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Comparative Study of LEACH, N-LEACH and SEP Routing Protocols for Wireless Sensor Networks

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***Abstract*— With the recent technological advancements, wireless sensor networks are emerging as the main fabric for communication technology. Networking altogether hundreds or thousands and low-cost microsensor nodes grants the user to precisely supervise inaccessible environment. The lifetime of the sensor network is greatly prioritized, which can be achieved with the help of routing protocols. Routing protocols provide us the transmission path which is the main cause for energy consumption. This research work shows the comparative study of LEACH, N-LEACH, and SEP routing protocols of WSNs.**

Keywords*— *Power Consumption, LEACH(Low Energy Adaptive Clustering Hierarchy), N-LEACH, Network Lifetime, SEP(Stable Election Protocol), WSN (Wireless Sensor Network).

I. INTRODUCTION

WSNs are developing at a quicker rate with the present technological advancements in sensor technology. Wireless Sensor Networks consists of small, lightweight, approximately inexpensive, low-power sensors well-known as microsensors. These microsensors nodes are able to sense the environment and provide an adequate result with greater accuracy. The WSNs are generally spread out in remote areas for a various range of application like habitat monitoring, climate monitoring, seismic abnormalities, security supervision and a lot of scientific applications. In most cases, the sensor nodes are randomly spread out with finite power. The choice of appropriate routing protocol is an important task to deliver the collected data from its origin to destination point.

So principal approach for using clustering routing protocol is to minimize the energy consumption by the sensor nodes as the battery replacement of the microsensor nodes is generally impractical. Routing in WSNs requires a detailed self-examination than classical wireless networks, due to many restraints in thevdeployment of sensor nodes (for example storage capacity and energy efficiency). WSNs handles a large quantity of data, handling such large data of sensors deployed in an area causes this network to suffer performance problems. And the energy processing means of this network suffers extremely. Moreover, there are many protocols designed to rectify all the defects in such WSNs. Among those protocols are LEACH, N-LEACH (New-LEACH) and SEP.

II. LEACH PROTOCOL

The first ever cluster based routing protocol developed for WSNs was LEACH [1]. It is auto-organizing, robust clustering protocol. It uses randomize rotation to circulate energy load equally. In LEACH, few sensor node announces themselves as CHs at a provided time with bound likelihood. These cluster head (CH) announce their position to the other sensors within the n/w. By selecting CH that requires min. energy for communication as their CH, every node selects the cluster they want to belong.

When all the nodes are grouped into a cluster. Each CH designs a timetable for nodes in its cluster, which allows the radio elements of every non-cluster head node to be turned off for all the time until its time for data transmission comes, thus minimizing the energy dissipated within the individual sensors. Then the CH collect and aggregate all the data obtained from nodes and transmits it to the BS.

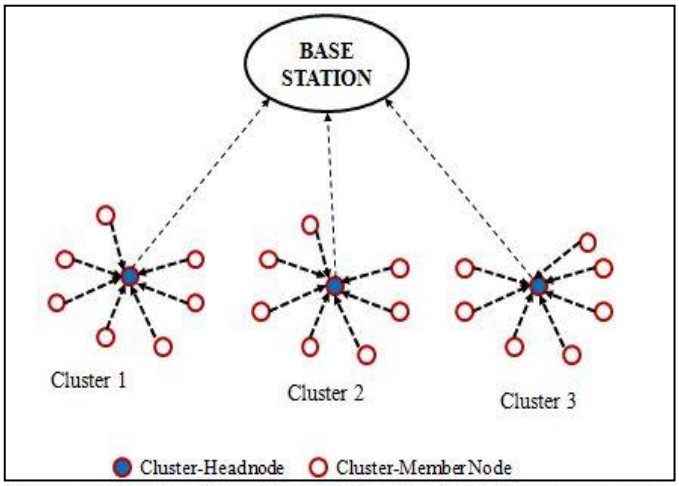

Figure 1. Cluster head selection and data aggregation in LEACH clustering routing protocol for Wireless Sensor Network.

As becoming the CH uses more energy than the non-CH sensor nodes, so to proper utilizing energy consumption of the nodes throughout the network CH sensor nodes shouldn't be fixed, it shouldn't be same for next rounds [1]. Therefore, a set S of node nominate themselves CHs for time't', however at time 't_1+t' a new set S' of nodes nominate themselves as CHs. This judgment to turn into CH depends upon the energy left in the sensor node.

There are two types of phases in LEACH routing protocol [2]:

a) Set-up
b) Steady-state

Working of LEACH routing protocol splits in many rounds, these rounds have two phases in each round. LEACH is a self-organizing clustering routing protocol which mainly aims for reducing the energy usage by the sensor network.

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A. Set-up phase

It begins when the clusters are organized. The main aim of this phase is to build a cluster and choose the CH by selecting the node with the max. energy. Following are the three steps involved in this phase:

1. Cluster head advertisement
2. Cluster set up
3. Schedule Creation

Where to be CH or not for the first round is decided by the nodes initially before the clusters are being created. Every node nominates itself a CH for the current round on the basis of the formula:

$$T(n) = \begin{cases} \dfrac{P}{1 - P * (r \bmod \frac{1}{P})} & if\ n \epsilon G \\ 0 & otherwise \end{cases} \quad (1)$$

Where,

T(n)→ threshold
P → desired percentage of CH
G → set of node that have not been cluster head for last (1/p) rounds

When the number '*n*' is less than T(n), then for this round the node become CH. Once a node is chosen to become the CH, it couldn't become CH for the next round until all node becomes the CH for at least one time. This is generally useful for energy balancing. Then the node in the clusters sends an advertisement message (announcing it is the CH for the current round), all the non-CH nodes receive this advertisement and sends the joining request to CH telling them that they are the members of that CH in that cluster. Depending upon received signal strength of advertisement message this decision of being cluster member is taken. A lot of energy is saved by the non-CHs by turning off their transmitter all the time except for the designated time slot for data transmission.

Then the every chosen CH prepare a schedule for nodes member and after deciding the number of nodes in the cluster TDMA lineup is generated. Then every node follows this lineup and transmits only in the allotted time.

B. Steady-state phase

It begins when data transfer to the BS happens. After the creation of the cluster, TDMA schedule is established, data transmission starts [2]. Considering node always have data to send, each node sends the data in their allocated time interval which utilizes a minimal amount of energy of the nodes. The radio of non-CH could be turned off until the allocating time interval, while the radio of cluster should always be turned on to receive all data their member nodes. Then cluster head combines all the collected data, performs the signal processing function to compress the data and then forwards it to the base station.

C. PROS AND CONS [5]

1. CH combines the complete data.
2. Power consumption is minimized due to single hop routing from sensor nodes to the CH.
3. System lifetime of the wireless sensor network increases.
4. Irregular enrgy distribution due to the randomly defined clusters.
5. Network used is homogenous.
6. No. of cluster are not optimized.

III. SEP PROTOCOL

In the classical approach of clustering, the routing protocols are randomly distributed and are static, base station coordinates and sensor field dimensions are known. When the first node dies the nature of such network become unstable, specifically in the presence of heterogeneity sensor nodes. In classical method it's expected that all sensor nodes begins with an equal amount of energy, hence they can't utilize the full gain of heterogeneity sensor nodes

Georgios Smaragdakis, Ibrahim Matta and Azer Bestavros in the paper [3] suggested stable Election protocol (i.e. SEP) for heterogeneous conscious clustering to increase the time interval before the first node dies. SEP is built on the estimated probabilities of every sensor node to be cluster head depending upon the energy left out in every sensor node. In SEP protocol it is proposed that *m*-sensor nodes of the total '*n*' number of nodes have *α*- times more energy than the other sensor nodes. These 'm' sensor nodes (nodes having more energy) are referred as advanced nodes while other '1-m' nodes referred to as normal nodes.

LEACH confirms that the stable region would be larger than the unstable region in the homogeneous network. And when the first sensor node dies, remaining other sensor nodes are anticipated to die within next few rounds, due to well uniform energy distribution. LEACH produces enormous unstable region in presence node heterogeneity[3]. due to unstable CH selection process, which in heterogeneity in WSNs contains all the normal nodes with equal energy despite of having advanced sensor nodes, due to which nearly all the time no CH is elected and the advanced sensor nodes are ineffective (doesn't do anything).

Therefore a new heterogeneous aware routing protocol (SEP) has introduced, whose objective is to extend the stable region and accordingly reduce the unstable region and also enhancing the quality of response of WSNs being heterogeneity sensor nodes [3].

IV. N-LEACH PROTOCOL

N-LEACH is proposed by Rajiv Kr Tripathi, Yatindra Nath Singh and Nishchal K. Verma in there paper [4], which is also referred as New-LEACH clustering protocol. N-LEACH is proposed to provide energy balancing for WSNs.

In classical LEACH protocol, sensor nodes are randomly distributed and the CHs are automatically selected (as few nodes choose themselves as the CH in first round). And there is an unknown number of CH selected (since they are randomly selected), so sometimes the WSNs have less number of cluster heads while sometimes have more number of cluster head. This increases (sometimes decreases) the burden on the particular CH, if the number of CHs selected are less (or more) than the optimal number of CH. Since the number of CHs are fixed and sensor nodes choose the CHs with closest distance for the data transmission so amount of supported node may varies from cluster head to cluster head. Which in turn introduces uneven load circulation among the sensor nodes in the WSNs.

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N-LEACH algorithm balances this energy consumption and significantly increases the system lifetime upon comparing with LEAC algorithm.

First protocol used for energy balancing was LEACH, even though it has some drawbacks which are[4]:

- In cluster head selection process the residual energy not considered.
- The likelihood of being cluster head of any sensor nodes is according to expectation that all sensor nodes have same energy, which isn't there for heterogeneity nodes.
- Because of random selection in LEACH the cluster head number is not fixed. And each cluster head uneven number of sensor nodes members which causes uneven energy dissipation.

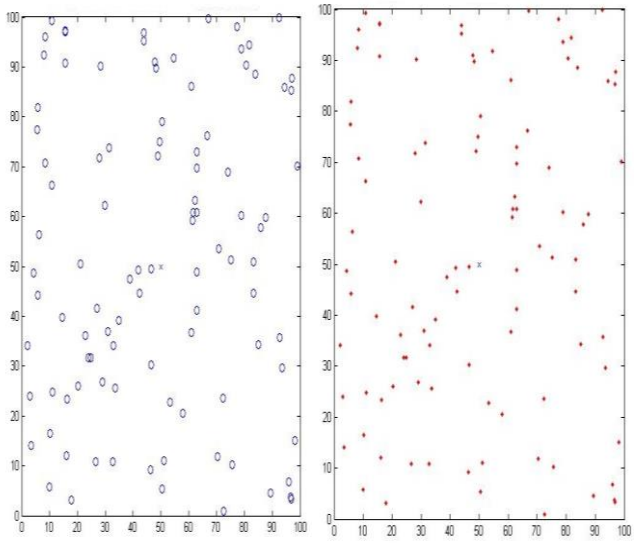
The N-LEACH protocol yields even more balanced energy utilization by the sensor nodes in wireless sensor networks. It uses a rule where only the number of supported nodes for clustering is considered. In this cluster head selection algorithm is as follows:

In the beginning when the data transmission starts for the first round G is fixed to be -1 for all the nodes. Then epoch operation is carryout after each (n/k) rounds, if the sensor node is having energy E > 0 and G < 0 & satisfies T_n (required threshold) then the nodes are eligible to be cluster head otherwise not. Then the sensor nodes will be cluster heads picking threshold T_n in between 0and 1. When the sensor nodes turn into cluster heads, they support N no. of nodes. And if this N is greater than the average of N (which is equals to n/k) then high energy loses occurs and if N is smaller than the average of N then a bit of energy is saved with this node compared to other sensor nodes. With this for the next rounds if the cluster head sensor nodes supports more number of nodes in a cluster, it will not be able to become cluster head for few rounds unless if it supports less than the average of N nodes. And hence N-LEACH protocol was developed where sensor nodes can only be able to spend average of N energy in each (n/k) rounds.

V. OUTCOMES OF THE WORK

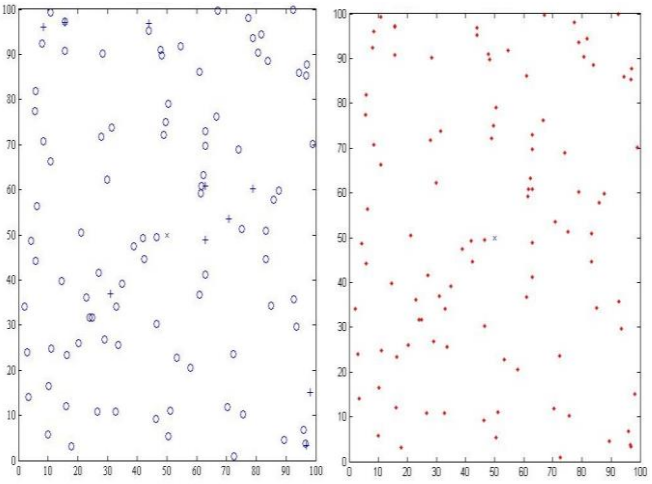
To appraise and analyse the efficiency of LEACH, SEP and N-LEACH routing protocol for clustering in the WSNs, we have simulated these protocols using MATLAB with following parameters taken into consideration. A WSN field is considered of dimension 100m x100m. Total number of sensor in the network field are n=100. The base station is fixed and at the centre of the WSN field. These 100 nodes are randomly distributed, and each one of them have same initial energy (0.5J) in case of LEACH and N-LEACH, while in SEP protocol advance node and normal nodes with different energy are considered. We have taken 20000bits/packet data and simulated it for 500 rounds.

The wireless sensor network for LEACH, N-LEACH and SEP is as shown below:



(a) (b)

Figure 2: Wireless sensor network for LEACH and N-LEACH, (a) when all nodes were alive, (b) When all nodes are dead.



(a) (b)

Figure 3: Wireless sensor networks for SEP with normal nodes and showing with 'o' and '+' respectively, (a) when all nodes were alive, (b) when all nodes are dead.

Figure 4 shows that NLEACH have more stabilized cluster head selection then LEACH and SEP for the most of the time so clustering could be sustained for longer period.

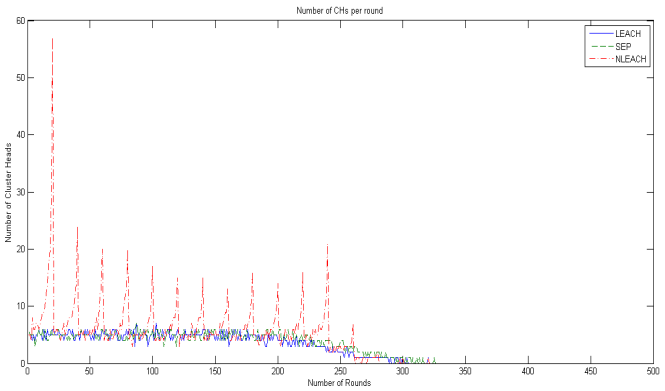


Figure 4: Number of CHs per rounds for LEACH, SEP and NLEACH

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We simulated LEACH, SEP and N-LEACH for 500 rounds with 20000bits data package each round. The life of the following is shown below in figure 5.

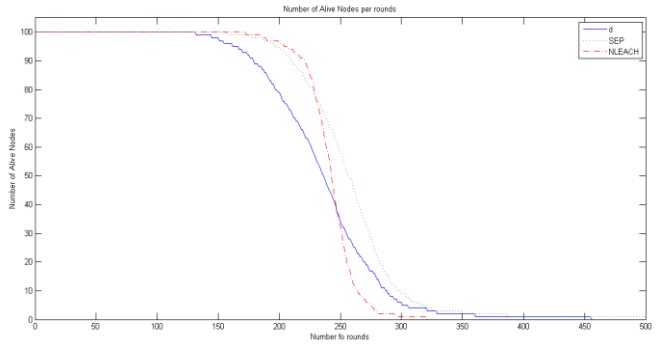

Figure 5: Comparison between LEACH, SEP and N-LEACH, for number of alive nodes per each rounds.

It is observed that SEP protocol allows mores sensor nodes to be alive for more number of rounds than the LEACH while it is more balanced in N-LEACH due to even number of clusters through rounds.

Here figure 6 shows the percentage of nodes dead for LEACH, SEP and N-LEACH for each rounds. The simulation results that the death period of first node sensor nodes with SEP protocol for is longer than the N-LEACH and LEACH protocols while sensor nodes following N-LEACH protocol is more stabilize for higher number of rounds.

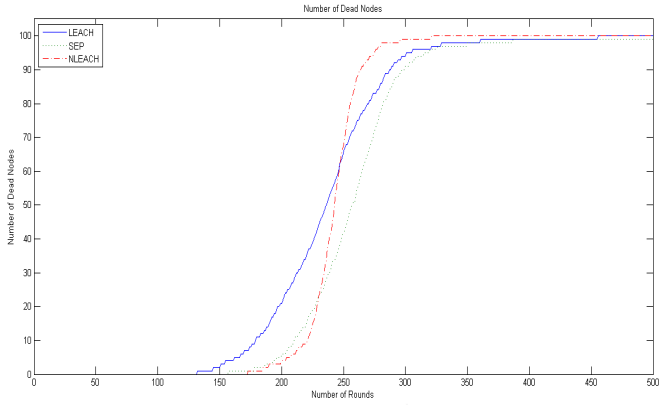

Figure 6: Comparison of LEACH, SEP and N-LEACH showing percentage of dead nodes with respect to number of rounds.

TABLE I
LIFETIME OF NODES

Death of Node	1%	50%	90%
LEACH	132	236	287
SEP	152	257	297
N-LEACH	173	243	264

In table I it is shown that sensor nodes with LEACH protocol dies much earlier than the SEP and N-LEACH protocols following sensor nodes. And also N-LEACH have longer lifetime than the other two clustering protocols.

The gain in percentage for the NLEACH in comparison with LEACH clustering protocol when the first node die is

$$gain\ (in\ \%) = \frac{(173 - 132) * 100}{173} = 23.69$$

Gain in percentage for NLEACH in comparison with SEP clustering protocol when the first node die is

$$gain\ (in\ \%) = \frac{(173 - 152) * 100}{173} = 12.13$$

Gain in percentage for SEP in comparison with LEACH clustering protocol when 90% nodes of the sensor network dies is

$$gain\ (in\ \%) = \frac{(297 - 287) * 100}{297} = 03.36$$

Gain in percentage for SEP in comparison with LEACH clustering protocol when ninety percent nodes of the sensor network dies is

$$gain\ (in\ \%) = \frac{(297 - 264) * 100}{297} = 11.11$$

VI. CONCLUSION

The comparative study of three LEACH, SEP and N-LEACH clustering protocol is being done. With the help of simulation done in MATLAB, it is shown that when 1% nodes of the WSN are dead NLEACH is 23.69% and 12.12% more efficient than LEACH and SEP respectively. While when 90% nodes of the WSN are dead SEP is 3.36% and 11.11% more efficient than LEACH and NLEACH respectively. So N-LEACH have larger stability period than other two protocol are more unstable. Also SEP protocol provides longer network lifetime due to its heterogenetic nature, SEP's advance nodes provides the network to be alive for longer time.

VII. REFRENCES

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