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Smart Clustering LEACH (SC-LEACH) Protocol for Improved Network Survivability in Wireless Sensor Networks

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Abstract*: *Wireless Sensor Networks (WSN) are becoming increasingly popular by the virtue of its diversified applications. Nevertheless WSN faces various research challenges despite its ease of implementation. One of the major issues of concern is the energy efficiency which is closely related to the lifetime of the network. Low-Energy Adaptive Clustering Hierarchy (LEACH) is proven to be an efficient way to route packets in WSNs. However the performance of the LEACH can be further enhanced by lessening the frequency of cluster reformation. In this paper we propose a novel Smart Clustering LEACH (SC-LEACH) protocol which is an advancement over the traditional LEACH protocol. The results of the proposed algorithm were validated through simulations.

Index Terms*: *Adaptive Clustering, Threshold, Smart Clustering, Alive Nodes.

I. INTRODUCTION

WSNs have become an integral part of the modern communication era. Since its inception, it has become increasingly popular due to its suitability in different applications. Unlike a wired network, WSNs lack the infrastructural support. Also for some applications, WSNs are deployed in hostile areas where replacing or recharging the batteries would become infeasible. Thus the algorithms used in WSNs have to be energy efficient.

There are ample number of works being carried out in this area and many energy aware protocols are developed for WSNs. LEACH is one of the finest algorithms that is best suited for WSN applications. LEACH being a clustering approach assures a better network availability. However the algorithm could be further improved if the cluster formation frequency is reduced. In LEACH, if one of the Cluster Heads (CH) drains out its energy during communication, the process of cluster reformation would be initiated. However if another eligible node in the same cluster is made to take over the CH, we can avoid many control packet exchanges which not only saves the energy but also reduces the routing delay. In this paper, we propose a novel SC-LEACH algorithm which modifies the existing LEACH protocol during the cluster reformation process. Initially SC-LEACH works same as that of LEACH. The improvement in the energy efficiency can be appreciated once the CH's energy goes below threshold.

The rest of the paper is organized as follows: Section II highlights the principle of clustering hierarchy in WSNs. Section III details the traditional LEACH protocol for WSNs. Section IV gives an insight into the novel SC-LEACH protocol proposed. Section V presents simulation results and analysis and finally section VI concludes the paper.

II. CLUSTERING HIERARCHY

Routing in WSNs can take place in two different ways. One is the flat routing wherein the packets are routed in multi-hop fashion and the other is the clustering approach where a group of nodes form a cluster with one of the nodes being the CH. All nodes in the cluster communicate to CH and the CH in turn conveys the information to the Base Station (BS). It is seen from the literature that the cluster based routing protocols assure better energy efficiency in comparison with the flat routing protocols. The most vital piece of bunching strategies is that the whole system is separated into little gatherings called Clusters. Every cluster has its own CH which handles the responsibility of transferring sensed data from the member node to the BS and also advocates and controls the member nodes. The process of clustering is shown in Figure 1. Usage of clustering topology plays a very significant role in reducing the energy consumption of WSN.

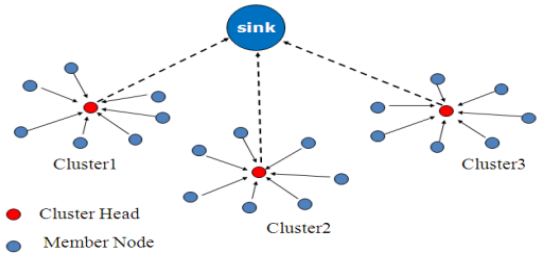

Fig1: Typical Cluster structure of WSN

There are many challenges that arise during the process of designing clustering mechanism. It very important, to concentrate on the fast growing technology and increasing number of sensor nodes in a network. We should concentrate on making an efficient network, which is feasible with alterations made during updates. One of the very important elements in clustering is to group a bunch of nodes together to establish a cluster. Each of the clusters will communicate with the sink (BS) through a node elected to be the CH.

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One node out of the nodes in a cluster is elected to be the CH for a specific cycle.

The CH handles the operations like, data aggregation, data processing and transmission. In any cluster, all nodes collect the data from the real time environment and transfer the same to the CH and the CH will have the responsibility to aggregate the collected data and transmit the same to the sink or the BS. As the CH is assigned with additional responsibilities along with the normal operations of the normal nodes, they consume more energy compared to other nodes in the cluster.

The effectiveness clustering depends on multiple parameters. A few of them are addressed below:

Number of Clusters: This is decided depending on the total number of nodes in a network. Sometimes the position of nodes are also considered to decide the number of clusters for any network.

Cluster size: Cluster size is almost uniform amongst all clusters. However it depends on the positions of the nodes.

Routing: Type of the routing influences the network performance. Generally the communication from the cluster members to the CH is direct. Whereas direct or multi-hop routing can be used for the transmission between the CH and the BS. Multi-hop routing is proved to be more energy efficient.

Maximum energy is consumed during the data transmission, thus planning for a proper routing strategy will increase the efficiency of the overall network. But, the energy is mostly wasted during the process of selection of CHs in a network. Higher consumption of energy will in turn reduces the overall operation time for that specific node. To assure an extended lifetime of the overall network, it is very important to manage the responsibilities between nodes in any cluster. LEACH is proven to be one of the most efficient clustering based protocols. There is signified methodology to form clusters and elect a CH. The Section III details the working principle of LEACH protocol.

Table 1: Margin specifications

Margin	*A4 Paper*	US Letter Paper
Left	18.5 mm	14.5 mm (0.58 in)
Right	18mm	13 mm (0.51 in)

III. LEACH PROTOCOL

LEACH is an extremely famous versatile clustering approach. LEACH protocol is a typical representation of hierarchical routing protocol. LEACH upgrades energy efficiency of the framework by forming clusters in light of signal strength received. There are principles of grouping and selection of random CHs to improve the life span of resource constrained sensor networks. LEACH protocol is a TDMA based MAC protocol. The principal aim of this protocol is to improve the lifespan of WSNs by lowering the energy consumption required to create and maintain CH. The operation of LEACH protocol consists of several rounds with two phases in each: Set-up Phase and Steady Phase.

All the nodes having energy greater than a specified threshold value and have not been served as a CH in previous 'K' rounds will become eligible to be selected as a CH of a specific cluster. The CH is selected using a random function, and each node is likely to get an opportunity to be the CH at least once in the overall network performance. A node which was selected to be the CH in the previous 'K" rounds cannot be selected again as CH in the current round. The CHs collect data from its cluster members, aggregate the information and the fused data is then conveyed to the BS. These additional operations being performed by the CH will account for the additional energy drain and hence CHs lose energy quicker than other nodes in the cluster. If a CH dies sooner than the expected time or within the specified time of a round, then the whole cluster will not work and the cluster fails to communicate with the BS. The process of it is shown in Figure 2.

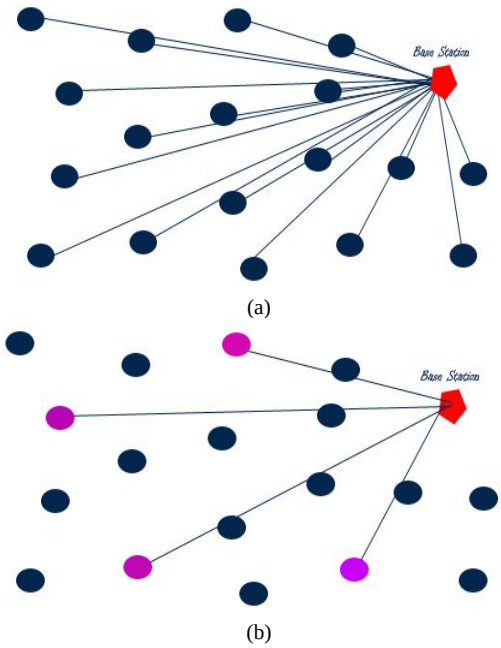

Figure 2: (a) Sensor Nodes Communicating their Energy to Base Station and (b) Election of Cluster Head by BS

LEACH is proved to be one of the most efficient protocols for WSNs. There are many advantages in LEACH when compared to many of the clustering protocol, but the process of random selection of CH poses some disadvantages. Random selection of CH is proved to be inefficient in terms of energy and may causes network failure. This paper presents a new protocol SC-LEACH wherein the CH selection is designed to be dependent on energy. Transfer of the responsibility of CH between nodes in a cluster will in turn improve the efficiency of any cluster.

IV. ENERGY ORIENTED NEW CH SELECTION FOR LEACH

It has been analysed from the LEACH protocol that the re-election process of the CHs consumes more energy as the entire process has to be carried out by the BS and thus requiring more packet exchanges. Also as the LEACH follows time dependent CH re-election process, the process may not assure energy efficiency. This paper aims at proposing a new protocol that can offer a lesser CH re-election process. In the proposed algorithm the re-selection of the CHs is done only for those CHs whose energy goes below the threshold set. The nodes can continue to be the CHs as long as it's energy is beyond the set threshold.

This can certainly reduce the packet exchanges amongst nodes and thus assuring better energy efficiency.

We have introduced the concept of re-election of CH on the basis of energy of the CH. In LEACH the process of CH selection and re-election happens in random with respect to time (specifically random selection of CH with scheduled time). The initial stage of election of CH is done based on the energy available with each node. Initially, all nodes are expected to have 100% energy and the proposed algorithm follows the normal LEACH algorithm. However, the re-election of the CH does not happen on any specific/random time, instead it happens only when the energy of any of the CH goes below the specified threshold energy. New CHs are selected based on the residual energy of the other nodes in the cluster. The node with highest energy will be elected to be CH on priority basis. Elected CH will have to take care of reforming the clusters and finding the new route.

New CH will be selected in the following steps: Firstly, once residual energy of the current CH goes below the specified or threshold energy level, the CH intimates the same to the BS. The BS then initiates energy request packet to all the nodes of the specific cluster. Secondly, nodes with the highest energy and above the specified threshold energy will be elected to be the new CH. The new CH, will re-initiates the process of forming a new cluster. The network topology of the improved algorithm is shown in Figure 3.

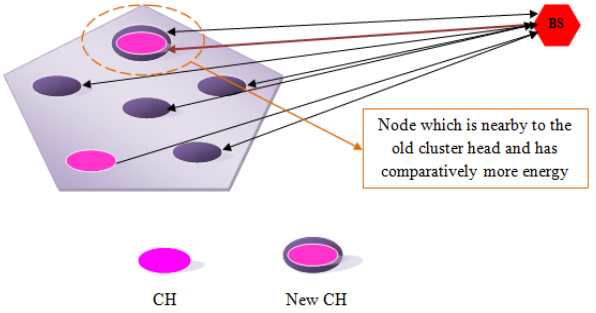

Figure 3: Re-election of New Cluster Head for a cluster by Base Station

The new CH recreates the new cluster, by inviting all the nearby nodes. In this process, nodes already being the members of other clusters do not respond to this request. Thus, only the free nodes join the new CH and form a new cluster. During this process, nodes which are beyond the transmission range of the new CH may not receive the invitation and thus may not be able to join the new cluster. Such nodes do wait for some predefined period and declare themselves as a CH and starts communicating with the BS. Once any node declares itself as a new CH then it again starts the process of formation of a cluster. By this way, no node is left alone or out of a cluster, and every-node will have a cluster to communicate. This idea can be better appreciated if the network is mostly static.

The next section gives a comparative analysis of the proposed protocol with the traditional LEACH.

V. SIMULATION RESULTS AND ANALYSIS

The proposed algorithm was developed and the performance of the same was compared with the traditional LEACH. Table I shows the simulation parameters used for the study.

Table I: Common Parameters considered for simulations of LEACH and SC-LEACH

Parameter	Specifications
Simulating Environment	NS2
Number of Nodes	100
Antenna Type	Omni-Directional
Deployment of Nodes	Static
Simulation Time	300 Sec
Initial Energy of the Nodes	2 Joules
Mobility Pattern	Nil

The proposed SC-LEACH is compared with traditional LEACH in terms of total energy consumed. The figure 4 shows the result of the comparison. It is seen from the graph that both algorithms exhibit sudden peaks in the energy consumption. These peaks are corresponding to the CH nodes. However it can be observed from the plot that overall energy consumed by nodes is less in the proposed algorithm. The performance would vary depending on the value of the energy threshold set.

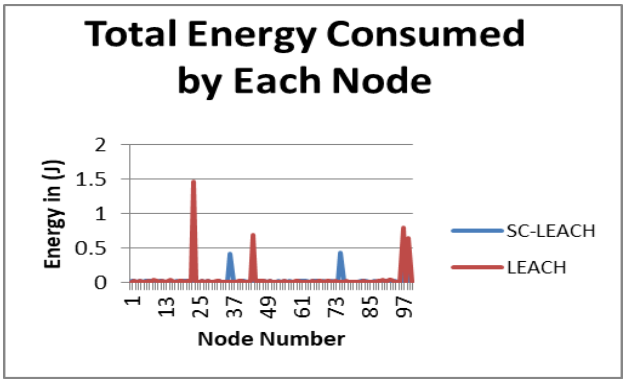

Figure 4: Comparison of Energy Consumption of Nodes after Stipulated Simulation Time

Considering a span of one round, energy consumed by all nodes is considered and the same is plotted with respect to the performance of LEACH in figure 5. It was found by dividing the total energy consumed by each node by the number of rounds the node being actively participating the data transmissions. The comparison shows the efficiency of the proposed algorithm, as there are very limited communications for the reformations of clusters and CHs.

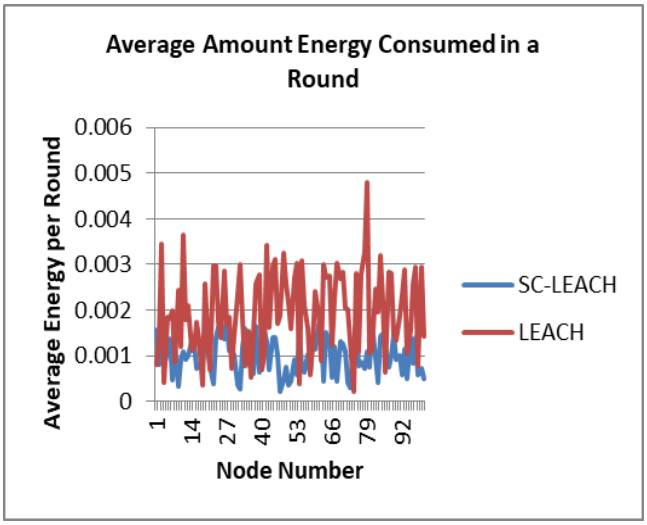

Figure 5: Comparison of Average Energy Consumption in one round

The overall energy consumption as a function of simulation time has been plotted in Figure 6. It can be seen from the graph that the SC-LEACH algorithm has proven to be consuming less energy for the overall network operation. The performance of the proposed algorithm can be further appreciated for longer simulation time as the chances of reforming of clusters increase with the increased simulation time.

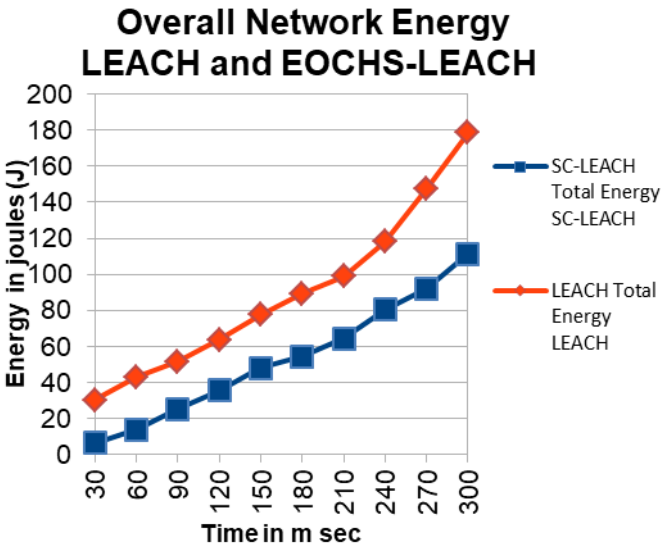

Figure 6: Comparison of Total Energy Consumed after the Stipulated Simulation Time

Total number of packets generated in both algorithms is depicted in figure 7. Traditional LEACH generates more packets than the proposed algorithm. This may due to the fact that the proposed algorithm works on the basis of the threshold and the reformation of the cluster becomes sooner compared to the case of traditional LEACH. Thus for a particular simulation time SC-LEACH generates lesser packets. Nevertheless this parameter is dependent on the threshold set.

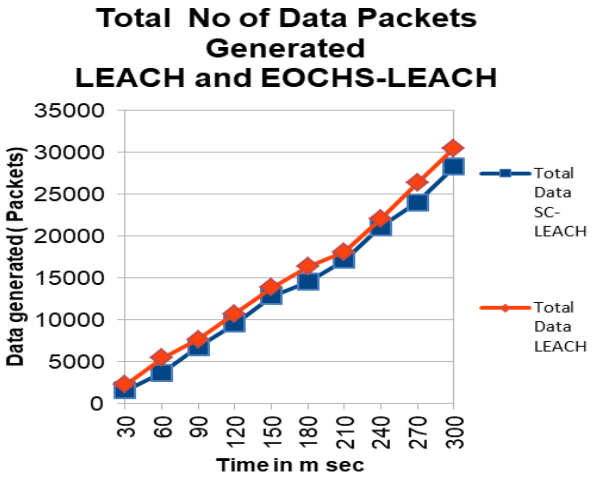

Figure 7: Comparison of Total Number of Data Packets generated/Transmitted

Nodes that are capable to serve as the intermediate nodes are termed as alive nodes. A plot of total number of alive nodes is presented in figure 8. Although the performance seems to be similar at the initial stages, the proposed SC-LEACH protocol outperforms LEACH for longer simulation times. This is because of the fact that SC-LEACH not only re-elects CH based on energy parameter but also lessens the packet exchanges during the cluster reformation phase. The proposed algorithm has all the nodes alive where as the traditional leach has come down to 82 alive nodes out of 100 after 300 sec of simulation.

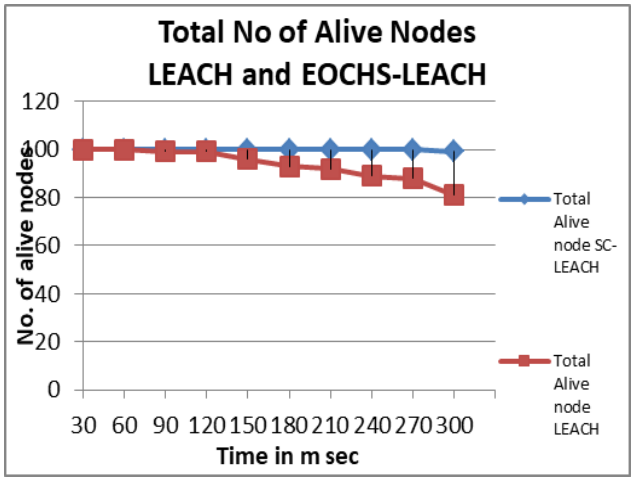

Figure 8: Comparison of Total Number of Alive Nodes after Simulation

VI. CONCLUSION

The paper has presented a novel approach to improvise the traditional LEACH protocol so as to assure increased network lifetime. The advantage of the proposed SC-LEACH protocol is two-fold. Firstly it avoids CH nodes to become dead nodes by relieving them from additional responsibility as soon as their energy goes below threshold. Secondly the process of cluster reformation is made partially distributed so that other clusters are not affected by the process. The proposed algorithm is compared with the LEACH protocol and the results have showed that the SC-LEACH outperforms LEACH in terms of energy consumption. SC-LEACH can be further improved by making the complete process of cluster reformation handled within the cluster itself. The CH can elect its successor and the same can be intimated to the other members of the cluster. This would certainly save time and energy consumed during the cluster reformation process.

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