

EERRSCR -Energy Efficient Level Based Robust Reliable and Scalable Clustered Routing Protocol for WSN

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ABSTRACT

A wireless sensor network that consists of huge number of tiny sensors with transceivers can be an efficient component for collecting data from different environments. The data collected from the environment that specifies the characteristics or an event detected is conveyed through an intermediate nodes to a center device called Base Station or Sink. The conveyance of information or data should be made to consume less energy resources of the sensor nodes because the energy is limited to WSN nodes. Clustering is an important solution for this issue since nodes are grouped into clusters and Cluster heads are selected from each cluster so that data is transmitted through cluster heads only to reach the Base station in order to reduce the energy consumption. In this paper a robust scalable energy efficient cluster based routing algorithm is proposed to organize the nodes in a wireless sensor network into clusters. It uses nodes reliability, robustness, energy, scalability and density to select the CH.

Keywords: Wireless Sensor Networks, Cluster Head, Energy Efficiency, Routing Protocol

1. INTRODUCTION

A wireless sensor network (WSN) is a wireless network consisting of a group of transducers called sensors that uses radio to monitor physical or environmental conditions. It includes a gateway that provides wireless connectivity back to the wired network[1],[2]. Commonly monitored parameters are temperature, humidity, pressure, wind direction and speed, illumination intensity, vibration intensity, sound intensity, power-line voltage, chemical concentrations, pollutant levels and vital body

functions. Every sensor node consists of a transducer, microcomputer, transceiver and power source. The transducer generates electrical signals based on sensed physical effects and phenomena. The microcomputer processes and stores the sensor output. The transceiver receives commands from a central computer and transmits data to that computer. The power for each sensor node is derived from a battery.

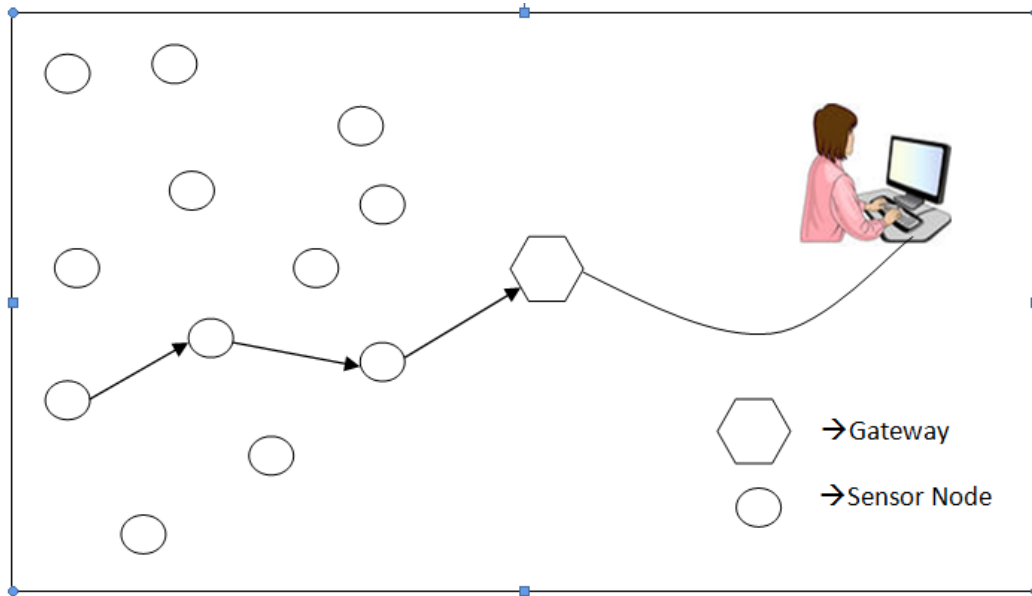


Figure 1. Simple WSN

Each sensor node is both a sensor and a router, and its computing ability, storage capacity, communication ability and power supply are limited. Due to this limited energy and communication ability of sensor nodes, it seems especially important for protocol development, system design and performance evaluation in wireless sensor networks so that the sensing data can be transmitted to the receiver effectively[3][4]. In this paper clustering is used to give a highly robust, reliable and scalable communication. Also energy consumption is mainly concentrated so the life time of network can be extended significantly.

Many number of clustering protocols for WSNs have been discussed in the related work. In WSN, reliability, robustness and scalability are also the major issues in addition to energy efficiency[5]. If nodes are fixed, it can be handled with existing hierarchical routing protocol. But, when node moves, continuous updation should be made in hierarchical routing to effectively achieve reliable, robust, scalable and low energy communication in WSN. In WSN, hierarchical routing protocols are introduced to avoid link and processing overhead while using more number of nodes. In this, nodes in a network are formed as groups and different functionalities are assigned inside and outside a group. Each group in a hierarchical routing are called cluster. Clustering techniques are the most common hierarchical protocol and it is highly helpful for energy efficiency in WSNs. Each cluster consists of a cluster head

(CH) and cluster members (CM). The number of Cluster head varies depending on the application and the need. CHs have major role in managing the CMs, receiving and processing data from them. CHs can communicate with the BS directly(CH-BS). So CHs consume more energy than that of CMs due to their high responsibility of network organization, data collection and long distance data transmissions to the BS. Hence, re-clustering or re-selecting cluster heads periodically is mandatory to balance the energy consumption of each sensor node.

This paper consists of Section 1:that explains the introduction of WSN, Section 2: that describes the related work, Section 3: that briefs the proposed system, Section 4 :which describes results and discussion and Section 5 :ends with a conclusion and future enhancement.

2. RELATED WORK

Though hierarchical routing protocols have very few limitations such as need of time synchronization, non-optimal routing and high overhead for cluster formation and maintenance, they expose many gorgeous rewards by fulfilling the constraints in WSNs. Compared to other routing protocols, hierarchical protocols offer a more realistic solution to handle very large networks with their enrichment to better utilization of wireless channel bandwidth, minimized energy consumption and cost. Many number of hierarchical clustering routing protocols are available to consume the energy for WSN. These protocols differ with the identification of cluster heads and the formation of clusters. In this paper, few of them are discussed and their pros and cons are also given.

Heinzelman et al.[6],[7] introduced LEACH which uses distributed clustering technique and TDMA schedule to avoid collision among CHs. It makes group of nodes into clusters, wherein one node will act as a cluster head and it gathers data from non member nodes and sends it to BS. The clustering involves only one iteration after which, a node decides whether to become a CH or not. To ensure balanced energy among all nodes, LEACH assigns a fixed probability to every node, so as to select itself as a CH. After fixing the CH, it floods an advertisement message, to all non- clustering nodes in order to determine which cluster it belongs to, by identifying the CH that can be reached using the least communication range in its set-up phase. Once the clusters are formed dynamically in each iteration, the time to do the iteration is also calculated. Next is the Steady-State phase in which frames are generated and nodes send their data to the intended Cluster Head. Once the CH receives all data, it performs data aggregation. In addition TDMA/CDMA MAC scheme is also used to reduce inter and intra-cluster collisions.

Lindsey et al.[8] proposed PEGASIS in which instead of clustering, a chain is formed with nodes so that dynamic cluster formation overhead is avoided and transmission distance is also reduced. Cluster Heads are selected in a sequential order. Any node, whose neighbouring nodes distance is greater than the threshold value, cannot become a cluster head. Cluster Heads will circulate a token to the nodes which are connected in a chain so that they can know who is the cluster head and

which direction the message is to be passed. When any node dies, the chain is reconstructed with the same procedure to bypass the dead node.

Manjeshwar et al.[9] introduced TEEN, which uses Hard and Soft threshold values to collect the data continuously from the environment. Due to this the amount of transmissions and energy consumption is reduced significantly. Cluster Head floods this fixed values to its member during cluster change. Nodes sense the environment continuously and the first time a parameter from the attribute set reaches its Hard Threshold value, the node goes on its transmission and sends the sensed data. This sensed data is stored in a variable called Sensed Value(SV).

Manjeshwar et al.[10] describes APTEEN, in which the count time is included in addition to threshold values to minimize the energy consumption. Like TEEN the Cluster Head broadcasts set of attributes which the user is interested in obtaining data about, Hard Threshold(HT), Soft Threshold(ST), slot to each node and also the maximum time period between two successive reports sent by a node to non cluster head nodes in every cluster change period. When significant event occurs and the nodes' data is beyond HT, then transmission occurs. If there is no transmission for a time period equal to the count time, it is forced to sense and retransmit the data.

Ossama Younis et al. in[11] introduces HEED, in which the cluster head selection is fully dependant on nodes' residual energy and their ability to control the energy. To form the clusters the knowledge about the network is not required. It assures that every sensor is exactly being a part of one cluster and the Cluster heads are also clearly distributed.

T.Shankar et al.[12] describes EEUC, as it selects CHs with greater residual energy to support multi hop routing and to avoid hot spot problem so the life time of network can be increased. In this, the clusters which are closer to the BS will be small in size while compared to faraway clusters. Since, the closer clusters will consume more energy than others the Sink node broadcasts a "HELLO" message to all nodes with some energy. So each node can calculate the approximate distance to the BS based on the received signal strength. This helps us to generate the clusters of unequal size. First, tentative CHs are identified to compute final CH election. Every node can become a tentative cluster with the probability T, a predefined Threshold. Each CH calculates the competition radius in which the energies are compared to those of tentative CHs and the one with maximum energy is elected as a new CH. In the case of tie in energies, the node with smaller node ID is elected as CH. In order to support multi hop routing, more clusters is to be formed nearer to the BS.

Parendra Kumar Singh et al. and Md.Farukul Islam et al. proposes EECCPAR in [13],[16] about clustering for energy efficiency. According to that clustering is not done in every round and the residual energy is used to select the CH. In this tables are maintained to store the information about the neighbours. This information is regularly updated with their neighbours. Each and every node is now calculating the weight and distance with their neighbours and based on the same CHs are identified. Now CHs broadcast an advertisement message to the non cluster head members so that they can join with any one CH based on the energy it has received from them.

Meenakshi Diwakar et al. proposes EELBCRP[14], to minimize the energy usage of CHs and also to minimize the number of cluster creation. Three phases are

introduced. In the first phase that is setup phase BS floods some minimal power to the nodes. All the receiving nodes of this signal is designated as Level 1. Now the BS floods with some increased signal strength of previous and the receiving nodes of this signal is designated as Level 2. The same procedure is continued to form the levels with all the nodes in a network. The second phase is the cluster setup phase so that the possible number of clusters are formed in each level. Like LEACH, the nodes in each level are free to decide whether to become a CH or not for a present round by selecting a random value between 0 and 1. Now the CHs broadcast their advertisement message with energy informing their presence to non cluster head nodes. So non cluster head nodes will join with CH based on the energy value it has received. After forming the clusters the member nodes can transmit the data to their Cluster Head. The third phase is inter cluster routing so that the CHs aggregate the data and forward it, to next level CH. The same process continues till the forwarding data reaches to the Base Station.

Hameet Kour et al. proposes H-HEED[15] and it uses nodes energy to form the clusters of different levels in a network. By this method the number nodes will die in every round and is controlled and also depends the energy value. Different levels are designated as level 2, level 3 etc. Nodes in each level are classified as the number equal to the level number. For example, in level 2 the sensor nodes are classified as advanced nodes and normal nodes. In level-3 the nodes are classified as super nodes, advanced nodes and normal nodes.

Md.Farukul Islam et al. suggests ECHERP[16], according to which re-clustering is not done in every round. Also if the distance from BS to the transmitter node is too long then the energy usage is also high. Clusters are formed as levels and each level CHs are also identified so that the CHs can have a transmission with Base Station when there is a data to transmit. Since first level CHs are very closer to the BS, they have a direct communication with the BS and the energy usage for transmission is also minimized. CHs that are far away from BS can communicate with BS through intermediate CHs and the energy usage for transmission is also high. Here Base Station should have a global knowledge about the network. From Base Station a unique ID is provided to each and every node in a network for identification of CHs non cluster head nodes and also to which CH it belongs is very easy. In the absence of data transmission nodes are turned off. Also nodes are permitted to have a transmission in the assigned period only. In this way the energy consumption is minimized significantly. The network lifetime is also extended considerably.

Chung-Horng Lung et al. proposed DHAC[17], as a clustering protocol of collecting related nodes together first and then the cluster head is selected. It requires only one hop information to form the clusters. Also the location information is not required. In DHAC cluster formation is done in the initial stage only and re-clustering is not required. So it is consuming very low energy and the life time is prolonged considerable.

3. PROPOSED SYSTEM

In the midst of numerous proposed routing protocols in the past, hierarchical routing protocols significantly contribute to system scalability, network life time and energy consumption. Normally, all existing clustering protocols require global knowledge of the network and based on the same only it will decide the levels or clusters. But in this proposed EERRSCR (Energy Efficient Level Based Robust Reliable and Scalable Clustered Routing Protocol for WSN) routing protocol, no global information is required to form the levels. Also the CH will be identified by some factors and it is automatically increasing the quality of the cluster. So it is providing highly robust, reliable, scalable and energy efficient communication and the network lifetime is also prolonged[18][19][20]. The operation of EERRSCR is divided into three phases: Level finding, cluster head selection and cluster formation. Average connectivity to be calculated with these factors and the cluster head is identified based on the same. Also the direction of transmission is also identified whether it is directly to sink or through Cluster Head, thus reducing the energy consumption and prolonging the network lifetime.

3.1 Level Finding Phase

In the level finding phase the network is divided into different levels of clusters in top-down fashion. It can be used in very large networks. Initially it forms Level-1 cluster, then Level-2 cluster and so on. The Level-1 cluster is formed as follows: Base Station or sink node floods the HELLO packet to the network with hop count as zero. Upon receiving this message the nodes in a one-hop distance within a communication range will form a Level-1 cluster.

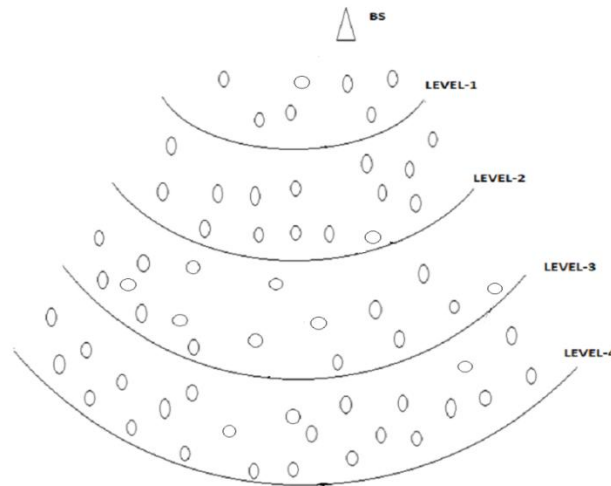


Figure 2. Levels of Cluster

Now Level-1 nodes floods this message further and nodes which receives this in a two hop distance from Base station will form a Level-2 cluster. Clusters at Level

3,4,.....,n are selected in similar fashion with a hop count of 3,4,.....,n respectively from Base Station. The algorithm for Level finding is given below:

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1) Sink Node(Message msg with hop count=0 &
           sequence number)
2) Sensor Node(Message msg) {
           if (current Hop Count>msg Hop Count +1)
           then current hop count=msg hop count+1
           update and flood msg }

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Algorithm 1. Level Finding

3.2 Cluster Head Selection

The process of selecting various wireless sensor nodes to be CHs for a given WSN is called clustering. Dividing the entire network into clusters would reduce the energy consumed for data communications.

ERSLBRP is a hierarchical routing protocol and it is permitting the nodes to gather information from environment when event occurs or if there is any new information and sends to their cluster head and cluster head forward the same to base station. single hop communication is done within the clusters and between CH to Base Station. In this phase cluster heads are selected in each level. The number of CHs in a level is predetermined with the total number of nodes in a corresponding level. There may be more than one cluster head in a level but the minimum distance between them will be of more than one hop. The cluster heads are identified by the factors reliability, density and energy. This is calculated by the formula:

$$SF(N_i) = w_1 \times RF(N_i) + w_2 \times DF(N_i) + w_3 \times EF(N_i) \quad (1)$$

Where,

$SF(N_i)$ \rightarrow Selection Factor of Node i

The Selection factor for each node in a level is calculated and floods throughout the same level. The first component $w_1 \times RF(N_i)$ is used to improve the reliability of the node. Where, $RF(N_i)$ is the reliable factor of node i and it is closely associated with nodes delivery ratio. Each sensor node finds its neighbour node to sends the message to it and calculate the delivery ratio. DR is one of the factor to

identify the multi-hop path to the sink node. It is calculated by the following equation:

$$DR(N_{ij}) = \frac{\sum R_{ji}(t)}{\sum S_{ij}(t)} \quad (2)$$

Where,

- N_{ij} → Delivery Ratio of Node i to j
 R_{ji} → Number of receiving packets from the node j to i
 S_{ij} → Number of sending packets from node i to j
 t → Total transmission between the neighbouring nodes

Now the nodes reliable factor is calculated from DR by the formula:

$$RF(N_i) = \frac{\sum_{j \in Neigh_i} DR(N_{ij})}{|Neigh_i|} \quad (3)$$

The second component $w_2 \times DF(N_i)$ is the average number of neighbouring nodes and called as density factor of node i. If a node has higher connectivity, it has high consistency of communication due to high message successive rate. The nodes density factor is calculated by the formula:

$$DF(N_i) = \frac{|Neigh_i|}{\text{Total Number of Nodes in a Level}} \quad (4)$$

The third component $w_3 \times SF(N_i)$ is the energy factor of node i which gives nodes residual energy. If the energy of node goes low that will not be considered for the case of cluster head selection.

$$EF(N_i) = \frac{RE(N_i)}{\text{avg}(RE(N_j)) \text{ where } j \in \text{Number of Nodes in a Level}} \quad (5)$$

Where,

- $EF(N_i)$ → Energy Factor of Node i

According to the need of application or requirements the three weighing factors (w_1 , w_2 and w_3) can be selected.

3.3 Cluster Formation

The method of Cluster Head selection is also very important because the power consumption is reduced considerably with the best Cluster Head and the network life time can be extended. So many research is carried out in finding the number of nodes belongs to a cluster[21][22][23][24][25][26][27][28]. All the selected cluster heads now send ADV message in the same level announcing their presence as CHs. By receiving an Adv message a node does the following :i)if it is a member of any cluster already, then it simply ignores the received message ii)Else it will calculate the

distance towards all the cluster Heads in the same level and whose distance is less a node which will join with the same as a member. A cluster is formed by associating a CH with some nearest (i.e, minimum distance) non-cluster head node in this way. The same procedure is continued with all other nodes in the same level not assigned to a cluster yet, until all nodes belongs exactly to the cluster of which it is the cluster Head. In order to avoid backtracking problem nodes check the distance before transmission. If node's distance to the Base Station is less than that of Cluster Head , the data is directly transmitted to Base Station instead CH.

3.4 Advanced Forward Aware Factor

In clustered routing protocol , sometimes even though the non cluster head nodes in a cluster are closer to the Base station than the cluster head they will transmit data to cluster head first, and then it will be forwarded to base station[29]. This backward transmission of data leads to more energy consumption. To avoid the same, this paper proposes a new routing protocol ERS�BRP which includes advanced forward aware factor to find the next hop node for transmission in addition to reliability factor, density factor and energy factor.

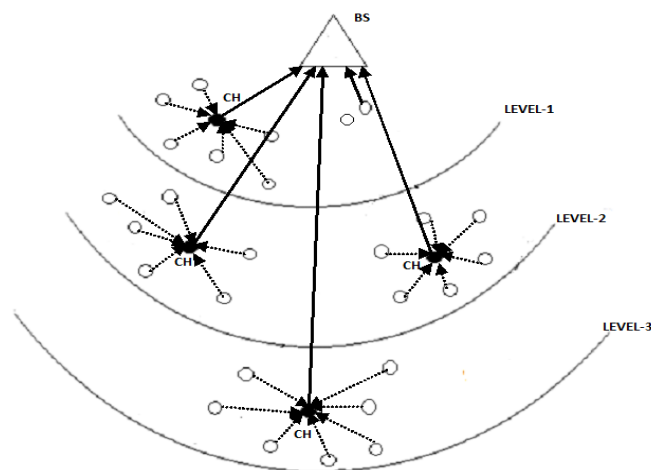


Figure 3. Data Transmission from CH to BS

According to this, if a node has a data to transmit it will see the distance towards its cluster head and also towards the base station. Finally the data is transmitted to the minimum distance node i.e) either cluster head or base station. Due to this the nodes' energy is utilized very efficiently and the network life time is also prolonged considerably.

Step 1:Node Deployment

Step 2:Level Finding $L_1, L_2 \dots L_n$

Step3 :For Each Level $l \in L$

Step 3.1 :Number of cluster head need to manage the network lifetime and connectivity

Step 3.2 :Find $RF(N_l)$ for all nodes in the Level l

Step 3.3 :Arrange the nodes in descending order on the basis of $SF(N_l)$

Step 3.4 :Select the highest value node from the ordered list with a minimum of two hop distance

Step4 :Broadcast ADV message from each CH to non cluster head members

Step5 :Transmit data from CH to Base Station

Algorithm 2.Cluster Formation and Routing

4. SIMULATION AND PERFORMANCE RESULTS

In this paper the performance of the proposed protocol EERRSCR is assessed with LEACH and DHAC protocols. As described in related work, LEACH is also energy efficient protocol and the cluster head is identified randomly. DHAC is also an energy efficient protocol without reclustering process. The proposed protocol EERRSCR is tested with the network simulator NS-2(version NS 2.34). The results are obtained in terms of three factors: reliability, density and energy. Let's deploy N number sensor nodes in a grid area of sensor field and the entire network is divided into k levels. The Base station is located at the top of the network. The initial energy of each node is assigned uniformly and the delivery ratio, average consumed energy and the network life time is measured and the same is plotted in a graph.

Three metrics are used to analyze and compare the simulation results for clustering and energy efficiency: network life time, energy consumption and delivery ratio. The metrics are evaluated for LEACH, DHAC and EERRSCR with different input data.

4.1 Performance is Evaluated in terms of Delivery Ratio

The result is shown in graph between number of nodes and the delivery ratio of the same. The delivery ratio is calculated with the formula :

$$DR(N_{ij}) = \frac{\sum R_{ji}(t)}{\sum s_{ij}(t)}$$

If the delivery ratio of a node is high, data loss is reduced considerably. So it increases the reliability of the communication.

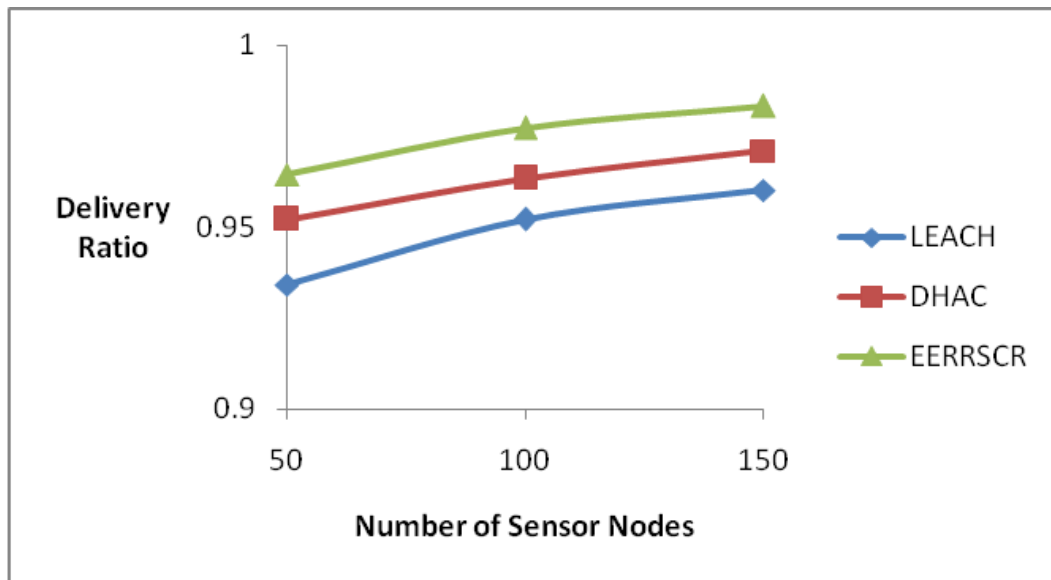


Figure 4. Number of Nodes versus Delivery Ratio

In the above figure the comparison is made with various protocols' delivery ratio and different number of nodes. Simulation result shows that the EERRSCR gains much better performance while compared to other protocols. Analysis starts from 50 nodes and the delivery ratio is about to 97%. When it is increased to 100 and 150, the delivery ratio of the communication is also increased further.

4.2 Performance is Evaluated in terms of Energy

Average consumed energy in a metric shows the average consumption of energy per round over time in the network. It carries out various functions like transmitting, receiving, sensing, aggregation of data etc.

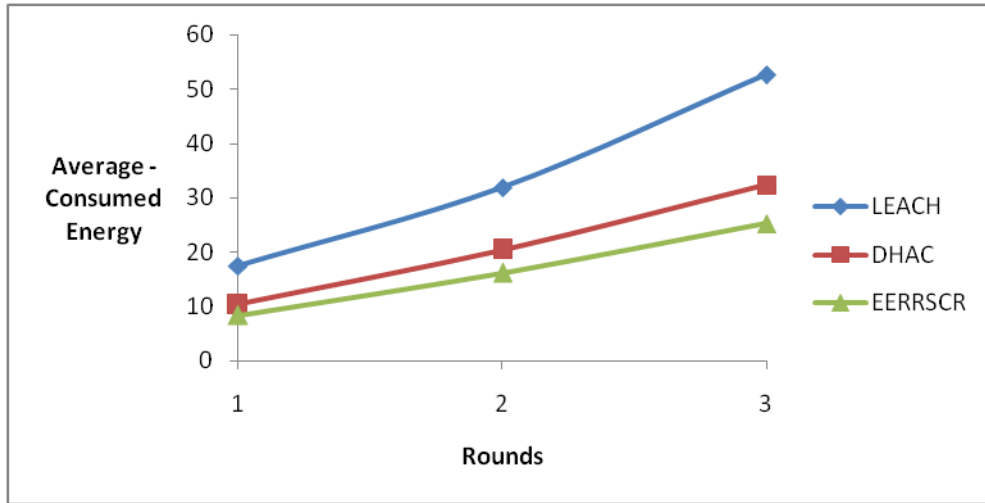


Figure 5. Cluster Rounds versus Average Consumed Energy

The above graph depicts that the average consumed energy of the protocol EERRSCR is less than 10 L. It is a great difference while compared to other protocols.

4.3 Performance is Evaluated in terms of Network Lifetime

Figure .6 gives the network life time correspondence to different protocols when the Base Station is placed at a fixed place. It can be noticed that EERRSCR has the longest network lifetime. Compared to EERRSCR , DHAC and LEACH provides shorter lifetime.

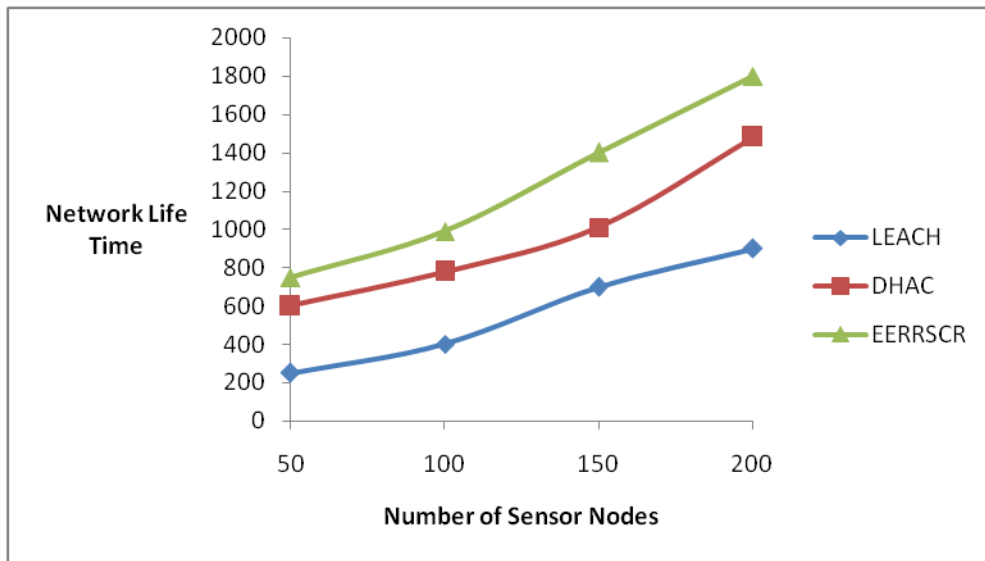


Figure 6. Number of Sensor Nodes versus Network Life Time

5. CONCLUSION AND FUTURE ENHANCEMENT

In this paper, an energy efficient robust, reliable and scalable level based routing protocol has been proposed. The network is splitted as levels with nodes hop count. The mathematical formula to select the Cluster Head have been given. The protocol is developed in a network simulator NS 2.34. The simulation result shows energy consumption of nodes, robustness, reliability and scalability. So the life time of network is prolonged for the proposed protocol EERRSCR greatly while compared to DHAC and LEACH. In future instead of transmitting the data from nodes to Cluster Heads in the same level upper layer Cluster Heads also selected for forwarding if the distance is lesser. So the delay can be reduced during transmission. Second, by balancing the number of nodes for a Cluster Head the overhead of the same can be reduced. Third, in order to select efficient Cluster Head fuzzy concept can be included.

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