ELDC: An Artificial Neural Network based Energy-Efficient and Robust Routing Scheme for Pollution Monitoring in WSNs

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***Abstract*— The range of applications of Wireless Sensor Networks (WSNs) is increasing continuously despite of their serious constraints of the sensor nodes' resources such as storage, processing capacity, communication range and energy. The main issues in WSN are the energy consumption and the delay relaying data. This becomes extremely important when deploying a big number of nodes, like the case of industry pollution monitoring. We propose an energy-efficient load-balancing group-based WSN called ELDC, where groups may have different sizes and different routing protocols. We use a group chief node selection technique for each group which is based on an artificial neural network and allows intelligent group organization. Our proposed technique is highly energy-efficient capable to increase sensor nodes' lifetime. Simulation results show that it outperforms LEACH protocol by 42%, and other implemented protocols by more than 15%.**

***Keywords*—**Group-Based Networks, Load balancing, Prolonging Network Life, Residual energy, Sleep mode.

I. Introduction

Wireless Sensor Networks (WSNs) consist of tiny and cheap sensing nodes focused on collecting environmental data. They can be used in a variety of environmental monitoring and control systems like surveillance, disaster management, outdoor climate, indoor temperature and industrial pollution [1]. Sensor nodes are usually scattered and operate on a set of limited resources. The environmental pollution can be monitored and controlled from remote locations continuously with high precision using small sensor nodes forming a WSN [2]. Usually the techniques for air quality monitoring like gas chromatography (GC) are bound by installation expenses, time and durability of the installed devices. Therefore, all the desired data cannot be collected from a vast field and may not be available for a long period. Currently, the industry air pollution monitoring system is becoming more feasible by using latest advances in WSNs technology. The deployment of such system integrated with WSN technology decreases costs, time and allows us to quickly reconfigure the system. Moreover, networked sensors in industry air pollution monitoring system enable low-cost and continuous environment observation. Sensors monitor the environment and send directly or indirectly, through other sensor nodes, the acquired data to the main control center. The main problem in such case is how to enlarge the life span of the network as long as possible by assuming that sensor nodes are non-rechargeable.

Normally, industry environment monitoring implies big areas, which requires deploying large number of nodes for the good coverage, detection probabilities and minimize the false alarms. Some works have proven the benefits of group based networks [3]. In group based networks, each group has its own group ID and a central node is selected in each group. Any node can keep the record of the group IDs of the whole network. Every node forwards its data to its neighbors towards the destination node. The nodes lying on the borders of the groups, known as border nodes, facilitate group member nodes to communicate with other groups' nodes. Moreover, different groups may have different routing protocols.

Many researches have proposed cluster based networks, which is a subset of group-based networks, to improve the network performance. Each cluster has a cluster head (CH) considered as the main node of the cluster and its duties are to communicate with other clusters and the base station (BS). As CHs carry out more tasks, they are usually selected on the basis of their remaining residual energy [4]. Generally, the CH nearer to the BS has more workload due to more traffic, so it tends to waste its battery early. For this purpose an efficient topological technique is required [5].

The main focus in this work is to make the network more energy-efficient to increase its life span. Following this purpose, we propose an energy-efficient load-balancing group based WSNs called ELDC, which extends our previous protocol, EEMDC [6], by adding features of EEUC [4] and some new group-based energy saving techniques. This mix of techniques equally utilizes the energy of all nodes in the network. We have also proposed a new type of node in the network named Chief Node. It identifies the nodes with lower energy than a threshold in order to put them in sleep mode.

The remainder of the paper is structured as follows. In section II, we briefly discuss the work already done in this area of study. We present our proposed intelligent protocol in section III. The algorithms and flow charts are explained in section IV. Simulation results are shown in section V. Section VI concludes the paper and draws our future work.

II. Related Work

A lot of work has been done for making WSNs more energy efficient. In LEACH [7], communication from nodes to CH and CH to nodes is single hop and it uses the probability of selecting CHs. CH selection is performed after one round [7]. In order to improve the energy consumption, a technique of forming a chain of sensor nodes was proposed in PEGASIS [8]. Sensor nodes have to find a close node to the CH in the same cluster, which creates multi-hop communication. Some authors propose a hierarchical routing protocol (HRP) aiming of prolonging the network life [9]. Another protocol in which sensor nodes select their coordinator, and it uses a multi-hop communication system, is presented in [10].

An extension of LEACH protocol, called pLEACH, is presented in [11]. It defines the mechanism for selecting the CH based on the highest remaining residual energy. Hybrid Energy efficient distributive protocol (HEED) [12] is also an extension of LEACH protocol. It runs as a multi-hop routing protocol when the CH communicates with the BS. Its CH selection mechanism is based on calculating the intra-cluster communication cost. In HEED, every node works individually and it does not give any idea about the size and density of the network. Some hierarchical clustering protocols came into the scenario in [13]. For each node they consider its weight, its distance from other nodes as well as its energy.

DECSA protocol [14] divides the network into three levels, each one having its own CH. The CH of the third level communicates with the CH of the second level, the CH of the second level communicates with CH of the first level, and the CH of the first level sends the data to the BS. EAMC [15] is an energy-aware hierarchical clustering algorithm which has the ability to reduce the communication complexities. In this protocol, CH selection is performed between nodes with higher energy and after a specific period of time, the CH is rotated to increase the energy efficiency, but it does not reduce the number of CHs in the WSN. Minimum Transmission Energy (MTE) protocol [16] has the ability to reduce the workload and increase the energy efficiency by sending data only to nodes which possess MTE. While selecting CH between nodes, MTE does not check the amount of energy left with a particular node which could lead to destroy the network operation and also can decrease the lifetime of the network.

Energy-Efficient heterogeneous clustered (EEHC) protocol for WSNs [17] can be applied to an environment of homogenous natured nodes. Any node in the cluster can become a CH by considering their remaining energy. A tree-based clustering protocol (TBC) for WSN is presented in [18]. TBC has a tree-shaped structure of nodes where CH is the root of the tree and the height of the tree is specified with the distance between a node and the CH. A single-hop technique is used for sending data from the CH to the BS. EADC [19] utilizes a threshold value to send data from the CH to the BS. CH can send data directly to the BS if the threshold value extracted from the proposed protocol is greater than the distance of these two network nodes, i.e. CH and BS. On the other hand, if the distance is higher than a threshold amount, it uses those CHs which have higher energy on the path as a relay node to send data to the BS. In [20], a clustering scheme EECS is proposed in the context of energy efficiency. This protocol has been used in applications where data gathering is required. The CH selection criterion depends on the outstanding residual energy of the network nodes. In DDAR [21], authors control the level of energy consumption by analyzing the remaining energy, distance and dynamic number of CHs in the network. In the setup phase, each node sends its information like outstanding energy to the BS, which in turn determines the best possible candidate CH from the available nodes in the network.

EEUC [5] demonstrates how unequal clustering based on the size of the cluster and number of nodes in a cluster can be efficient to reduce the energy consumption of the network. EEUC keeps the size of the cluster big when the cluster is far away from the BS, but introduces more inter-cluster communications, which results in more energy consumption. The clusters near to the BS are smaller in size, but they are over-burdened with relay jobs of its predecessor clusters, which also increases its chances of death. EEUC mechanism proposed the basic sizes of the clusters of the network and also the CH selection algorithm. The effort of EEUC is aimed to balance the energy consumption of all nodes.

Recently, we proposed an energy-efficient multi-level and distance aware clustering (EEMDC) mechanism for WSNs [6]. In EEMDC there are three logical layers in network divided by area factor. Layering depends on hop count. In other words, it is the distance from the BS. The practice shows that its efficiency is better than previous approaches. Table 1 show a comparison table with the discussed protocols.

Clustering Protocol	Clustering methods	Routing Type	Cluster Size	Energy Efficiency	Additional features	Location awareness	Connectivity of CH to BS
LEACH	Distributed	Cluster based	variable	Very Low	fairness	No	Single-hop
HEED	Distribute	Cluster based	variable	Moderate	Load Balancing	No	Multi-hop
DDAR	Centralized	Cluster based	variable	Good	Load Balancing	Yes	Multi-hop
EEMDC	Hybrid	Cluster based	variable	V. High	Load Balancing	No	Multi-hop
EEUC	Distributed	Cluster based	variable	Good	Load Balancing	No	Multi-hop
ELDC	Distributed	Group based	variable	V. High	Load Balancing	No	Multi-hop

Table 1: comparison between different state-of-the-art protocols

After the review of these systems, we have observed that none of them is a dynamic group based network with layered structure, which increases the scalability while decreases the energy consumption. These features are mainly needed in industrial WSN. Moreover, we also include an Artificial Neural Network for selecting nodes with higher roles.

III. PROPOSED TECHNIQUE

Inspired in EEUC [4], we propose a group based protocol that includes the idea of dynamic sizes of clusters. The implementation of a group based network with layered structure for WSN shows a positive change in the energy consumption of the network. Each group communicates with other groups through the border node nearest to the destination group (instead of using CH connections) [22], which let us have very large WSNs for industrial pollution monitoring.

This paper implements the mechanism of EEUC on group based network with different communication techniques and having no CH. Groups replace clusters in our scenario and border nodes are kept responsible for communication with other groups. Moreover, the duty cycle of the sensor nodes, which consume more energy as compared to others, is changed. The system is based on a pair of queues, which make sensor nodes to switch into sleep mode if their consumption exceeds a threshold [23]. When the network begins, every node calculates its number of neighbors to which it can send packets directly through one hop. This process is performed at each layer separately, as the proposed protocol is following a three layered structure.

Each group, identified with a groupID, selects a central node by estimating the diameter of the network and selecting the node at the center of the diameter (diameter is known because it is estimated from the beginning and every time the topology grows). Moreover, when the network begins, the node with most number of neighbors becomes the chief node of that specific layer (in case of draw, it is selected the node whose groupID is higher). By this process the system has three nodes claiming themselves as chief nodes due to the three layered structure. All nodes send information about their remaining residual energy along with their IDs (called nodeID) and their neighbor nodes' IDs to their group's central nodes. The central nodes pass them to the border node of that group and they forward the information to the chief node of its layer. This process is performed to maintain the residual energy of all the nodes at almost equal by implementing few algorithms discussed below.

The tasks which are performed by a chief node include:

1) Collect the value of the remaining residual energy of all the nodes within the layer.

2) Calculate the average energy on the basis of the information available.

3) Calculate the energy threshold, which is estimated as a function of the average energy.

4) Store REST and NEXT queues in its memory.

The algorithm procedure is as follows (it is explained in the flow chart diagram of Figure 1). First, each node checks and compares the threshold value with the residual energy of all nodes. The value of threshold is always kept smaller than the average energy. The lower the value of threshold will tend to the higher number of cycles due to minor difference with the average energy. We used a proportional value of threshold i.e. half of the average energy. If it finds the remaining energy of a node lesser than the threshold, then it saves that node's ID in the REST queue. When it finds another node whose energy is lesser than the threshold, then an additional check is performed. This check verifies that the node, which is a candidate to be in REST queue, is a neighbor of those who are already in REST queue. If its neighbor's ID is found in the REST queue, then the node is kept it in NEXT queue. The nodes which are in the REST queue sleep till the end of current iteration (see Algorithm 1). Then, the procedure is repeated during a period of time T_1. Next iteration begins scanning the NEXT queue and swapping one by one to the REST queue. When the remaining residual energy of the chief node is lower than a threshold, a new chief node is selected based using an Artificial Neural Network (ANN).

A. ANN for Chief Node Selection

Intelligent techniques are being implemented for monitoring the environment with successful results. But most of them are implemented in the monitoring process, not in the network organization process. Our system decides who is the Chief Node based on the remaining energy, the number of neighbor nodes, the amount of data that is being transmitted, the amount of signal interference, measured by SNR (Signal Noise Ratio), and the threshold values. The basic idea is that the nodes estimate which is the best Chief Node taking into account those issues that affect most to the energy consumption, which are the fact of transmitting much data, the fact of having many neighbor nodes, which may imply to route many data, and the signal interference, which is very common in industrial environments. There is a training phase, which provides the weights and thresholds for each node for the remaining energy, the number of neighbors and the amount of data that is being sent.

The popular type of neural network architecture i.e. Adaptive Reasoning Theory (ART) is used for training nodes towards the pattern matching and selection of nodes having the most suitable resource patterns. Initially the training process outputs the list of nodes which satisfy the energy matric criteria. The whole network is covered by this process in an iterative manner. To reduce the redundancy only adjacent nodes are monitored and marked. The training module enables the selected nodes to find for a set of their adjacent nodes that they monitor. At the end of whole process, the three most suitable nodes with their values are outputted (as explained by the formula in Algorithm 2). The node having the highest output value is then selected as a chief node.

The node estimates the sum of the products of weights with each parameter Z. Then, it adds the biases of each node to the calculated sum. Finally, it is estimated the output for each node according to an equation (shown in Algorithm 2). Using the condition $\sum_{K=1}^{n}(W_K Z_K)$ > threshold, and defining the perceptron's bias, b≡−threshold, as a measure of how easy it is to get the perceptron to output 1, we will obtain next output.

$$output = \begin{cases} 0 \ if \ \sum_{K=1}^{n}(W_K Z_K) + b \leq 0 \\ 1 \ if \ \sum_{K=1}^{n}(W_K Z_K) + b > 0 \end{cases} \quad (1)$$

The output of a sigmoid neuron is estimated as follows.

$$f(x) = \frac{1}{1+e^{-x}} \quad (2)$$

where $x = -\sum_{K=1}^{n}(W_K Z_K) - b$

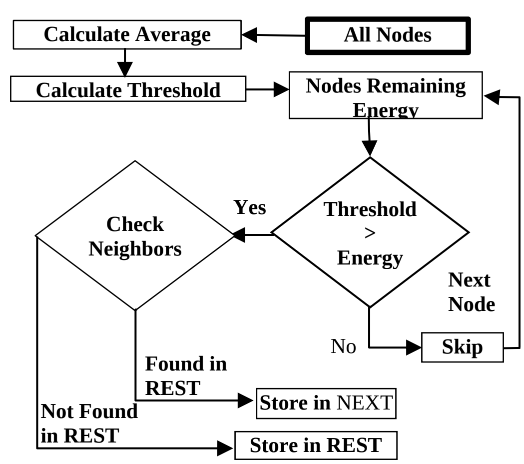

Figure 1. Flow Chart Diagram

Algorithm 1. Chief Node Selection Algorithm

Input: RE, Neigh, NodeID

```
Output: maximal.NodeID
  1.  set maximal.Value ← 0
  2.  maximal.NodeID ← Null
  3.  for each node i from 1 to N
  4.    C1 ← (RE × 1) + (Neigh × DW)
  5.    if C1 ≥ maximal.Value
  6.      then set maximal.NodeID = i
  7.    end if
  8.  end for
  9.  return maximal.NodeID
```

Algorithm 2. Chief Node Selection Algorithm using ANN

```
Input: weights and biases, network pattern
Output: Out1, Out2, Out3
      // Propagated the input forward through the network:
  1.  for all nodes in the Hidden layer
      //Calculate sum of product of weights and inputs to the node
  2.  Calculate ewf(WZ) < −(∑_{K=1}^{n}(W_K Z_K)) //
  3.  Add the Biase of each node to the calculated sum
      //Calculate the output f(x) for each node
  4.  Calculate f(x) < − 1/(1+e^{−x})
  5.  end for
  6.  for all nodes in the Output layer
      //Calculate the sum of product of weights and inputs to the
      node
  7.  Set OutPut ←f(WZ) = (∑_{K=1}^{n}(W_K Z_K))
  8.  Add the Biase of each node to the calculated sum
      //Calculate the output f(x) for each node
  9.  Calculate f(x) < − 1/(1+e^{−x})
  10. end for
  11. Output Layer: Node1 ouput:out1, Node2 ouput:out2, Node3
      ouput:out3;
  12. if (out1> out2 &&out1> out3)
  13. Return ("Selected as Chief node")
  14. else
  15. Return ("Works as a regular node")
  16. end if
```

Algorithm 3. Chief Node Functionality Algorithm

```
Input: NodeID, NodeEnergy, NeighborID
Output: Stores NodeID in REST and NEXT Queues
  1.  Set Total-Energy ← 0
  2.  for node i from 1 to N
  3.    Set Total-Energy ← Total-Energy + node(i). Energy
  4.  end for
  5.    Set Avg-Energy← Total-Energy / N;
  6.      threshold ← f(Avg-Energy)
  7.  for each node j from 1 to N
  8.    if (node(j).energy <= threshold)
  9.       for each node in REST
  10.        if REST.nodeID = node.neighborID
  11.           then Store Next←nodeID
  12.           else Store REST← nodeID
  13.        end if
  14.      end for
  15.   end if
  16. end for each
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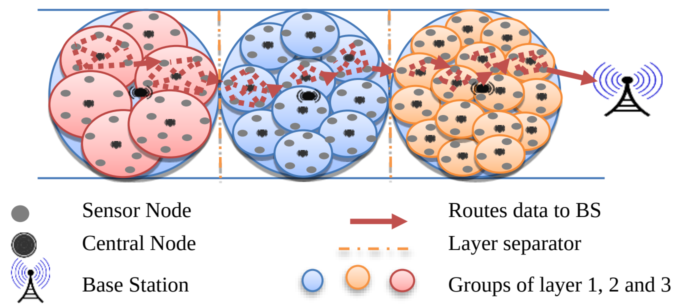

Figure 2. Message Flow Diagram

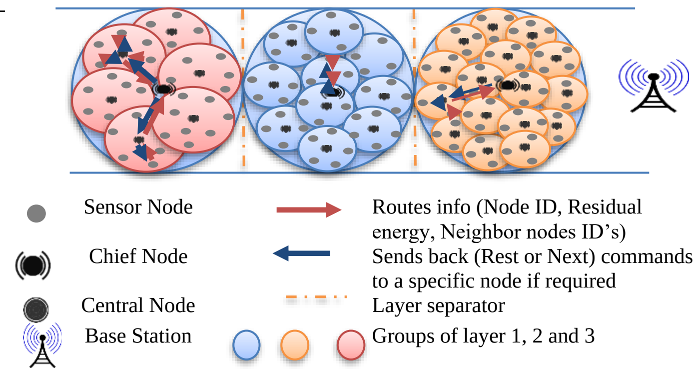

Figure 3. Chief Node Process Diagram

While implementing a network by using EEUC mechanism, BS calculates the distance between itself and the nodes. It facilitates the creation of non-overlapping clusters with different sizes. EEUC technique utilizes unequal clustering mechanism and inter-cluster multi-hop communication. In such case the CHs receive data from all the nodes in a cluster and forward it to the BS. Clusters nearer to the BS are preferred to be smaller in size to reduce energy consumption in the multi-hop communication among clusters. CHs collectively forward the received data packets from all cluster nodes to the BS. Moreover, a three layered structure of EEMDC is followed. A delay factor for those nodes, which consume more energy, is introduced. This factor is used by the system to send a sleep command to a specific node. In the beginning, each node counts its neighbor nodes through which it can send packets directly by on-hop.

IV. Process Flow Diagrams

A. *Process Flow Diagrams*

When a node becomes a chief node, it takes some responsibilities which are briefly described in this section.

B. *Algorithm Describing Chief Node's Functionality in ELDC*

After a specific time T_1, all nodes send their remaining energy information to the chief node of its layer, which estimates their average energy and the threshold in order to know in which queue the node should be placed (REST or NEXT). Algorithm 3 describes the procedure.

C. *Message Flow from Sensor node to BS in ELDC*

Sensors sense data from the environment and send them to the border node of the directly or through multiple hops [24]. The border node forwards the data to another border node of another group, which is closest to the BS. The data transmission is made towards the BS as shown in figure 2.

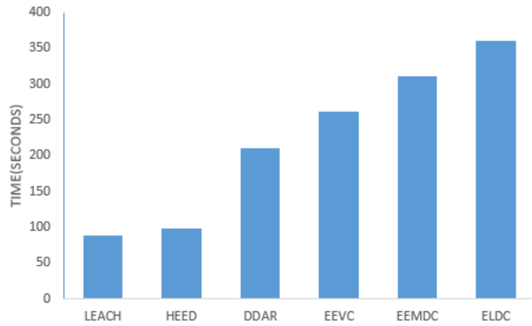

Figure 4: Time until the first node dies

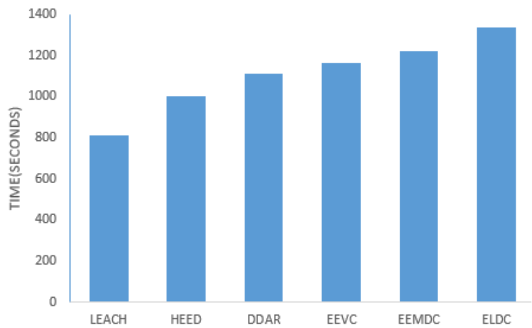

Figure 5: Time until the last node dies

D. Selection of a Chief Node

When a chief node's remaining residual energy reaches to its critical level then it invokes the selection process of a new chief node. In Algorithm 1, RE is used to show the remaining energy of a node. Neigh indicates for number of neighboring nodes. The value DW, a positive number, is used to put the importance factor weight in the neighbors' number to specify the chief nodes selection. The algorithm takes the RE, number of neighbor nodes and the nodes IDs of nodes to be considered as chief nodes. For each node *i* and a value *Ci* is obtained using its RE and Neigh. The highest value of DW causes higher variations in the values of C's. In case of larger number of neighbor nodes, the number the value of DW is preferred to be smaller. We used DW=8 in our experiments. At the end of code the highest C is returned in the form of an object maximal which keeps the node's ID for chief node's selection.

E. Chief Node Processing in ELDC

The information, consisting of its nodeID, its remaining residual energy and the nodeIDs of the neighbor nodes, is sent by all nodes to the chief node of that layer. The chief node performs its estimations according to the formula given in the flowchart and algorithm. Then, it replies back to those nodes whose remaining energy is lower than the threshold value and sends a command either of REST or NEXT.
The functionality of a chief node is described in algorithm 3.. The chief node receives the information regarding the remaining energy of all the nodes and sums it up to an object total energy. Then the total energy is divided by the number of nodes to calculate the average energy. The threshold is obtained by applying a function on the average energy. We used a simple technique by taking the threshold equal to half of the average energy. In the next segment all the energies of all the nodes are compared with the value of threshold. The nodes having lesser or equal energy level compared with the threshold are kept in the REST while in this process the neighbors are also checked in the REST queue. If found, then the specific nodes are transferred to the NEXT queue.

F. Analyzing Power Consumption

The proposed algorithm uses Heinzelman et al. for power consumption [7]. In this approach it's considered that the main factor of power consumption is data communication, which further depends on two factors: data reception and transmission. The model demonstrate the power to transmit a bit to a distance of d is

$$P_t(d)=a1+a2*d\text{^}2 \quad (1)$$

Where the parameters a1 and a2 depend on the transmitter circuitry, and n is the path loss exponent for the environment, which often has a value between 2 and 4. In our model a1, 2, and n are considered to be 50 nj/bit/m^2, 100 pj/bit/m^2 and 2, respectively.
In our model, the energy consumption is a constant value per bit for data reception. It is assumed as constant with B and values equals 50 nj/bit.
It is assumed for our experiments that all sensor nodes are sensing the environment and generating traffic at a fixed rate. Therefore, total power consumption for receiving and forwarding a bit to the next hop equals:

$$P_f(d)=B+a1+a2*d\text{^}n \quad (2)$$

If the remaining battery energy is denoted as ei for the sensor node i, then the lifetime of the node i is as follows:

$$li= e_i/((r_{ri}*B)+(r_{ri}+r_{gi})*(a1+a2*di\text{^}n)) \quad (3)$$

Where r_{ri} is receiving data rate to node i, r_{gi} is the data generated rate in node i and di is the transmission range.

V. SIMULATION

The simulations have been performed using OMNET as a simulator and Castalia as a plugin for the WSNs' environments., The reason behind selecting the simulator is its layered style, depicting real sensor environments truly, and availability of the object oriented paradigm's features. Table 1, shows the parameters used to perform the simulations. Let's briefly explain the parameters used in the simulation. Initially simulation is performed on an area of 100m* 100m and then it is increased to 500m*500m, in order to experience the effect on protocol during dense environment. Each node has assigned initial energy of 12 joule. The packet header size is 25 bytes, which contains packet related information. The data packets contain information that is exchanged during the communication. The number of node parameter invites for spare and dense environments and their effect on the simulation results. The control packet size parameter is used for exchanging control information between the nodes. The broadcast size packet parameter reveals the size of the packet. The round length paper tells about the duration of each round while the Eelec parameter stands for electronic energy using by the sensor nodes for communication.

Simulation Parameter	Value
Network Area	100m*100m to 200m*300m
Initial Energy	12 Joules
CH Percentage	0.05
Packet header Size	25 byte
Data Size	500 byte
Number of Nodes	100 to 500 nodes
Simulation Time	500 Sec
Control Packet Size	100 bit
Broadcast packet size	25 bytes
Round Length	20 sec
E_{elec}	50 nj/bit
E_{fs}	10 pj/bit/m4

Table 1: Parameters used in simulation

The results show that ELDC outperforms some of the most important cluster based protocols suggested for WSNs. Initially, the experiments are started by taking 50 nodes with 3 layers. The nodes' distribution per each layer is made by using the formula Layer_1= ½ (Total number of nodes), Layer_2 = 1/3(Total number of nodes) and Layer_3=Total number of nodes – number of nodes in (Layer_1 + Layer_2). The experiments gave optimal results with this formula of distribution. The experiments ended with 100 nodes having 50 nodes in layer 1, 32 nodes in layer 2 and the remaining 18 nodes in layer 3. The number of nodes per group are kept approximately equal in all the layers. With hundred nodes, each group are assigned 8, 9 or 10 nodes. The network is divided into different number of groups and clusters for experimented protocols. With LEACH protocol the network is divided into 20 equal clusters each having 5 nodes. While rest are divided with an unequal ratio of 5% to 10% of all nodes per group or cluster. Figure 4 shows the time given when the first node dies in LEACH, HEED, DDAR, EEUC, EEMDC and our proposal (ELDC). Results show that ELDC protocol improves than all the studied protocols. The first node of LEACH dies at 88th second. The HEED, DDAR, EEVC and EEMDC have values 98.9, 210.87 and 310.8 sec in this experiment. ELDC gives the highest time for first node's death i.e. 360 seconds.

Figure 5 presents the time until the first node dies. It shows that last node of ELDC dies at 1338.1 sec while in case of LEACH, HEED, DDAR, EEUC, and EEMDC it is about 810.84 sec, 999.6 sec, 1109.79 sec, 1161.88 sec, and 1223.52 sec respectively. So, it clearly shows that ELDC is giving better results than the others.

Figure 6 shows the energy consumption of the studied protocols along the time. The simulation results show that ELDC consumes 23% less energy than LEACH, 9% less energy than HEED, 6% less energy than DDAR, 5% less energy than EEUC, and 2% less energy than EEMDC. So ELDC outperforms the conventional protocols.

Figure 7 shows the number of nodes alive along the time. This simulation shows that the ELDC has 90 nodes alive after 800 s. But LEACH, HEED, DDAR, EEUC, and EEMDC have 1, 61, 72, 80, and 85 of nodes alive, respectively, after 800 s. Hence, ELDC is better than the other protocols.

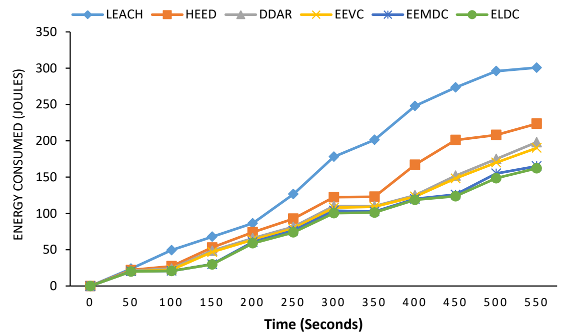

Figure 6: Energy Consumption as a function of the time.

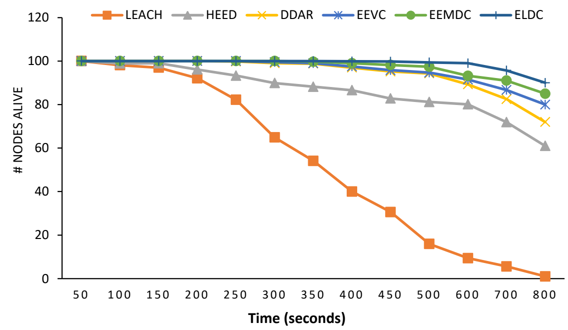

Figure 7: Number of Nodes Alive as a function of the time

VI. Conclusion and Future Work

In this paper, we have proposed a new protocol called ELDC, which includes advantages of both EEMDC and EEUC mechanisms and avoid the limitations of both. Moreover, adding a new feature of controlling some nodes from dying early with changing the trend of forming groups in the group based network. By combining these features in a single protocol, we proved by experiments that all nodes decrease their residual energy at the same pace. If some nodes consume their energy quickly, then the other nodes support them and let them be in sleep mode by sending sleep commands after every round. We have also presented a selection plan for the chief node, which includes features from industrial environments. It is needed when very large networks (thousands of nodes in one layer) is going to be implemented and it is needed scalability.

Further work will be focused on securing chief nodes as the current proposal does not address any measurement for securing chief nodes from external attacks, by adding an authentication in the sensor nodes and security in the routing protocol [25].

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