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Various Energy Efficient Routing Protocols for Wireless Sensor Networks

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Abstract*: With the latest technological advancement wireless sensor network are developing more efficiently at faster rate and in present days it become the core of communication technology. Wireless sensor networks (WSNs) enables the reliable monitoring the remote areas. These WSNs are composed of sensor nodes which are powered by batteries, to communicate with each other for environmental monitoring. Efficient energy utilization is the main issue for WSN. Thus to increase the lifetime of the network various energy routing protocols are developed. In this paper we discuss about various routing protocols for efficiently utilizing the energy of the sensor nodes in the WSNs.

Key Words*: Communication Technology, Energy Efficiency, EEDA, LEACH, NLEACH, Routing Protocols, SEP, Wireless Sensor Networks (WSNs).

I. INTRODUCTION

With ongoing technological developments in communication technologies, WSNs are increasing significantly. This area of WSNs includes immense range of applications (for example environmental monitoring, medical monitoring, military security, industrial monitoring and diagnostics, infrastructure protection). The WSNs constitute a large amount of sensor nodes together to the necessary location (work environment) to supervise the region. Wireless device networks typically consist of many sensor nodes that need to be regulated, as well as the BS. The challenging task in WSNs to efficiently transmitting the data sensed to the BS. Clustering methods could also be used to transmit information efficiently and increase the network's lifetime.

The sensor nodes in WSNs are split into different narrower groups in the clustering method and one of the sensor nodes acts as CH among each lower group. The CH gathers, consolidates and s sends the information at the other sensor nodes to the BS. Those little nodes are driven by the battery. Although they have a tiny battery because of their lower size.

The adequate use of the battery is therefore essential to improve the lifespan of the entire network. The proper utilization of the battery i.e., networks lifetime can be done by selection proper energy efficient routing protocol for these WSNs. Few of the routing protocols are LEACH routing protocol, SEP routing protocol, N-LEACH routing protocol, EEDA routing protocol. Figure 1 shows the basic structure of WSN.

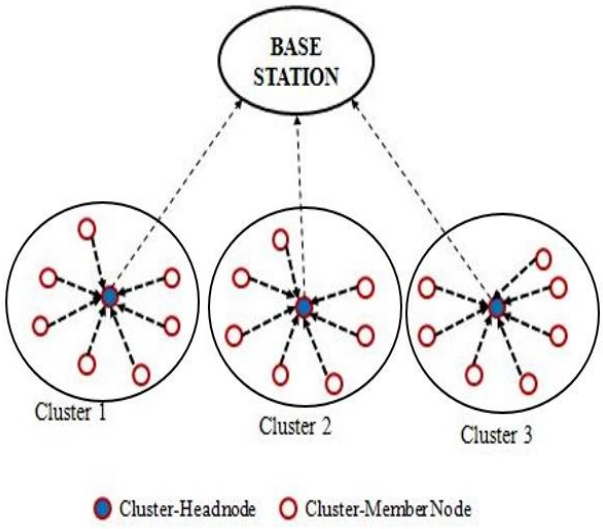

Figure 1: Basic structure of WSN.

II. RADIO ENERGY DISSIPATION MODEL

In WSN while communicating the sensor nodes dissipates some energy on transmitting or receiving the data. This energy dissipation on transmitting/ receiving the data can be easily understood by the radio model. Figure 2 shows the radio energy dissipation model. It comprises of a block of transmitter and receiver. The transmitter dissipates energy in this radio model to operate electronic transmission and transmit amplifier whereas the receiver disintegrates energy to operate receive electronics.

Thus to transmit k-bit message to distance d the radio energy used up is:

$$E_{Tx}(k,d) = E_{Tx\text{-}elec}(k) + E_{Tx\text{-}amp}(k,d)$$
$$E_{Tx}(k,d) = E_{elec}*k+\varepsilon_{amp}*k*d^2 \quad (1)$$

And to receive k-message the radio energy used up is:

$$E_{Rx}(k,d) = E_{Tx\text{-}elec}(k)$$
$$E_{Rx}(k,d)=E_{elec}*k \quad (2)$$

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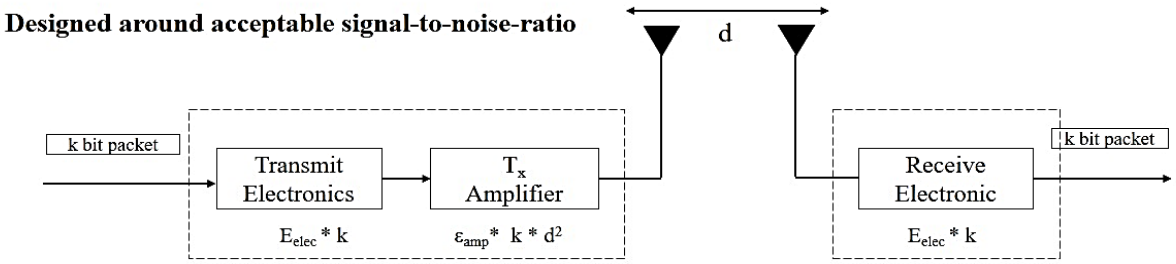

Figure 2: Radio energy dissipation model

III. ENERGY EFFICIENT ROUTING PROTOCOLS

Energy efficient routing is a method to form cluster with the fixed number of nodes from all the sensor nodes randomly placed in the network. Every cluster have their own local BS (sometimes also known as CH). In a cluster the nodes collects the data from the deployed area and send it to the local BS where this local BS (CH) receive the data from the sensor nodes, aggregates it and send it to the BS. All this process needs energy and the sensor nodes are small battery powered so main perspective to use energy efficient routing protocol is to minimizing the energy expenditure since the replacement of battery is nearly impossible as the sensors are deployed in remote areas. Many of them are designed to minimize this energy consumption. And a few of them are:

A. Low Energy Adaptive Hierarchy (LEACH)

Low Energy Adaptive Hierarchy (LEACH) is consists of homogenous nodal network, it means that all nodes in the network have same initial energy. LEACH uses randomize rotation adaptive clustering method to increase lifetime of the network. The cluster forms using LEACH protocol are totally random in each round. In LEACH in the initially every sensor node can become CH with probability p_{opt}. This choice is produced at the start of each round by selecting a random number in [0 1] separately by each node S∈ G. When that random number is lower than that of the T(s) limit then in the present round the node will become the CH. The threshold is set as:

$$T(s)=\begin{cases} \frac{p_{opt}}{1-p_{opt}(r \bmod \frac{1}{p_{opt}})} & if\ s \in G \\ 0 & otherwise \end{cases} \quad (3)$$

Where,

r→current round number
p→desired percentage of CH
G→Set of nodes that have not been elected for the last (1/p) rounds

Note: Here one round means all sensor nodes sends the data to their CH once. LEACH operation is splits up into rounds where each rounds consist of setup phase and steady state phase[2].

1. Set-up phase

In setup phase the clusters are organized. Initially few of the sensor nodes elects themselves are CH (CH) based on optimal threshold T(n). Then these CH sends an advertisement message saying they are CH for the current round to each of the sensor nodes in the WSNs. The non-CH nodes receives the advertisement message, and the nodes which are nearer to that CH sends the joining request. Then the CH sends the message that it the CH of those cluster member in the cluster upon which the cluster member sends the acknowledgement to their CH. And thus Clusters are formed. This process only occur in the first round after that based up the residual energy the CHs are elected i.e., sensor nodes having more energy left out will become the CH in the next round and such that each time random clusters are formed based on the energy level[2].

2. Steady-state phase

Data transfer to the BS takes place in a steady state stage. The clusters will be created and CH will be identified. The CH then generates a TDMA timeline by which the transmission of the information for the sensor nodes is chosen. Data transmission takes place with assistance of this activity oriented TDMA timetable. The sensor nodes turns on only when any event occurs otherwise the sensor nodes sleeps. Large amounts of energy are redeemed thru this technique as the sensor nodes just transmit the information when necessary. The CH will always be prepared to receive. The CH collects and combines the cluster member's data, which is then aggregated and then sent to the BS[2]

B. Stable Election Protocol (SEP)

Unlike the LEACH routing protocol which is meant for homogeneous network, the Stable Election Protocol is meant for heterogeneous network. The heterogeneous network consists of a few sensor nodes 'm' in WSNs which have *α*-times more energy than the rest of the sensor nodes. These 'm' sensor nodes are called as advance sensor nodes while the remaining other sensor nodes are called normal nodes[3].

The period from the initialization to the 1st node's demise is called the period of stability period. While the period from death of first node till the death of the last nodes is called the instability period. WSNs having high stability period are better and have high lifetime of the network. Since after the death of the first node the network becomes unstable. LEACH with homogenous network have high stability period and low instability period. LEACH with heterogeneous network have very low stability period then the instability period. Which concludes that LEACH is more suitable for homogenous network. Hence SEP protocol is used in case of heterogeneity aware WSNs. SEP expands the heterogeneous network's stabilization area and therefore reduces the instability region. This improves the reaction quality of heterogeneous sensor nodes.

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C. N-LEACH

In the LEACH routing protocol the clusters are randomly formed. Due to which each time random CH is being elected and random number of cluster member are there in each cluster. There will be uneven energy utilization in each clusters, in some it is high which some have low energy consumption because of this uneven cluster member in the clusters. The CH with more members in the cluster would consume more energy compared to CH having fewer members in the cluster, thus spending more energy. Thus, energy balancing is the proper use of the sensor network's power consumption.

The N-LEACH protocol gives the sensor nodes in WSNs a far more balanced use of energy. With such a algorithm, only the nodes endorsed for clustering are regarded. For this algorithm, the CH choice is made by following way:

Initially, G is set to be -1 for all nodes when the data transmission begins. After each (n / k) round, unless the sensor node has energy $E > 0$ and $G < 0$ & fulfills T_n, only sensor nodes are eligible to be CH otherwise. The sensor nodes would then be CHs selecting the T_n limit around 0 and 1. When the sensor nodes become CHs, they endorse the nodes no. of N. And if this N is higher than the $N_{average}$ (which is equal to n / k), then heavy energy losses occur and if N is lower than the $N_{average}$, then this node saves some energy compared to other sensor nodes. With that for the next rounds, when the CH sensor nodes in a cluster accept more nodes, it will never be able to be CH for a few rounds until it produces less than the average N nodes. N-LEACH protocol has now been created in which sensor nodes can only spend N energy on average in each (n / k) round[4].

D. Energy Efficient Clustering and Data Aggregation

A modern data communication and CH election technique is suggested in the EECDA protocol to improve the network's lifespan and stable duration. It would be chosen for data communication after the choice of CH route with elevated residual energy rather than the route with less residual energy. So the CH masses the data at first then transmits it to the BS. In EECDA protocol first the 'n' sensors are deployed in the square field, all the sensor nodes and BS are immobile after deployment. It forms the heterogeneity aware network in terms of node energy. CHs performs the data aggregation. BS is not energy limited compared to other sensor network. This approach contains four phases[5].

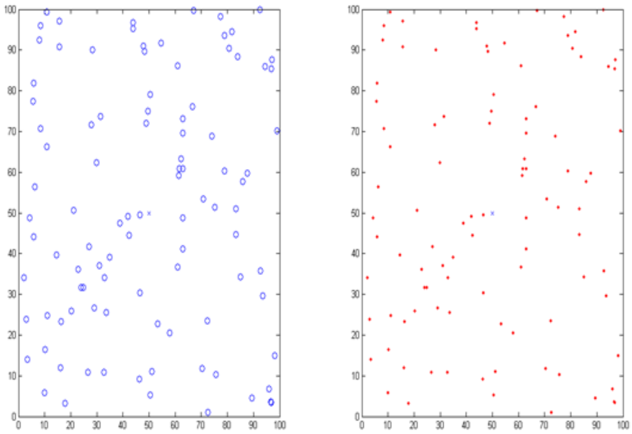
1. Finding optimal number of clusters.
2. CH election,
3. Route selection and
4. Data communication.

The ideal number of clusters is chosen by selecting suitable CHs for the WSNs each CH informs all other sensor nodes that this is the CH of the designated cluster and that is acknowledged by the cluster member. The route is chosen that needed minimal energy dissipation. The elevated residual energy path is suitable for data communication. The information gathered by non-CH nodes is transmitted to the CH while the CH masses and compresses the info and then sends it to the BS

IV. IMPLEMENTATION OF PROTOCOLS

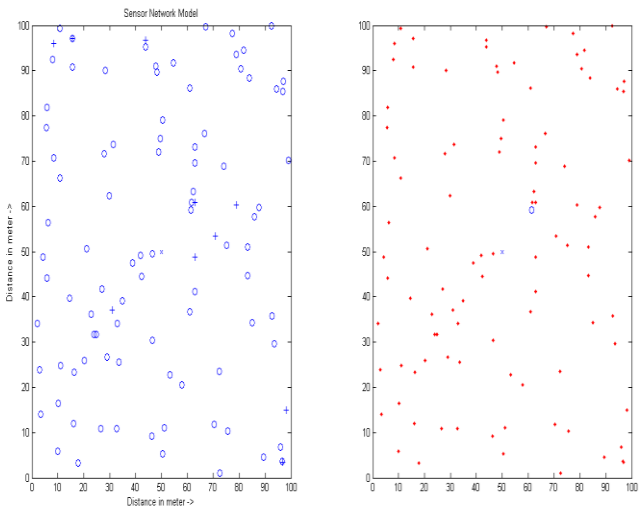
To evaluate and compare the performance of various energy efficient routing protocols we performed simulation of LEACH, SEP, N-LEACH and EECDA protocols on MATLAB simulator with the following scenario:

- The area of WSNs field is (100 x 100) m^2,
- Total 100 nodes are randomly deployed,
- The BS of the sensor network is located at the center of the WSNs (i.e., at x=50, y=50),
- Initial energy node =0.5J,
- Transmit and receive electronics is $E_{Tx} = E_{Rx} =$ 50nJ/bit.
- The Transmit amplifier = ε_{fs}=10pJ/bit/m^2; ε_{mp}=0.013pJ/bit/m^2,
- Data aggregation energy = E_{DA}=5nJ/bit.
- Total number of rounds for simulation = 500
- Each node have 20000bits/s of data packet to send to the BS.



(a) (b)

Figure 3: WSN having 100 nodes randomly deployed to form homogenous network (a) when all nodes were alive, (b) When all nodes are dead.



(a) (b)

Figure 4: WSN having 100 nodes randomly deployed to form heterogeneous network: (a) when all nodes were alive, (b) when all nodes are dead. Here 'o' shows the normal node while '+' shows advanced nodes.

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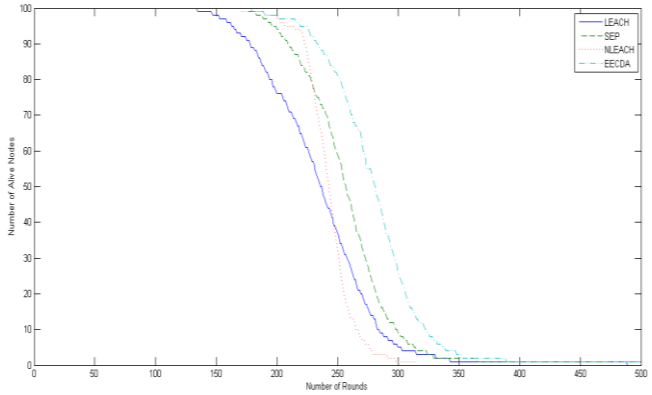

Figure 5: Number of alive node vs number of rounds for various energy efficient routing protocols.

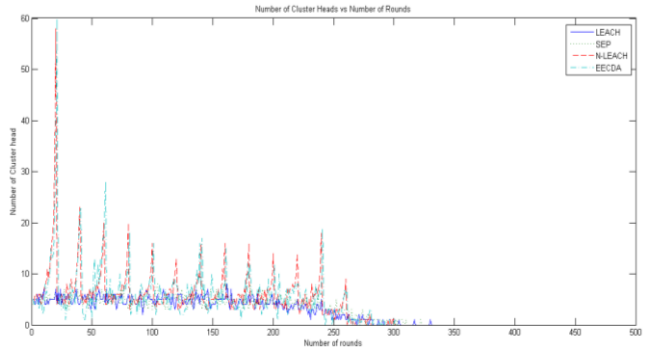

Figure 6: Number of CHs vs. Number of rounds for various energy efficient routing protocol

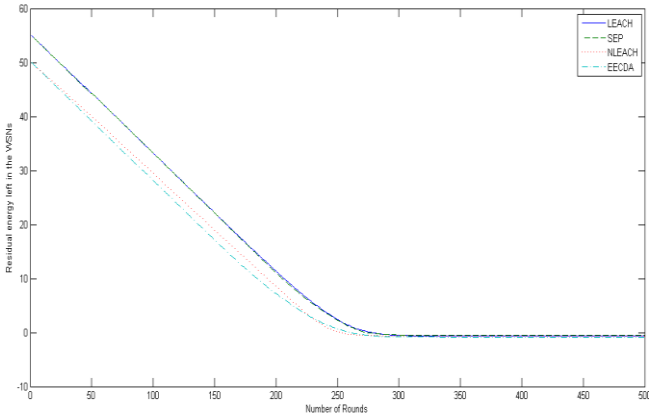

Figure 7: Residual energy vs number of energy of various energy efficient routing protocols.

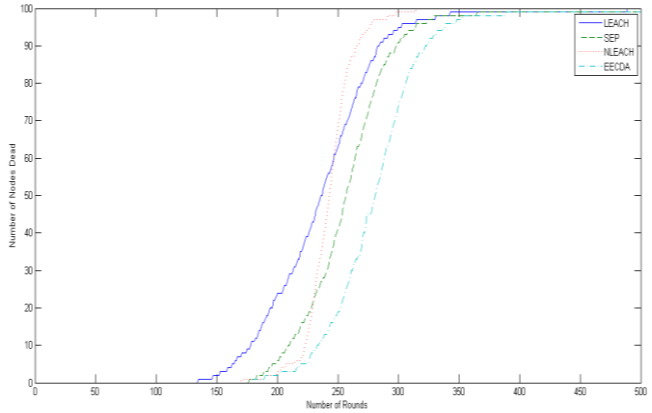

Figure 8: Number of nodes dead versus number of rounds

The figure 4 depicts the number node alive in the network with respect to number of rounds. While the figure 5 number of CHs in every round for LEACH, SEP, NLEACH and EECDA protocols. Figure 6 shows the residual energy left out for these protocols and Figure 7 shows the death of the sensor nodes with respect to the number of rounds simulated. It is clear from these figure that EECDA is much stable then the other protocols for the WSN. The NLEACH provides more balanced CH selection method for these such network.

The first node of dies at 134th round with LEACH, protocol 170th round with NLEACH protocol, 176th round with SEP protocol and 179th round for EECDA routing protocol. Which give us the overview that heterogeneous network provides large stability period compared to homogeneous network. The 50% of the network is dead at 235th round with LEACH and at 242nd round with NLEACH protocol, at 256th round with EECDA routing protocol.

V. CONCLUSION

From the above simulation result we conclude that stability and lifetime are the main part of the WSNs. EECDA protocols provides the large stability period than the other energy efficient routing protocol. N-LEACH gives more balanced utilization of energy. EECDA is 5.02% more efficient compared to NLEACH, 1.67% more efficient than SEP protocol while EECDA is many time more efficient than LEACH protocol. And since data transmission and reception of large data need data to be compressed and aggregate,

which is done by EECDA protocol, and it also improves the network performance with use of heterogeneity aware network.

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