UEDS: Uniform Energy Distribution Scheme for Energy Efficient Wireless Sensor Networks

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Abstract

One of the major issues in wireless sensor network (WSNs) is limited energy in battery operated wireless sensor nodes. Minimizing energy dissipation and maximizing network lifetime are important issues in the design of wireless sensor networks. There are various routing protocols like flat, location-based, QoS (Quality of Service) based, hierarchical routing etc. in which optimal routing can be achieved to save energy in sensor nodes. Hierarchical routing (cluster-based routing protocols) have shown to be more scalable and energy-aware. The basic idea of clustering is to use data aggregation mechanism in the cluster head to reduce the amount of data transmission, thereby, reduce the energy dissipation in communication. LEACH (low-energy adaptive clustering hierarchy) is well-known & divides the whole network into several clusters, and the run time of network is broken into many rounds. In each round, the nodes in a cluster contend to be cluster head according to a predefined criterion. The proposed protocol divides the network into layers. The energy consumption is balanced in the proposed protocol by calculating the average residual energy of the various layers in the network. Cluster heads are elected uniformly from the entire network area. Residual energy is calculated from each layer. Cluster head from the layer which have minimum residual energy level will send data to next layer cluster heads and cluster head from the remaining layers will send the data directly to the base station. Simulation results prove that the proposed protocol is energy efficient compared to similar protocols given in the literature.

Keywords: *WSN, Energy, Cluster Head, Base Station, Sensor Node*

I. INTRODUCTION

Wireless sensors networks are used to sense the environmental conditions and communicate the collected data wirelessly to a centralized processing station known as base station (BS). These consists of numerous Sensor Nodes (SNs) spread over the target region with a motive to capture the physical or chemical changes occurring in their vicinity. These are often deployed in remote and in inaccessible areas which are hazardous and extreme [1] [2] [3]. Therefore, a wireless sensor has not only a sensing, but also on-board processing, communication, and storage capabilities. With these enhancements, a sensor node is often not only responsible for data collection, but also for network analysis, correlation, and fusion of its own sensed data and data from other sensor nodes. Major applications of WSN include agriculture, disaster management [4] [5], health monitoring [6], pollution monitoring [7], etc.

The proposed protocol divides the network into layers. The energy consumption is balanced in the proposed protocol by calculating the average residual energy of the various layers in the network. Cluster heads are elected uniformly from the entire network area. Residual energy is calculated from each layer. Cluster head from the layer which have minimum residual energy level will send data to next layer cluster heads and cluster head from the remaining layers will send the data directly to the base station. Simulation results prove that the proposed protocol is energy efficient compared to similar protocols given in the literature.

II. LITERATURE SURVEY

Since very beginning the energy has been a major concern for the WSN as it is to be installed in the regions where the SNs remain unattended and can't be reached in order to recharge or replace the battery. The researchers have come up with various schemes in order to enhance the overall lifetime of the WSN by efficiently utilizing its resources.

Authors in [1] proposed a low-energy adaptive clustering hierarchy LEACH, a protocol architecture for micro sensor networks. LEACH includes a distributed cluster formation technique that enables self-organization of large numbers of nodes. It use algorithms for rotating cluster head positions in order to evenly distribute the load among all the SNs. The results show that LEACH can improve system lifetime by an order of magnitude compared with general-purpose multi hop approaches**.**

Researchers in [2] have proposed a centralized routing protocol called Base-Station Controlled Dynamic Clustering Protocol (BCDCP), which distributes the energy dissipation evenly among all sensor nodes to improve network lifetime and average energy savings. The performance of BCDCP is then compared to clustering-based schemes such as Low-Energy Adaptive Clustering Hierarchy (LEACH), LEACH centralized (LEACH-C), and Power-Efficient Gathering in Sensor Information Systems (PEGASIS) [3]. Simulation results show that BCDCP reduces overall energy consumption and improves network lifetime over its comparatives.

Authors in [4] proposed an Energy-Efficient Level Based Clustering Routing Protocol (EELBCRP) for wireless sensor networks. Network is partitioned into annular rings by using various power levels at base station and each ring having various sensor nodes [5]. The residual energy of each SN and its distance from the BS is considered for electing a cluster-head.

Authors in [5] has proposed a routing protocol for maximizing the lifetime of a WSN through energy efficient clustering method for cluster head selection which is based on residual energy, distance & reliability. In this research work the mechanism to increase the lifetime of sensor nodes controlling long distance communication, node balancing and efficient delivery of information is developed.

Authors in [6] proposed an energy efficient routing protocol in which each SN sends information about its current location and energy level to the BS. The BS runs the simulated annealing algorithm to determine the clusters for that round. Then a chain routing between clusters is established to reduce the amount of SNs which communicate with the base station. It not only extends the lifetime of the network, but also improves the energy efficiency.

Authors in [7] have proposed and evaluated a distributed energy-efficient clustering algorithm for heterogeneous WSNs, which is called Position-Based Clustering (PBC). This protocol is an improvement of LEACH-E [20, 42]. In PBC, the cluster-heads are elected by using probabilities based on the ratio between residual energy of each node and the remaining energy of the network. It uses a 2-level hierarchy by selecting an intermediate cluster head for data transmission. Moreover, it uses a new technique for cluster formation based not only on the received signal strength of the cluster head's advertisement but also on its position.

Authors in [8] proposed a novel Energy Efficient Clustering and Data Aggregation (EECDA) protocol for the heterogeneous WSNs which combines the ideas of energy efficient cluster based routing and data aggregation to achieve a better performance in terms of lifetime and stability. EECDA protocol includes a novel cluster head election technique and a path would be selected with maximum sum of energy residues for data transmission instead of the path with minimum energy consumption.

III. SYSTEM MODEL

The aim of this article is to propose a new energy efficient routing protocol for WSNs. The WSN consists of a large number of sensor nodes. Typically the sensor nodes are placed in a remote area to fulfill the needs of monitoring or surveillance. All the sensor nodes are battery-operated. The life of a node depends upon the battery. In addition to forwarding the node's own data it also plays a role of an intermediate node by receiving and forwarding the other nodes' data towards the base station or sink.

A number of successful efforts have already been made to achieve this goal, but still there is a need to work on this area for further improvements. Network and data link layers in a sensor node play a vital role in the WSN communication. The network layer is used for path determination and the MAC sub-layer of data link layer controls the channel access and forward or receive the data to/from neighbor node or sink. Routing and MAC [9] protocols are used for data communication in WSNs. The consideration of energy efficiency is essential for any kind of protocol. The purpose of this research is to design an energy-efficient routing protocol for WSNs. In this thesis the existing protocol which is a cluster based protocol known as LEACH (Low Energy Adaptive clustered hierarchy) is improved by using the combination of single hop and multi hop communication technique. In this work we proposed a uniform clustering technique along with circular layers across the network area. Circular layers having their spacing equal to the sensing range of the sensor nodes, which gives better enhancement in uniformity and the life time of the network.

A. Model Assumptions

- All the SNs are nodes are Homogeneous.
- All the SNs are randomly deployed within a target region [1].
- BS is fixed and located at the center of the network area.
- All the network nodes can communicate with the BS.

B. Radio Energy Dissipation Model

In our work we assume a radio model with energy dissipated in the transmitting and receiving modes, shown in

Figure 1. In radio energy model energy dissipates to operate the transmitter or receive circuitry is shown in Table 1 below along with the various operations performed by the radio for data.

Table 1. Radio Energy Dissipation Parameters

Parameter	Value
Transmission Energy(Etx)	50 n/j/bit
Receiving Energy (Erx)	50 n/j/bit
Energy for Data Aggregation (EDA)	50 p/j/bit
Emp	0.0013 p/j/bit
Efs	10 p/j/bit

In this work free space (d2 power loss) and the multi path fading (d4 power loss) channel models were used. If the distance is less than a threshold, the free space (fs) model is used; otherwise, the multi path (mp) model is used

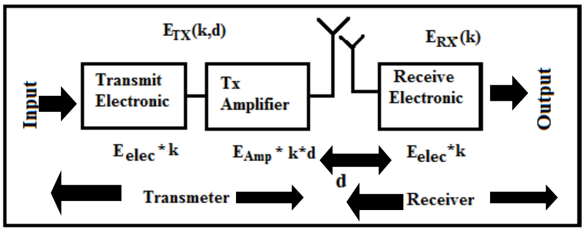


Figure 1. Radio Energy Model

Thus, to transmit a k- bits message over a distance *d*, the radio expends as:

$$E_{TX}(k,d) = \begin{cases} kE_{elec} + k\,\epsilon_{fs}\,d^2 if\ d < d_0 \\ kE_{elec} + k\,\epsilon_{mp}\,d^4\ if\ d > d_0 \end{cases}$$

The electronics energy depends on many factors such as the digital coding, the modulation, the filtering, and the spreading of the signal, whereas the amplifier energy Efs or Emp. To receive the message the radio expends energy as Erx(k) = k.Eelec. We have assumed that the radio channel is symmetric such that the energy needed to transmit a message from node 1 to node 2 is the same as the energy required to transmit a message from node 2 to node 1 for a given SNR.

C. Working

In the system model a random wireless sensor network of 100m*100m is created initially as shown in the Figure 2. LEACH creates a random network and performs the random election of cluster heads. The random cluster formation creates a non-uniform election probability of CHs. In order to overcome this problem, the proposed model the network area has divided into sub-divisions of area 20m X 20m. Say A be the set of sub-divisions $A = \{A_1, A_2, A_3, \ldots, A_n\}$ (see Figure 3).

In every round the cluster head (CH) is elected from each subdivision. The selection of CH is done on the basis of the residual energy. Among all the SNs within a subdivision, the one with maximum energy level is elected as a CH. This method lays a uniformity in the selection of CHs. The SNs connects to the nearest CH regardless of the subdivision it belongs.

The detailed functioning of the model is explained as follows.

1) Deployment of the SNs

Initially the SNs are randomly deployed. Figure 4 shows the schema of deployment of the network. It is assumed that, all the deployed nodes are homogeneous in nature and will have same amount of initial energy (i.e., 0.5 jules) along with a unique node id which makes them different to each other.

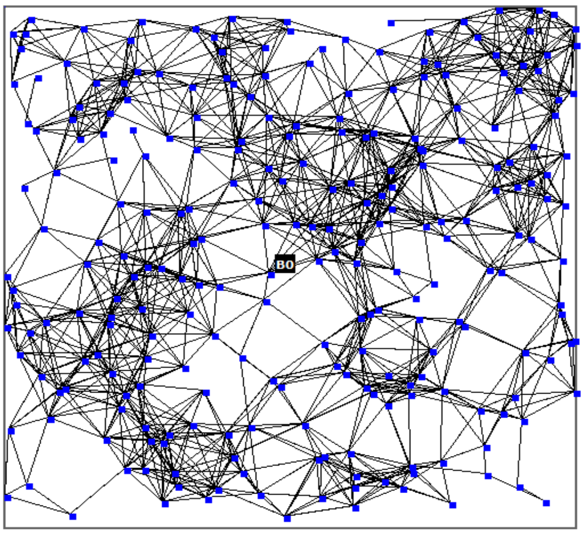


Figure 2. Deployment of the Network Nodes and BS

2) Deployment of the Base Station (BS)

Base station deployed is moveable in nature and in this work it is deployed in the center of the target region. It is assumed to have limitless amount of energy. Figure 2 shows the deployment of SN nodes as well as deployment of Base Station in the center of the target-region.

*3) **Partitioning of the Network Area (Sub-Divisions)***

After deployment of the sensor nodes the network area (100m*100m) is further partitioned into sub-divisions of 20m*20m. Figure 3 shows the schema of division of target region into small divisions of 20m*20m and we have named these small divisions as A_1, A_2, A_3, …, A_{24}, A_{25}. It is mandatory to choose only a single node as a CH randomly from these sub-divisions in each round of the functioning of the Wireless Sensor network. It will help in choosing uniform CHs from the whole area and uniform clustering will takes place which is not possible in LEACH.

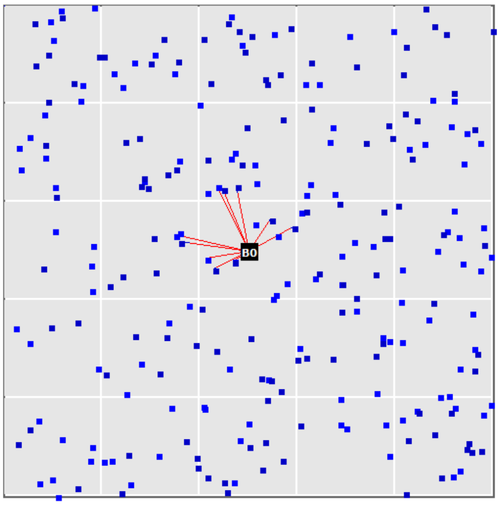


Figure 3. Partitioning of the Network Area into sub-divisions.

*4) **Layering of the Network***

The next step is to divide the network into different circular layers as shown in the Figure 4. These layers are named as L_0, L_1, L_2..., L_n from the nearer to the BS to outside. It is assumed to have the BS in Layer 0 always and these layers are spaced equal to the half of the sensing range of a sensor node.

In this work the layers are not functioning in the formation of the clusters or choosing of CHs not even in the deployment of the network nodes the only functioning of these layers is to select the type of communication strategy in the particular round for particular layer.

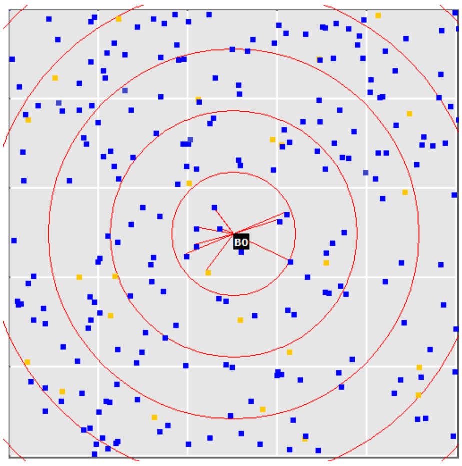


Figure 4. Layering of the network

Cluster Formation: After deployment of the network, sub-divisions and formation of layers the next step is to formation of clusters. The formation of clusters is done same way like in the LEACH scheme. As we have already partitioned the network area into subdivisions so a node randomly chosen as cluster head (CH) form each subdivision and it will broadcast a J_CH (join cluster head) request to all other SNs. SNs determine the intensity of the join signal sent by the CH and finalizes the CH whose intensity is more. Figure 5 shows the scenario of cluster formation.

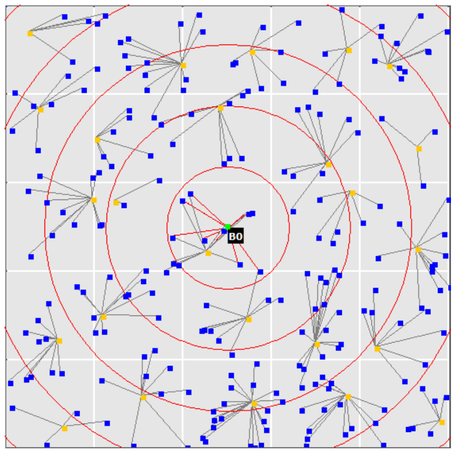
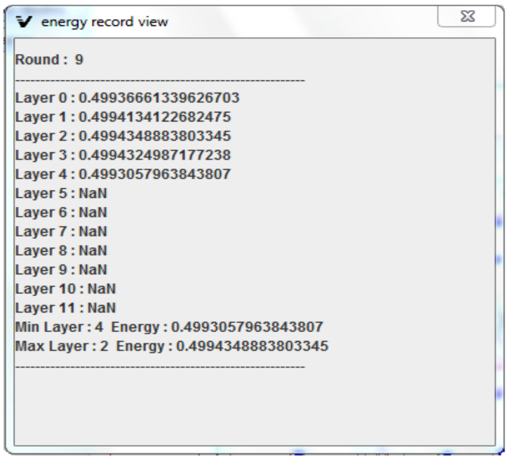


Figure 5. Cluster Formation

Combination of Direct and Multi-hop Communication: In this work, a combination of single-hop communication and multi hop communication based on the remaining energy of the various circular layers is being used. After running of the first round each layer will calculate their remaining average energy (RAE) which will help in performing of the combination of direct communication and multi hop communication on the basis of the following formulae:-

$$RAE = \frac{\Sigma Er}{\Sigma n} \quad (1)$$

where
Er = Remaining energy of all the node in the particular layer
n = Total number of nodes in the particular layer.



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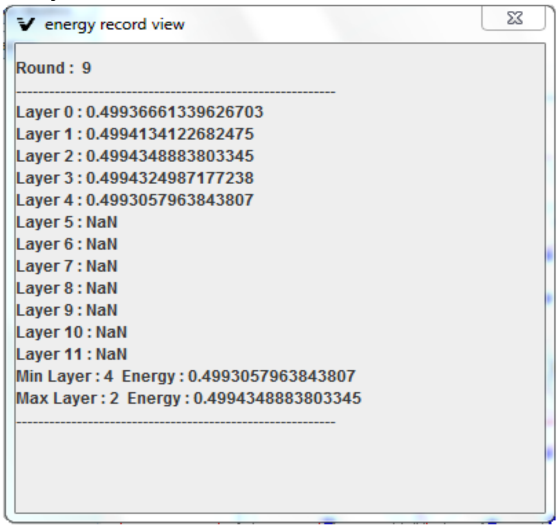

Figure 6. Energy Record

Figure 6 shows the record of energy of various circular layers. The CH in minimum energy level will use multi hop communication mechanism and all other CHs in maximum energy level layer and in other layers will use single-hop communication mechanism to the BS as shown in the Figure 7. Figure 6 shows that layer 4 has the minimum energy level and layer 2 has the maximum energy level, hence according to the scheme, layer 4 will send its data to the nearest cluster head in layer 3, which will send this data directly to the BS and all other CHs in layer 2 as well as in other layers except the layer 4 will transmit their data directly to the BS. This process is followed for each round. The flow of execution of UEDS is given in Algorithm-1.

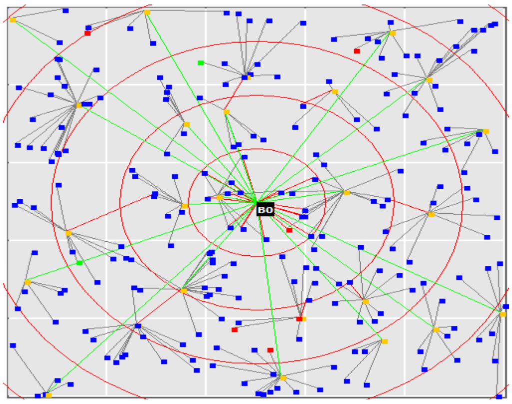

Figure 7. Scenario of Single v/s Multi-hop Communication

Algorithm 1

Step-1. Deployment of the sensor nodes in the network randomly.
Step-2. Partitioning of the deployment area into sub-divisions (20m*20m).
Step-3. Election of cluster heads in the network according to the election probability formula for various sensor nodes [only and at least one from each sub division (if n>0)].
Step-4. Partitioning of the deployment area into layers (spaced equal to the sensing range of the nodes). Calculation of threshold for various types of nodes so that every particular type of node must become cluster head in every round.
Step-5. Formation of clusters in the network by the cluster heads by sending a cluster join request message to all nodes
Step-6. Nodes join the cluster of a particular cluster head from which the message received is of highest signal strength.
Step-7. Data transmission by nodes according to particular assigned TDMA time slots.
Step-8. Cluster heads aggregate the data and send it to base station.
Step-9. Calculation of the average residual energy after first round for each layer.
Step-10. From second round the CH in the layer with minimum average energy will give its data to its nearest node in the next layer towards the BS (multi-hop communication)
Else
Each CH in other layers will send directly their data to the BS (single-hop)
Step-11. Go to step -3.
Step-12. **End**

IV. SIMULATION RESULTS AND DISCUSSION

The proposed model (UEDS) is simulated in java. Results of UEDS are compared with Low Energy Adaptive Hierarchy protocol (LEACH). The results show that UEDS make the network more stable and uniform as well as extends the network lifetime.

Simulation parameters used for the comparative analysis are given in Table 2.

Parameters	Values
Size of target region	100m*100m
Position of BS	(50,50)
Initial Energy	0.5J
Data Aggregation Energy Cost	50pj/bit
Number of nodes	200
Packet size	4000 bit
Transmitter Electronics	50nj/bit
Receiver Electronics	50nj/bit
Transmit Amplifier	100pj/bit

Table 2.Simulation Parameters

The following are the performance matrices used to evaluate the clustering protocols.

- **Stability Period:** The time interval between the start of the network operation and the death of the first sensor node is called stability period or stable region.
- **Instability Period or Unstable Region:** It is the time interval between the death of first node and the death of the last sensor node.
- **Network Lifetime:** The time interval between the start of the network operation and the death of the last sensor node is called network lifetime.
- **Number of Alive Nodes:** The total number of sensor nodes that have not yet depleted all of their energy.
- **Number of Dead Nodes:** The total number of sensor nodes that have consumed all of their energy and are not able to do any kind of functionality.

There is a trade-off between reliability and network lifetime. Network lifetime includes both stable and unstable regions. For the same stable region, a smaller unstable region means more reliability but a shorter network lifetime.

The simulation of proposed scheme is carried out and then compared with the existing protocol (LEACH). Here the simulation is carried out by considering two cases as:-

- Uniform Cluster Formation and Single Hop communication (UC-LEACH).
- Uniform Cluster Formation using both Single Hop and multi-hop communication method (UEDS).

Results show that both the cases are more energy efficient and more stable as compare to the existing protocol (LEACH)

A. UC-LEACH:

Here in this case the deployment area is divided into sub-divisions (small squares) and it is assumed to select a single SN from each sub-division as a cluster head randomly until all the SNs of particular subdivision will not die. It is different from static clustering because, unlike static clustering mechanism, in this scheme the CHs are changed after every round. However, the uniformity of the CH distribution within a target region is maintained because of the sub-divisional election of CHs.

The simulation results are prepared on the basis of dead nodes, energy consumption and number of rounds.

B. UDES:

Here in this strategy from the previous network, we have divided the network area into circular layers (Layer1, Layer2, Layer3...Layer (n)) spaced equal to the half of the sensing range of a sensor node. The average residual energy of each layer is computed after each round and the layer with minimum energy level is identified. The CHs in all the layers having their energy level more than the minimum energy level layer sends their aggregated data directly (single hop) to the BS. But, the layer having minimum energy level transmits its data to the nearest SN towards the BS in the next layer and this SN will transmit this data to its CH which sends it directly to the BS. Hence this strategy is a combination of both single hop and multi hop communication strategy.

C. Comparison by Number of Rounds:

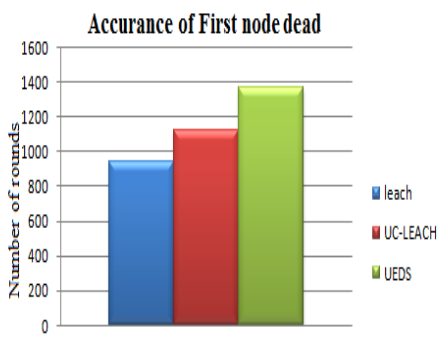

Figure 8. First Node Dead in LECH and UC-LEACH v/s UEDS-E

Figure 8 presents the number of rounds various schemes work before any node dies. The first node in the UEDS is dies after 1366 rounds while the first node in UC-LEACH and LEACH dies after 1126 and 939 rounds respectively. This shows that the UEDS performs 145% better than LEACH.

The numbers of alive and dead SNs for a given number of rounds are shown in Figure 9 and Figure 10 respectively. Here as shown in the simulation results the nodes in the existing protocol (LEACH) are dead after 2044 rounds but as in the proposed protocol (UEDS-E) only 113 nodes died in the same number of rounds.

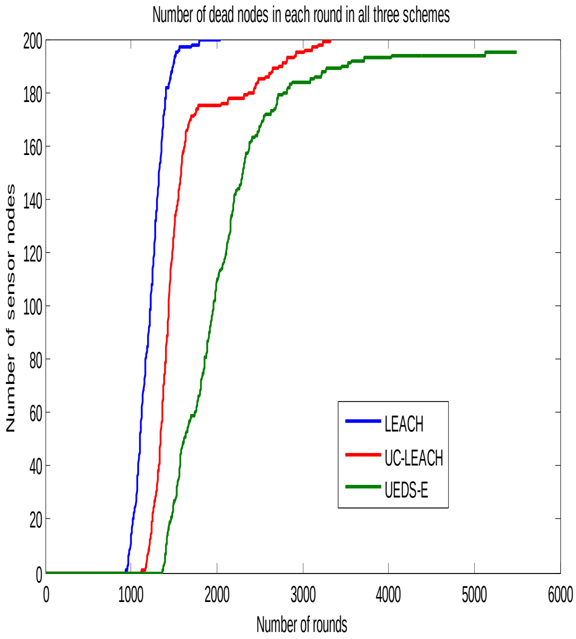

Figure 9. Comparison of Dead Nodes Among Existing V/S Proposed Protocols

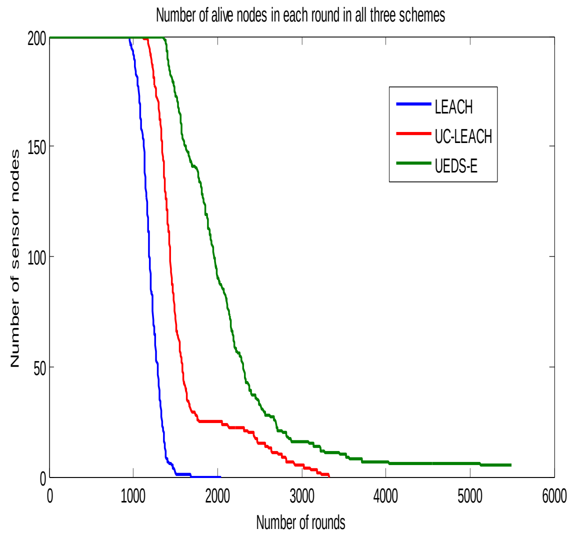

Figure 10. Comparison of Alive Nodes Between Existing V/S Proposed Protocols

Figure 10 shows that up to 938 rounds there are all the nodes of all three schemes are alive but at 939 first SN dies in LEACH but in the proposed schemes UC-LEACH and UDES the first node died at 1119 and 1366 respectively. After 1500 rounds 04 SNs are alive in LEACH but in UC-LEACH and UEDS, 73 and 174 SNs are alive respectively. Similarly after 2000 rounds only 01 node is alive in LEACH while 25 and 92 nodes are alive in UC-LEACH and UEDS-E respectively. This proves that our proposed both schemes (UC-LEACH and UEDS) are far energy efficient as compared to the existing protocol LEACH. After 3500 rounds UC-LEACH network is almost died but there are 10 nodes still alive in UEDS, thus UEDS-E is also far energy efficient as compare to both existing protocol (LEACH) and proposed (UC-LEACH).

D. *Comparison by Energy Dissipation:*

Figure 11, shows a graph of energy dissipation for LEACH, UC-LEACH and for UDES. The simulation results shows that after 500 rounds “0.205767614” is the total average energy dissipated by LEACH while it is “0.135347624” for the proposed scheme(UEDS),similarly after 1000 rounds the total energy dissipated by the LEACH is “0.390814648” while “0.26974599” for the UEDS-E. After 2000 rounds the energy consumed by leach is “0.499887244” while it is “0.446727088” by the UEDS-E, hence our proposed scheme is far energy efficient as compared to the existing protocol LEACH.

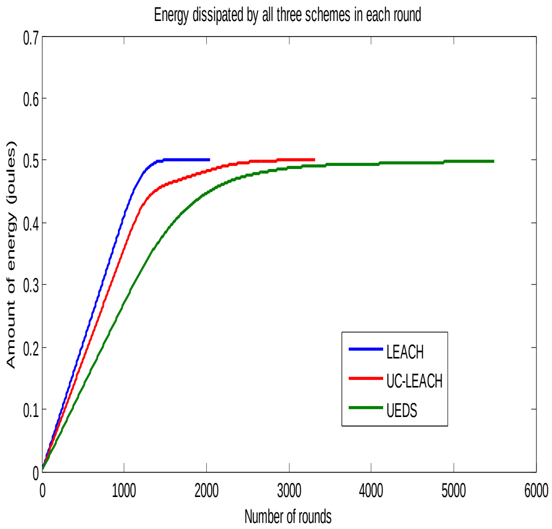

Figure 11. Dissipation of Energy in Each Round by LEACH, UC-LEACH And UEDS-E

Figure 12 shows another graph representing the remaining average energy of the network after each round. The graph shows that after 500 rounds the average remaining energy in UEDS is "0.364927112" while it is 0.321114724" and "0.294639821" in UC- LEACH and LEACH respectively. Similarly after 1000 rounds 0.089676317J energy left in LEACH while"0.141847833J" and 0.230521831J average energy left in UC-LEACH and UEDS-E respectively. Hence the UEDS is 194% and 108% more efficient as compared to the existing protocol LEACH and our proposed UC-LEACH respectively.

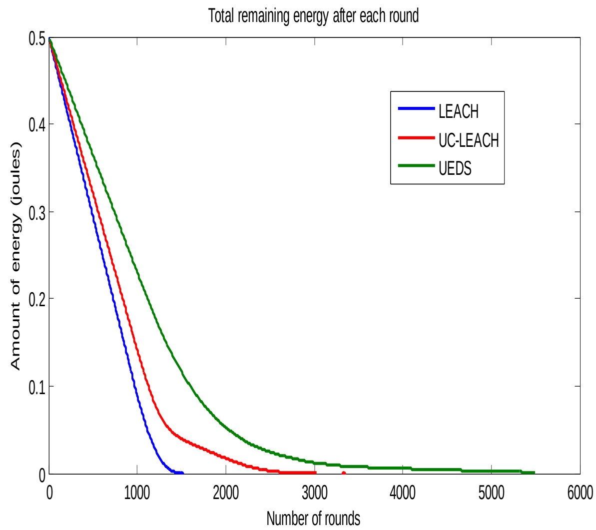

Figure 12. Remaining Energy After Each Round in LEACH, UC-LEACH And UEDS-E

E. Conclusion And Future Work

Limited energy is the major issue in WSNs, as the SN is a battery operated devices and battery is an exhaustible component. Minimizing energy dissipation and maximizing network lifetime are important issues in the design of wireless sensor networks. There are various routing protocols which in which optimal routing can be achieved to save energy in sensor nodes. Hierarchical routing (cluster-based routing protocols) have shown to be more scalable and energy-aware. The basic idea of clustering is to use data aggregation mechanism in the cluster head to reduce the amount of data transmission, thereby, reduce the energy dissipation in communication. LEACH (low-energy adaptive clustering hierarchy) is well-known & divides the whole network into several clusters, and the run time of network is broken into many rounds. In each round, the nodes in a cluster contend to be cluster head according to a predefined criterion. The proposed protocol divides the network into layers. The energy consumption is balanced in the proposed protocol by calculating the average residual energy of the various layers in the network. Cluster heads are elected uniformly from the entire network area. Residual energy is calculated from each layer. Cluster head from the layer which have minimum residual energy level will send data to next layer cluster heads and cluster head from the remaining layers will send the data directly to the base station. Simulation results prove that the proposed protocol is energy efficient compared to similar protocols given in the literature.

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