PERFORMANCE EVALUATION & IMPROOVEMENT OF LEACH – A WIRELESS SENSOR NETWORK PROTOCOL USING A NOVEL ALGORITHM FOR CLUSTERING

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ABSTRACT :
From past few years Wireless Sensor Networks has been an area which has fascinated many researchers to implement their new ideas for the betterment of human life using small tiny sensors. A Wireless Sensor Network is a network of sensors with capabilities to sense particular entities related to environment, to process data locally & to communicate information to the Base Station. Low Energy Adaptive Clustering Hierarchy (LEACH) Protocol is one of the renowned hierarchical routing approaches for Wireless Sensor Networks. In this paper we have proposed an novel energy efficient clustering hierarchy for the augmentation of LEACH protocol. The proposed clustering hierarchy focuses on the equalize energy distribution and area distribution for the clusters. The proposed method improves the life span of the network and also the data throughput of the Network.

KEY WORDS *: DWP, WDM, Enhanced (Modified) DWP, Rerouting and MTV_WR.*

1. Introduction

Wireless Sensor Networks (WSN) has extremely large potential to enlighten the future scopes in the field of Remote Sensing & Defense Departments because they expand human abilities to monitor and interact remotely with the physical world.

The recent proliferation in the field of Micro-Electro Mechanical Systems (MEMS) [1], Material Science, Digital Communication etc have developed the smart sensors with ability to collect & aggregate huge amount of hitherto unknown data. This tiny sensor, also called mote, possesses the improved spatial & temporal resolution and accuracy compared to the conventional sensors. Considering few of the restrictions such as battery life time, limited computing abilities and less memory, make the sensors non recyclable and they live until their powers fade away. So power consumption is the most crucial parameter for sensors. During the special applications the energy consumption in sensors should be controlled knowingly. The power of sensor cannot support more than far connection. Therefore to transmit data we need a multi sectional architecture [2].

Clustering is especially important for sensor network applications where a large number of ad-hoc sensors are deployed for sensing purposes. If each and every sensor starts to communicate and engage in data transmission in the network, great network congestion and data collisions will be experienced. This will result to drain limited energy from the network. Node clustering will address these issues. In cluster networks, sensors are partitioned into smaller clusters and cluster head (CH) for each cluster is elected. Sensor nodes in each cluster transmit their data to the respective CH and CH aggregates data and forward them to a central base station. Clustering through creating a hierarchical WSN facilitates efficient utilization of limited energy of sensor nodes and hence extends network lifetime. Although sensor nodes in clusters transmit messages over a short distance (within clusters), more energy is drained from CHs due to message transmission over long distances (CHs to the base Station) compared to other sensor nodes in the cluster. Periodic re-election of CHs within clusters based on their residual energy is a possible solution to balance the power consumption of each cluster. In addition, clustering increases the efficiency of data transmission by reducing the number of sensors attempting to transmit data in the WSN, aggregating data at CHs via intra-cluster communication and reducing total data packet loses.

Low-Energy Adaptive Clustering Hierarchy (LEACH) is the most popular cluster-based routing protocols in Wireless Sensor Networks. In LEACH the cluster heads are randomly selected and when the cluster head die then another node will be selected as cluster head. Therefore, the cluster head role is kept on rotating to balance the energy dissipation of the sensor nodes in the networks. As a result, the nodes cannot provide end to end delivery of the information. At the same time nodes break up their communication if they move out of the coverage area [4].

The rest of the paper is organized as follow. After Overview & brief idea on wireless sensor networks, the section 3 is totally dedicated to understanding and implementation of the architecture of LEACH & its very first variant LEACH-C. In this section we have successfully implemented both the protocols & discussed their result analysis & comparison. In section 3, we have proposed few improvements of LEACH protocol in the direction of development of energy efficient protocol. The simulation analysis of these improvements is also discussed in the same section. Section 4 consist concluding remarks & future work plans.

2. Low Energy Adaptive Clustering Hierarchy (LEACH)

LEACH [6] is cross layered protocol architecture for WSN which combines the ideas of energy-efficient cluster-based routing and media access together with data aggregation. The operation of LEACH is divided into rounds. Each round begins with a set-up phase followed by a steady-state phase. Setup phase includes three steps.

Step1 is the Custer Head (CH) selection and advertisement. To determine if it is its turn to become a CH, a node, n, generates a random number v, between 0 and 1 and compares it to the CH selection threshold, T(n). The node becomes a CH if v < T (n). The CH selection threshold is designed to ensure that a predetermined fraction of nodes, P, is elected CHs at each round. Further, the threshold ensures that nodes which served as CH in the last 1/P rounds are not selected in the current round. To meet these requirements, the threshold T(n) of a competing node n is expressed as,

$$\mathrm{Pi}(t) = \frac{k}{N - k * \left(r \bmod \frac{N}{k}\right)} \ : \mathrm{Ci}(t) = 1$$

Or

(1)

$$\mathrm{Pi}(t) = \ 0 \ : \mathrm{Ci}(t) = 0$$

If Ci (t) is the indicator function determining whether or not node has been a cluster head in the most recent (r mod $\frac{N}{k}$) rounds (i.e., Ci (t) = 0 if node has been a cluster head and one otherwise), then each node should choose to become a cluster head at round with probability Pi(t). Next the CHs broadcast an advertising message and its ID to non cluster head nodes (NCH) that they are ready to become CHs. Carrier Sense Multiple Access protocol is used to avoid the collision.

Step 2 of setup phase is cluster formation. All NCH listening to advertising message will select one node whose signal strength is maximum as its CH and send its ID, CH ID and a request message to join its cluster. Figure 1 shows the flow graph of the distributed cluster Formation algorithm for LEACH [6].

Step 3 starts after CHs receive all requests from NCHs. Now the CHs broadcast their ID, confirmation messages to their cluster members and the TDMA schedule to be used during the steady state phase which commences next.

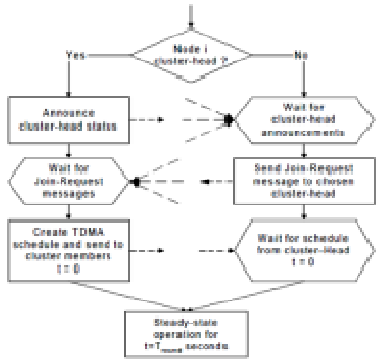

Figure 1 Flow graph of the distributed cluster Formation algorithm for LEACH

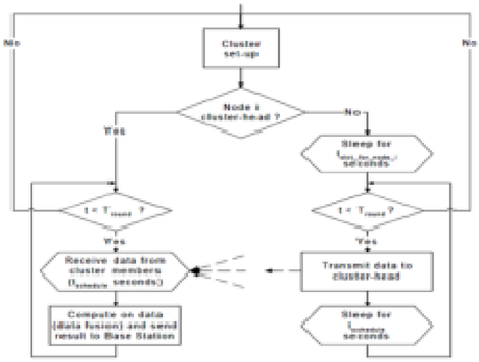

Figure 2 Flow graph of the steady state operation for LEACH

The Steady State phase consists of two steps. In Step 1 NCHs use the TDMA schedule to send their sensor data with their ID and CH ID to respective CH. The schedule prevents collisions among data messages and allows NCH to turn off their radio components until its allocated time slots. In Step 2 upon receiving data packets from its cluster nodes, the CH aggregates the data and sends them to the BS along with its CH ID and BS ID. The communication between a CH and a BS is achieved using fixed spreading code and CSMA. Figure 2 shows the flow graph of the steady state operation for LEACH [6].

LEACH-C

While there are advantages to using LEACHs distributed cluster formation algorithm, this protocol offers no guarantee about the placement and/or number of cluster head nodes. Since the clusters are adaptive, obtaining a poor clustering set-up during a given round will not greatly affect overall performance. However, using a central control algorithm to form the clusters may produce better clusters by dispersing the cluster head nodes throughout the network. This is the basis for LEACH-centralized (LEACH-C), a protocol that uses a centralized clustering algorithm and the same steady-state protocol as LEACH.

During the set-up phase of LEACH-C, each node sends in-formation about its current location (possibly determined using a GPS receiver) and energy level to the BS. In addition to determining good clusters, the BS needs to ensure that the energy load is evenly distributed among all the nodes. To do this, the BS computes the average node energy, and whichever nodes have energy below this average cannot be cluster heads for the current round. This algorithm attempts to minimize the amount of energy for the non-cluster head nodes to transmit their data to the cluster head, by minimizing the total sum of squared distances between all the non-cluster head nodes and the closest cluster head.

Once the cluster heads and associated clusters are found, the BS broadcasts a message that contains the cluster head ID for each node. If a node's cluster head ID matches its own ID, the node is a cluster head; otherwise, the node determines its TDMA slot for data transmission and goes to sleep until it is time to transmit data. The steady-state phase of LEACH-C is identical to that of LEACH.

3 Simulation Environment & Performance Comparison Of LEACH & LEACH-C

We have done the simulation for following conditions and energy model given below.

Conditions:

- Total number of nodes is 100
- The field is 100 x 100 m
- Base station at (50, 175)
- Each node starting with 2 Joules of energy.

Energy Model:

- RXThresh = 6e-9
- CSThresh = 1e-9
- Rb = 1e6
- Excvr = 50e-9
- Efriss_amp = 9.6741659015025702e-12
- Etwo_ray_amp

  = 1.3037037037037037e-15
- Ebf = 5e-9
- Pidle = 0
- Psleep = 0

Thresholds have chosen using original probs.

- Desired number of clusters = 5
- Spreading factor = 8
- Changing clusters every 20 seconds

Number Of Alive Nodes/Round:

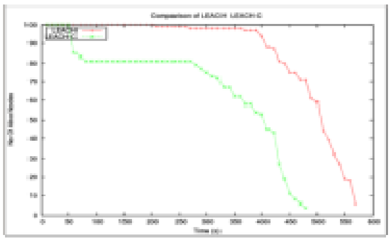

Figure 3 Comparison of LEACH & LEACH-C for Number of Alive Nodes/Round

Amount Of Data Received At BS vs. Alive Nodes

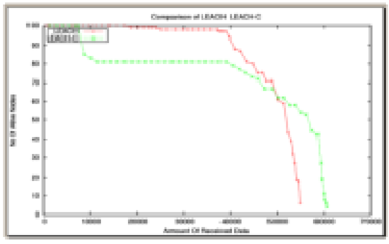

Figure 4 Comparison of LEACH & LEACH-C for Amount of Data Received at BS VS Alive NodesTime Vs. Amount Of Data Received At BS

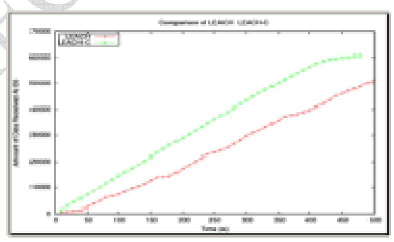

Figure 5 Comparison of LEACH & LEACH-C for Time VS Amount of Data Received at BS

Here in Figure 3 graph shows the Number of Alive nodes per round. This graph gives the information about the life time of network. As we can clearly see, LEACH- C has a short life span compare to the LEACH. Basically LEACH-C requires more energy to transmit the data & ultimately the energy consumption per round is very much high compare to LEACH. This is the main drawback with LEACH-C.

Here in Figure 4 & 5 We have tried to evaluate the LEACH & LEACH-C in terms of the amount of data received at BS. The results clearly show that LEACH-C has a higher data transmitting capacity with drawback of short life span

4 Proposed Energy Efficient Clustering Hierarchy

Drawbacks Associated With The LEACH Protocol

The main drawback of LEACH that we have observed during analysis part is its random Cluster

Head Selection algorithm. Here we have mentioned few of our analyze cons of LEACH protocol.

1. The Cluster Head Selection is depending on the selection of random number from 0 to 1. If the threshold value for the Node is more than the random number then and only then the node can become a CH.
2. In the [6], the authors of LEACH have mentioned that the best functioning of LEACH is depending on the maximum number of CHs. We have observed that the above mentioned random algorithm selects different number of CHs per round. This gives comparatively short life span of the network.
3. For the calculation of threshold the proposed equation in [6], don’t consider the current energy levels of each node. Due to this sometimes it happens that few nodes become CHs continuously in consecutive rounds. This results in the short life span of the network.

Proposed Algorithm

Our proposed clustering approach for LEACH is mainly divided into two parts.

1. Improvement in Cluster Formation - Equal Area Distribution for Clusters

The improvement suggested in this paper is limiting the number of cluster heads per round or in other words dividing the area into the finite number of grids. By doing this we are controlling the energy distribution between the nodes & making it even.

As described in the above sections in LEACH the CH selection is random & cluster formation is also unpredictable. This randomness results in an uneven energy distribution between nodes.

In the proposed method we have divided the whole area into the finite fix number of section. At beginning of every round the proposed improvement divides the whole area into finite sections and then decides the CH from each section. The division of area is a random process so by doing this we are equally distributing the energy load in between all the nodes equally. Also every node will get a chance to become a CH and this will result in a more even distribution of energy.

The simulation analysis of this approach shows a significant improvement in the network life time & throughput of the network.

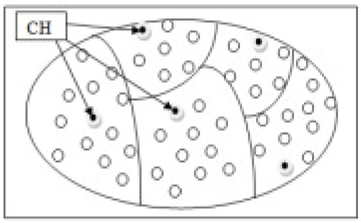

Figure 6 Equal Area Distribution By Limiting CHs Per Round

2. Improvement in the Cluster Head Selection - Energy Distribution based on the current weighting factor of the nodes.

As per the analysis of LEACH protocol we can came to a conclusion that the node which is assigned the CH duty will consume more energy compared to the other nodes of the clusters. Also the CH selection procedure is totally random which is not at all considering the current state of the node.

We have tried to overcome this draw back by calculating the weighting factor for each node in the cluster. Then the node with the highest weighting factor will get a chance to become a CH.

The weighting factor for the node is calculated using the following equation:

$$W(n) = \frac{p}{1 - p\left(r \bmod\left(1/p\right)\right)} * \left[\frac{Erem}{Einitial} + \left[1 - \frac{Erem}{Eaverage}\right]\right] \quad (2)$$

Here Erem signifies the remaining energy level of the node.

So the complete flow chart of the proposed energy efficient clustering Hierarchy for a round can be described as below. The simulation analysis of this approach shows a significant improvement in the network life time & throughput of the network. The Figure 7 shows the Life Span of the network. From the graph we can clearly observe that the proposed improvement significantly improves the network life span

The simulation analysis of this approach shows a significant improvement in the network life time & throughput of the network. The Figure 8 shows the Life Span of the network. From the graph we can clearly observe that the proposed improvement significantly improves the network life span.

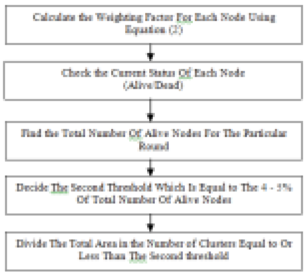

Figure 7 Flow Chart

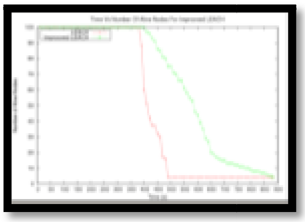

Figure 8 Comparison of LEACH & Proposed Improvement for Number of Alive Nodes/Round

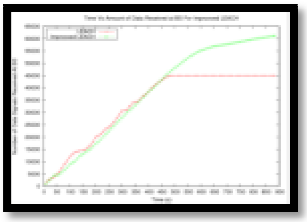

Figure 9 Comparison of LEACH & Proposed Improvement for Time VS Amount of Data Received at BS

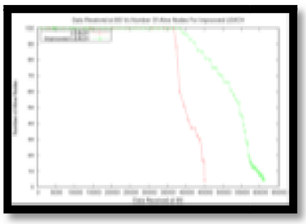

Figure 10 Comparison of LEACH & Proposed Improvement for Number Of Alive Nodes VS Amount of Data Received at BS

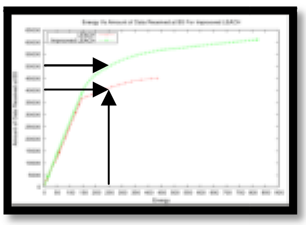

Figure 11 Comparison of LEACH & Proposed Improvement for Energy VS Amount of Data Received at BS

The Figure 9 shows the throughput analysis of the proposed improvement. From the graph we can clearly observe that the proposed improvement significantly improves the network throughput in terms of amount of data received at the BS significantly. From the above two analysis we can say that the network will be active for the long duration and so it will have the capability to communicate large amount of data compared to the conventional LEACH protocol.

Figure 11 shows the Energy Consumption of the network compared to the conventional LEACH. If we compare the above graph with the 200 J energy consumption point both the protocols provide almost same performance. This is the point where the conventional LEACH protocol the uneven energy consumption will take place and due to it the nodes will start dieing consecutively. The proposed improved LEACH will have even energy distribution even after this point also. So if we compare both at the 250 J energy consumption point the conventional LEACH have around 40000 B of data sent to the BS while at the same point the improved LEACH have around 50000 B of data sent to the BS. In short from this analysis we can conclude that the proposed augmented LEACH can send more amounts of data compared to the LEACH at same energy consumption level.

Figure 14 shows the graph between round number vs total amount of energy consumed for that round for total simulation. The figure clearly shows that improved LEACH consumes less energy compared to the original LEACH protocol.

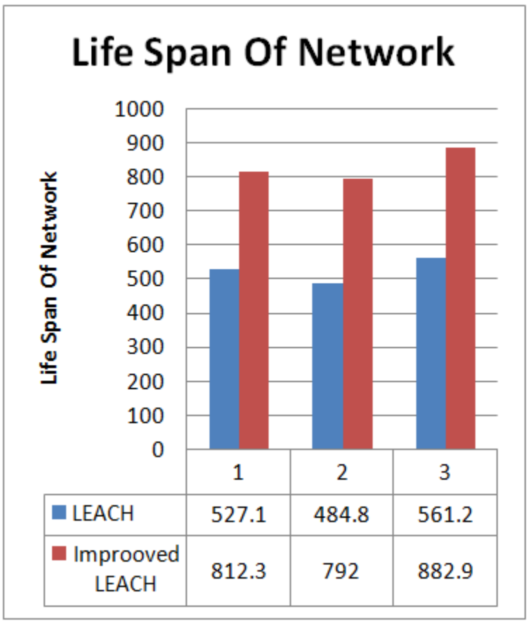

Figure 12 Comparison of Life Span Of Network for LEACH & Improved LEACH - Number Of Simulation

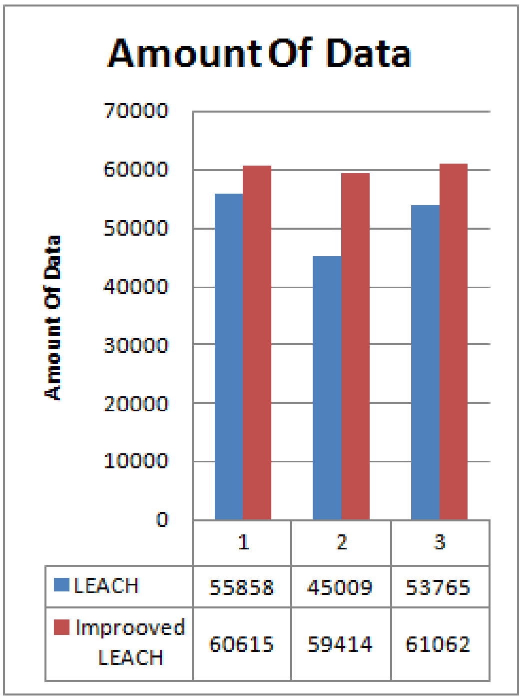

Figure 13 Comparison of Total Amount Of Data Received At BS for LEACH & Improoved - Number Of Simulation

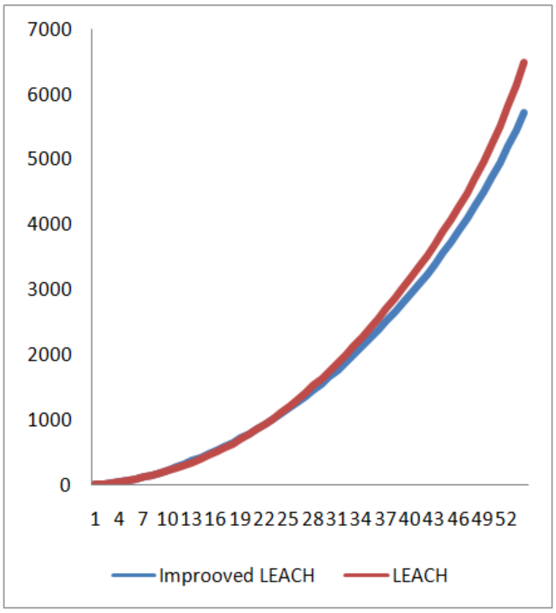

Figure 14 Comparison of Energy Consumption Per Round

5 Conclusion

The paper includes the overview about the WSNs. To improve performance of WSN, LEACH protocol is used. The drawbacks of LEACH are significantly improved in this approach. The Energy Efficient Clustering approach improves the life span of the network and throughput of the network significantly. The Energy comparison graph clearly signifies the reduction in Energy consumption.

6 Acknowledgment

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