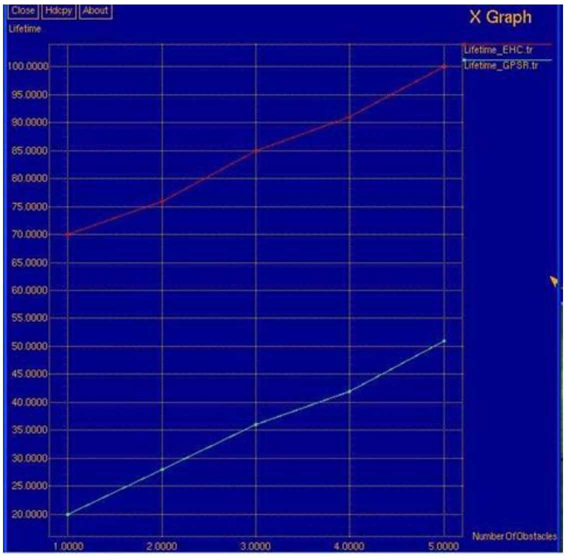

Figure 16. Lifetimes of EHC and GPSR

Thus the performance is evaluated with the metrics and performance measures. By the evaluation it is clear that the energy consumption is reduced and the network lifetime is prolonged.

CONCLUSION

Wireless sensor networks can be homogeneous as well as heterogeneous. In this paper, heterogeneous type of network is used. In the proposed work, an energy efficient heterogeneous clustering technique in WSN is implemented. Clustering is a highly excellent technique to reduce energy consumption and to increase the energy efficiency of the network. This will enlarge the network lifetime. Route identification technique decreases the delay and speeds the packet delivery in the network. Comparing the proposed technique with the existing technique shows the high performance of the proposed work. This work is implemented to mainly focus on the energy efficient clustered WSN to prolong the network lifetime.

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