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A mathematical optimization of the lifetime of the wireless sensor network using ML- based energy dependent clustering and tiered routing algorithm

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Abstract

Significant research work is being done in the field of WSN and standardization of many aspects is being looked into. The most well-known procedures for optimising energy in WSNs are using hierarchical topology. LEACH is a hierarchical topology which was introduced initially and served as the basis for achieving energy efficiency in WSN. However, LEACH has certain limitations which has led to a lot of research in improving the conventional LEACH performance. The current study is based on the use of certain algorithms and strategy to enhance the performance of the conventional LEACH protocol. By

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focusing on parameters such as cluster head formation, energy expenditure in transmission etc., the performance such as throughput and network life may be extended using this enhanced LEACH.

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1. Introduction

Routing protocol defines the rules which enable the path selection for travel of the data from sensor node to sink. The routing protocol of WSN faces huge challenges. To begin with, WSN network resources are few in terms of availability, processing capacity, and bandwidth. IP routing cannot be utilized in WSNs since changing IP addresses might cause significant cost in large or complicated WSNs. Further, owing to lack of resources, it is difficult to handle frequent changes in topology, especially in a mobile set-up [1]. WSN applications in general, do not allow for multicast or peer-to-peer communication between several multi-source communication devices. End to end data transmissions in WSN applications should happen within a given amount of time. However, many a times, saving of energy is more important than other performance parameters because all sensor nodes have limited energy, which eventually determines the network life [2]. Figure 1 depicts the basic categorization of Routing used in a WSN system.

Network Structure based categorization: There are three broad categories in which the network layout in WSN may be categorized: Flat, hierarchical & location based. In a flat routing topology, the activities and functions of all sensor nodes are similar. Hence, all nodes acting as routers are each other's peers without any organization or segmentation

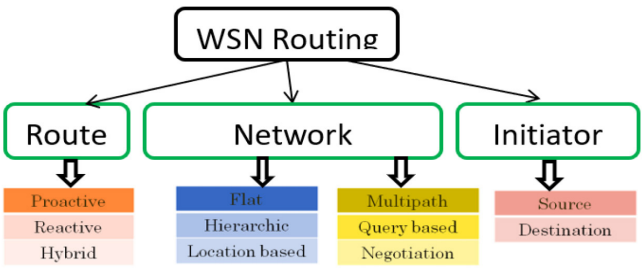

Figure 1

Classification of WSN Routing Protocol

structure between them. Flooding is generally used by these protocols to push the data from the nodes to sink. Flat routing protocols, are fairly effective in small scale networks [3]. Typical limitations of flat routing protocols include scalability, mobility, data aggregation, energy efficiency, multipath, overhead, and QoS. Typical Examples of Flat routing protocol include flooding and Gossiping, SPIN, Rumor Routing (RR), energy-aware routing (EAR) & Directed diffusion (DD) etc. In hierarchical WSNs, nodes execute diverse jobs in a hierarchical architecture and are typically organized into several clusters based on different criteria or measures. Clustering in routing has a number of advantages like it is scalable, saves energy by data aggregation and compression and is robust. Some examples of clustering protocols are Low Energetic Adaptive Clustering (LEACH), Distributed Energy Efficient Clustering, Hybrid Energy Efficiency Distributed (HEED) etc. Location based Routing helps build up a scalable network without increasing the burden of signaling overhead since all the routing decisions are localized internally through location information instead of requirement of global topology information. Positioning device like GPS is generally used for identifying the location. Some popular Location based protocols include GPSR & LAR [4].

1.1 *Overview of LEACH*

LEACH is a hierarchical clustering protocol which aims to reduce power consumption and enhance network life. The network is segmented in clusters, each with atleast one cluster head (CH) node. The CH is entrusted with the responsibility of aggregating and forwarding the data which it receives from the sensor nodes. LEACH thus banks an aggregation technique at the level of the cluster head which collates and compresses the data from individual sensor nodes into meaningful information which is finally passed onto the base station. Due to the complexity of action at the cluster-head node, resource requirement of the CH is relatively greater than the ordinary node. In case the cluster head dies, the ordinary nodes within the cluster are not able to communicate their data. LEACH works on dynamic random rotation of the cluster-head, which distributes the energy drain uniformly between the sensor nodes [5]. Operation of LEACH is thus split into rounds of specified length. There are primarily two phases in each round viz. (i) a set-up phase in which cluster formation happens, followed by Cluster Head (CH) advertisement and finally the creation of transmission schedule (ii) a steady state phase wherein data is transmitted by sensor nodes, which is aggregated and compressed at

the cluster head and then transmitted to the sink. LEACH is a single hop protocol which means that it is based on the assumption that the radio of each node has adequate power to communicate with the base station. However, energy loss would be very high in such a case [6]. Nodes which have served as a cluster head are restricted from becoming CH again till next P rounds. Subsequently, each node has a $1/P$ probability to become CH in the ensuing rounds. The TDMA schedule established by a CH defines the time at which the node can transmit its information. This helps to avoid the collision within a cluster. The nodes other than cluster heads communicate as per the time schedule. These nodes do no need to keep their radios on for the whole time except for their scheduled time slot.

2. Related Works

In [4] a network is divided into several layers with different coverage area. For balancing consumption of energy, the inner & outer diameter of a layer is calculated. The cluster heads are chosen as per the energy available with the nodes in the layer. In PEGASIS [7] the random cluster formation overhead is eliminated and it also aims to reduce the distance of communication of ordinary nodes, reduces the number of transactions of the nodes. The work illustrates a clustering protocol where the coverage is of the cluster is predefined prior to the Cluster Head selection activity The LEACH protocol is important since it introduced the concept of data fusion. Primarily, three demerits may be attributed to LEACH. One is that there is no clarity on the number of CHs in network. Then, in case of death of CH due to some reason, the cluster will be of no use because no data of cluster nodes will reach the sink. Finally, due to the distributed and random spread of the cluster Head, this sometimes result in the increase in energy consumption which can affect the entire network's performance. Today, large number of protocols have been developed based on LEACH, with most common objective of energy saving and data fusion. The authors in [8] propose a balanced 2-tier LEACH algorithm which enhances the life of the network by routing the aggregated data through an intermediate node which reduces the energy dissipation at the cluster head. TEEN [9] is a reactive protocol which works on thresholds and is quick to respond to changes in various parameters. In [10] the authors introduce a method of CH selection where the distance between the potential CHs is computed and compared to a threshold. If the distance does not exceed the threshold value, the candidate is selected as cluster head LEACH [11], are prominent techniques of WSN. CH election was introduced in LEACH, and DEEC

and SEP further improved it. In SEP weighted probability is used for CH selection. DEEC (Distributed Energy Efficient Clustering) attempts to ascertain the network lifetime so that energy drain of each node may be computed in each round. In [12] the authors have illustrated TSEP which uses heterogeneity of three levels to enhance SEP. This protocol has two level heterogeneity. DEEC protocol was modified by bringing in improvement in throughput and network stability.

3. Proposed Methodology

The proposed work is for enhancement of the LEACH protocol and is also applicable to other protocols where the cluster selection is randomized. The entire proposal is based primarily on two techniques aimed at enhancing the network lifetime and throughput. The first technique revolves round the cluster head replacement mechanism after a given round. Unlike the conventional LEACH protocol, in the Enhanced LEACH technique, the Cluster Head replacement / selection is not carried out blindly for all the CHs. Instead, the balance energy of each CH node after a round is compared to a threshold value. If the balance energy of a node exceeds the threshold value, the node is allowed to continue as CH for the subsequent round too. The positive aspect of adopting this practice is that energy is saved in cluster head replacement process after each round while the node is capable of serving as CH. Moreover, in order to be sure that the energy requirement for the cluster-member nodes is not high, the proposed methodology also aims to distribute the Cluster Heads uniformly in the network, such that CH are not concentrated in any part of the network. In conventional LEACH, the CH may concentrate in a certain area, and all the nodes may not find a cluster head within a close range. Hence, the idea is to divide the whole area into regularly shaped blocks to fill the whole coverage area of WSN. In each block, the LEACH algorithm is run to select a Cluster head in each block. This makes sure that the cluster head is within a very short distance from the nodes. The second technique is focused at the energy expenditure in the data transmission process. In a cluster-based network, typically, there are three types of transmission viz. (a) Intra cluster communication from the ordinary node to the CH (b) Inter Cluster communication between CHs (c) Communication between CH and Base Station Obviously, the energy needed in Intra cluster transmission would be practically quite less than the energy required for Inter cluster transmission.

4. Result Analysis

In this work, the simulation of proposed Enhanced LEACH is done using MATLAB by setting certain parameters at the beginning. Simulation is done till all nodes are dead. The system is simulated with 100 nodes. The Enhanced LEACH makes sure that the Cluster Heads are allowed to continue to serve as Cluster Heads till their energy dips below a threshold. Moreover, the algorithm also aims to uniformly distribute the cluster Heads in the network so that the cluster members do not have to consume large energy to communicate with the cluster Heads. (1) Network Life Time: In Enhanced LEACH higher stability period is achieved by modifying the algorithm of replacement of cluster head and also using differentiated transmission power level for intra and inter-cluster communication. Figure 2 indicates that the life of the network increases in enhanced LEACH vis a vis conventional LEACH as is evident from the number of alive and dead nodes during comparative number of rounds. Figure 3 indicates the network topology comparison (alive and dead nodes) for conventional LEACH and Enhanced Leach for given number of rounds. It is evident from the topology depiction as furnished in Figure 3 that the death of nodes in the Basic LEACH is much rapid as compared to the Enhanced LEACH**.** Throughput is a good measure of the routing protocol efficiency. Higher number of packets reaching base station is indicative of the efficiency of routing protocol. The throughput comparison shown in Figure 4 highlights the efficiency of the Enhanced LEACH over Conventional LEACH.

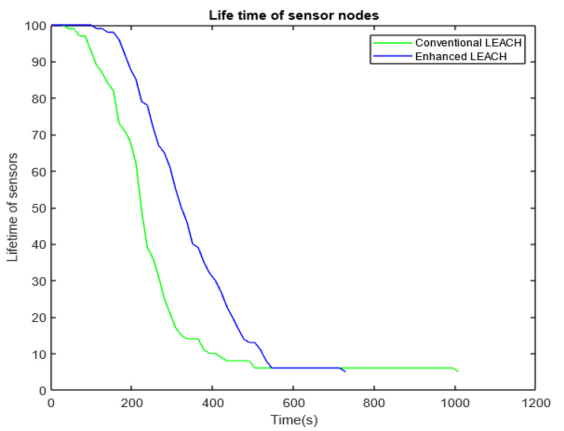

Figure 2

Comparison of Lifetime of Sensor Nodes

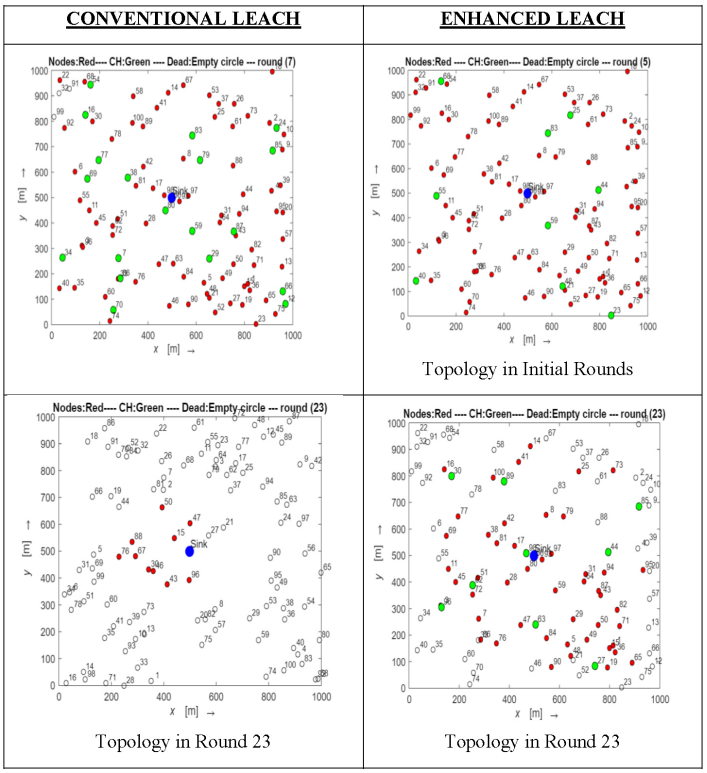

Figure 3

Network topology comparison in initial rounds and middle rounds

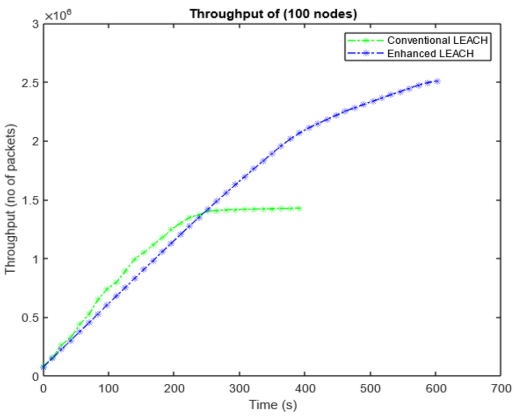

Figure 4

Comparative of throughput

5. Conclusion

The major limitation in WSN is Battery capacity and hence energy saving is the primary objective in WSN to make the network operate for a longer period. In this work, Energy efficiency is attempted by obviating the need of Cluster Head replacement every time and also uniform distribution of clusters. Moreover, the tiered approach in simulation by considering difference in energy expenditure of the of the intra-cluster and inter-cluster transmissions also saves energy. There is thus a significant rise in energy of nodes thus contributing to network lifetime enhancement and better efficiency.

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