DOI : https://doi.org/10.56452/7-2-544

ISSN: 0974-5823 Vol. 7 No. 2 February, 2022

International Journal of Mechanical Engineering

Selecting Cluster Heads Efficiently Using a Genetic Algorithm for the LEACH Wireless Sensor Network Protocol

Mukesh Joshi

Associate Professor, School of Computing, Graphic Era Hill University,
Dehradun, Uttarakhand India 248002,

Abstract:

Information is gathered via a Wireless Sensor Network (WSN) that is placed in unpredictable and remote locations. The biggest problems with WSN are on its security, service quality, and energy usage. Clustering is used to reduce the excessive energy usage in these networks. Network cluster heads are selected using the Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol. The energy use and distance to the base station are used to determine the cluster head. Cluster Head (CH) is the node with the most available power and the shortest path back to the home node. In this study, the cluster heads are chosen using a genetic algorithm in conjunction with the LEACH methodology. The aforementioned project is accomplished in MATLAB. The proposed LEACH procedure is evaluated against the outcomes of the current LEACH protocol. The energy consumption of the suggested method is lower than that of the competing methods, as shown by the comparative analysis and the attained results.

Keywords: LEACH, Clustering, Genetic Algorithm, Cluster Head

Introduction

To keep tabs on what's happening in the neighbourhood, a network has been set up. Multiple sensor nodes are deployed across the monitored area to gather data. The term "wireless sensor network" (WSN) is used to describe this system. The sensor nodes are more compact, and the work is done with the power available. Important data is gathered, analysed, and sent to users in response to changes in the environment. The data processing and computation capacity of such a network is low. Small computers called "motes" are spread across the network to act as data collectors [1]. These networks have the characteristics of being both energy-efficient and multifunctional. Several commercial uses for mote technology exist. They are useful for gathering data in pursuit of certain application goals. The motes establish connections in various configurations to achieve optimal performance.

The motes employ transceivers as a means of communication. The number of sensor nodes in a WSN might range from the hundreds to the thousands. Ad hoc networks, in contrast to sensor networks, deploy a smaller fraction of the total possible number of sensor nodes since they lack support from a preexisting network infrastructure. WSNs have been used to aid in the development of new types of applications with enhanced monitoring capabilities [2]. Using sensing nodes, WSNs are able to monitor the environment, process the necessary data, and transmit and receive the processed data. Sensing units in sensor nodes gather key environmental characteristics and transmit them to processing nodes for analysis. The Analogue to Digital converter (ADC) is used to transform the analogue signals produced by sensors into digital form. The brain of the sensor node is its central processing unit. The processor aids in task execution and component functioning [3]. Processor energy consumption varies with the tasks performed by the nodes. In WSNs, energy consumption rates are the single most crucial metric to monitor. Conserving power in both hardware and software is crucial if you want your network to last as long as possible. Data transmission uses much more power than data sensing and processing combined [4].

Since the transmission power of the sensor nodes is restricted, only short-range communications are employed among the nodes. Most WSNs' sink nodes are located far away from the area of interest, therefore events are detected nearer to the region. As a result, we use short-range communication to enable multi-path data packet forwarding through intermediary nodes. Routing in wireless sensor networks differs significantly from routing in conventional networks. In the event of a node failure, the routing protocols stipulate stringent energy-saving requirements. Different routing techniques have been utilised by different researchers [5]..

There are several classifications used to organise routing protocols. In the case of location-based protocols, routing is determined by the physical locations of individual sensor nodes. The data from the sensor nodes is necessary for determining the distance between any two specific nodes. In contrast to other protocols, data centric protocols really do something useful: they get information from sensor nodes out to the central hub. Each sensor node in an address-centric network communicates with the base station independently over its own dedicated connection.

This multi-layered structure is the result of a hierarchical methodology. After the clusters are shrunken down to their constituent nodes, a cluster leader is chosen. Using a CH enables communication between clusters and between clusters and sinks or CHs [6]. Data transmission occurs between individual nodes, although the distances covered by the hoped-for data might be rather considerable. LEACH, short for Low-energy Adaptive Clustering Hierarchy, is a clustering method that uses very little power. This method reduces power consumption to a minimum [7].

An enhanced version of the LEACH protocol, Power-Efficient Gathering in Sensor Information Systems (PEGASIS) is available. This protocol determines the order in which sensor nodes send and receive data from one another. Only one of the nodes in the chain of generators is chosen by this protocol to send data to the sink [8]. The TEEN protocol, short for "threshold-sensitive energy-efficient sensor network protocol," organises sensor nodes into swarms. The "cluster head" is the central figure in any given cluster. The cluster's sensor nodes provide reports of their observations to the cluster's brain. Limiting energy consumption in battery-operated sensor nodes is a major challenge in Wireless Sensor Networks (WSN). As well as being an appealing solution for authoritative tasks, progressive bunching has shown promise as a means of reducing sensor energy consumption. Grouped WSNs have an easily manageable structure thanks to CHs that operate as proximate controllers of system operations. Clustering that maximises vitality uses jump distances to the data sink to determine manageable cluster sizes. EC regulates bunch sizes by adjusting the probability that a hub will become a CH, allowing for more or less uniform utilisation of a WSN's total energy resources. Propose an efficient energy multi-hop WSN data collection convention and calculate its energy consumption in order to evaluate EC's performance. The event organisers have made reducing flagging costs and power use top priorities. As a result, the proposed convention will allow EC to more effectively regulate vitality levels. However, EC is not restricted to a specific data-gathering protocol and may instead accommodate a wide variety of protocols for transferring gathered data to a central hub. Sensors reporting packets to nearby mobile sinks is essential for data collection.

Regardless, sink portability might result in unexpected changes to the system architecture, and increasing the number of sinks may introduce unacceptable burdens for course support. Thus, a WSN's performance is highly dependent on how the directing convention is crafted to increase system performance while minimising convention overhead brought on by the movability of sinks. Group-based approaches are often well-suited for monitoring applications that need such a constant flow of sensor input; guiding standards are linked to reduce the expense of transmitting an information bundle on time. The LEACH framework, for instance, is a multi-tiered, self-organized, group-based method. Time Division Multiple Access (TDMA) planning divides the region under observation into a number of clusters, with CHs collecting data from the associated portion hubs in their clusters. Once the buffer is full, any remaining data is discarded and sent as a packet to the receiving station or the sink. After a certain amount of time, CHs are selected through BS message.

Literature Review

Roja Guntuku et.al.,(2021) Standard IEEE 802.15.4 is widely used in WSNs and the IoT. The biggest problem with WSNs is that they drain batteries quickly. This research uses the MAX LEACH protocol to reduce energy usage and extend the life of a network. The proposed work is an implementation of the IEEE 802.15.4-based media access control routing on the "SENSEnuts" hardware platform. Testing of the MAX LEACH protocol on the SENSEnuts platform revealed a 50% increase in network lifespan compared to the standard LEACH protocol. The SENSEnuts are used to track environmental factors like temperature and brightness as the findings are evaluated in various settings.

K P Sampoornam et.al.,(2021) The Wireless Sensor Network (WSN) is particularly vulnerable to a wide variety of assaults because of its special characteristics, such as its limited battery power, dynamic topology, and constrained bandwidth. Over the last several years, there has been a rise in attention paid to studies of security in WSNs. The complex nature of network security is exacerbated by WSNs' decentralised and autonomous nature. The wormhole assault is a significant threat to the wireless sensor network. DoS attacks from malicious nodes are wormhole attacks, in which the attacker builds a tunnel through which packets are replayed for the attacker's benefit, thus blocking the communication channel and corrupting the network's routing. In order to optimise a network, this article discusses how to simulate the LEACH protocol by controlling the number of Cluster Heads (CHs) in a way that minimises energy loss and maximises the network's lifespan. In this work, we evaluate LEACH's resistance against wormhole attacks.

Rehab Sattar et.al.,(2020) Maintaining the necessary Quality of Service [QoS] during the deployment of wireless sensor networks is still a major difficulty due to the need to provide the sensor nodes with limited energy. Whereas, the WSN field is seen as a useful resource for a wide variety of applications, from industrial and environmental monitoring to military surveillance and TRAC control. Clustering is the foundation of several routing systems. This study will compare the two versions of the LEACH protocol in terms of its features, benefits, drawbacks, network longevity, and overall performance. The suggested study makes use of a hierarchical clustering procedure using LEACH (low energy adaptive clustering hierarchy). The second kind, multi-hop LEACH, is used in situations when the sink is located on the periphery of the monitored region or farther afield, and where a broad zone is necessary..

Li Tan et.al.,(2019) The topology of an AWSN (Aerial Wireless Sensor Network) alters in real time as an aircraft patrols the area, with individual sensor nodes sometimes straying from their home clusters and bringing about a breakdown in communications. This study presents an enhanced version of the LEACH-M protocol for use in Aerial sensor networks in order to facilitate reliable data exchange between nodes. The protocol is based on the already-existing LEACH-M protocol and the MCR protocol, both of which are enhancements on the original LEACH protocol. To guarantee the outlier node may find a new home quickly and easily, a practical approach is given. The experiments demonstrate that the enhanced LEACH-M protocol outperforms the classic LEACH-M and MCR protocols by maximising network lifespan, data transmission efficiency, and performance..

Dynamic Cluster Head Selection Algorithm

D-LEACH is a variant of the LEACH protocol that takes into account the remaining energy in the nodes before beginning the cluster head selection procedure. After the first iteration, the cluster heads are chosen based on a probability distribution across the set of nodes supplied (N), and the available residual energy in the cluster heads is compared to a threshold value.
D-LEACH is an algorithm that minimises energy loss throughout the network by limiting the number of cluster heads that are chosen.
Figure 1 depicts the Dynamic Cluster Head Selection Algorithm.

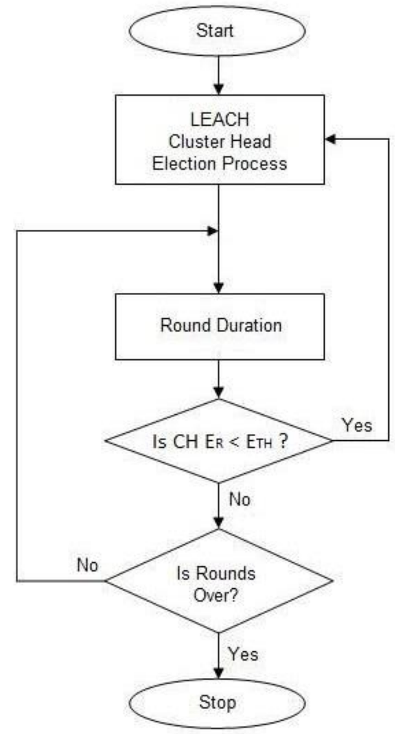

Figure 1 Dynamic Cluster Head Election Algorithm

Our modified EiP-based LEACH methodology is based on the ideas presented in the ICH-LEACH protocol. The foundation of the new algorithm is the EiP and the ICH-LEACH standard. Figure 1 depicts EiP-LEACH's cluster head election process. The suggested protocol is functionally analogous to the LEACH protocol. The suggested procedure differs significantly from LEACH in that it uses an energy-dependent metric for CH selection. The suggested strategy has each node ni produce a random number Ri (0 Ri 1).

The shift in how T(ni) is computed.If the current node's random number, Ri, is less than or equal to T(ni), then ni is designated as the CH node for the network, and the CH node sends out an ADV

DOI : https://doi.org/10.56452/7-2-544

message inviting other nodes to join the cluster. The goal of the ICH-LEACH protocol is to decrease energy consumption so that the network can run for longer and more data may be sent to the sink. We've also replicated LEACH's phase structure and cluster head count in our proposal. Sending data straight from the cluster-Head to the sink is the primary challenge of LEACH. As a result, a great deal of power is required for Data transmission. Furthermore, transmission is difficult and data is lost if the washbasin is too far away. Therefore, if the distance is great, an intermediate cluster-head is used to reduce the total amount of energy spent and sent in each cycle. An Updated LEACH Protocol That Relies on EiP: The LEACH protocol, based on the EIP, aids in selecting the best CH nodes, which in turn extends the life of the network. To extend the viability of the master cluster node and the network as a whole, the EiP LEACH protocol was extended to include a slave cluster head.

The Low Energy Adaptive Clustering Hierarchy (LEACH) protocol is an example of a routing protocol for WSNs. Cluster routing protocols typically consist of three phases: cluster head creation, cluster formation, and inter-cluster communication. So, LEACH algorithm likewise has these three phases, albeit it combines the first two—clustering and cluster communication—into a single operation.

Thus, the establishment of clusters and reliable data transmission are components of the LEACH protocol method. To ensure that the network's total energy is distributed fairly among all of its nodes, LEACH uses a mechanism based on equal probability to choose which nodes will serve as cluster leaders. As a result, the LEACH algorithm helps save power and extend the life of the network. LEACH's executive process occurs in cycles, which we refer to as "rounds." Within each cycle, clusters are created and data is sent. The steady data transmission phrase lasts significantly longer than the period needed for setup in order to preserve energy.

Network Simulator 2 (NS2) is used to run the simulation, using the following settings for the simulated network of 100 homogenous sensor nodes:

Table 1 Parameters considered for Simulation

Simulation Parameters	Value
Network Area	500x500 m^2
Total Simulation time	1000 Sec
Round Duration	10 Sec
Initial Energy in each node	0.1 J
Total Number of nodes	100
Probability of CH Selection	0.4
Threshold for E_R Comparison	0.4
Data Rate	1 Kbps

Experiments using a modified LEACH methodology, with the probability of cluster head selection varying from 0.1 to 0.5, are used to re-estimate the ideal number of cluster heads for the current situation, which was previously determined to be 5%. When the probability is low (say, 0.1), there are fewer cluster heads, and the nodes must send their data across a greater distance to reach the CH. Therefore, the first node death occurred rather quickly. Too many CHs were selected when the probability was set too high (for example, 0.5), leading to more work in CHs selection than was necessary before..

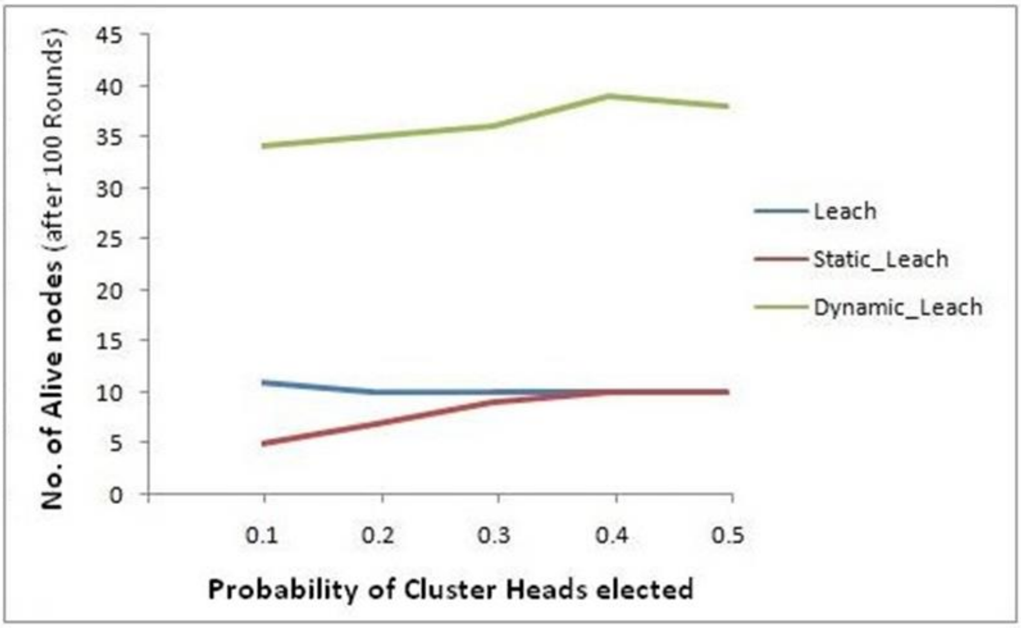

Figure 2 Comparison of Alive nodes in three protocols for various probabilities

Figure 2 shows that given a probability of 0.4, the number of surviving nodes after 100 cycles is greater than 1. Figure 3 shows a similar trend when comparing the three protocols based on the time it took for the first node to die.

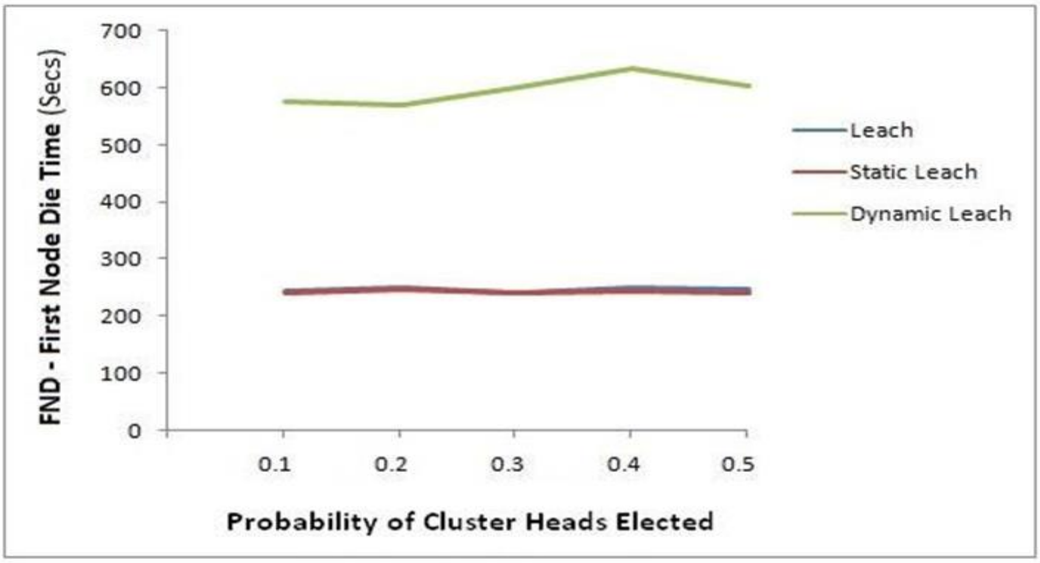

Figure 3 Comparison of First Node Die (FND) Time in threeprotocols for various probabilities

Thus, a probability of 0.4 is selected for cluster head selection, and additional experimentation is carried out to determine the best threshold value for comparing the cluster heads' residual energies.

According to the results of an experiment designed to estimate the threshold for residual energy in Cluster Head (ER), the number of CHs selected rapidly increased when the threshold was set at a high value (for example, 70% of the initial energy), resulting in more overhead during the CHs selection process. At the same time, the energy of the node operating as CH quickly reduced owing to intra and inter cluster communication when the threshold was set at low value (for example, 20% of starting energy). Therefore, we compare the residual energy of the sensor nodes at threshold values of 0.2 and 0.4 and conduct experiments to determine the best threshold value. Figures 4 and 5 contrast the D-LEACH protocol's threshold value of 0.2 with that of 0.4 in terms of the number of living nodes and the residual energy they leave behind.

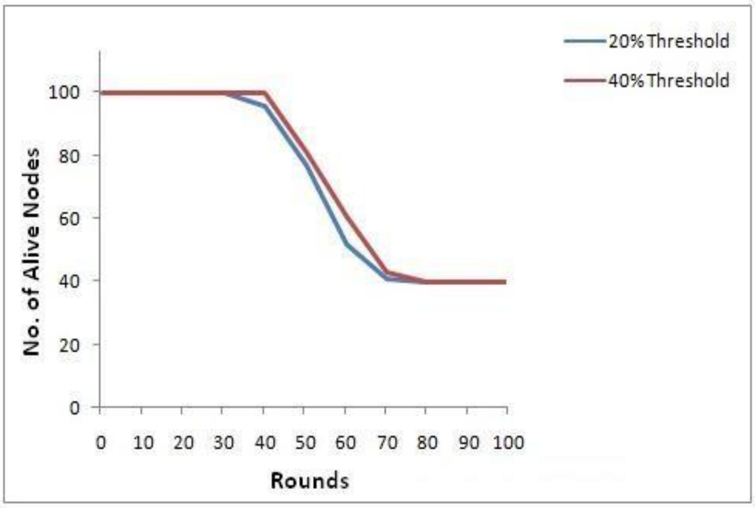

Figure 4 Comparison of Alive nodes in D-LEACH for various energythresholds

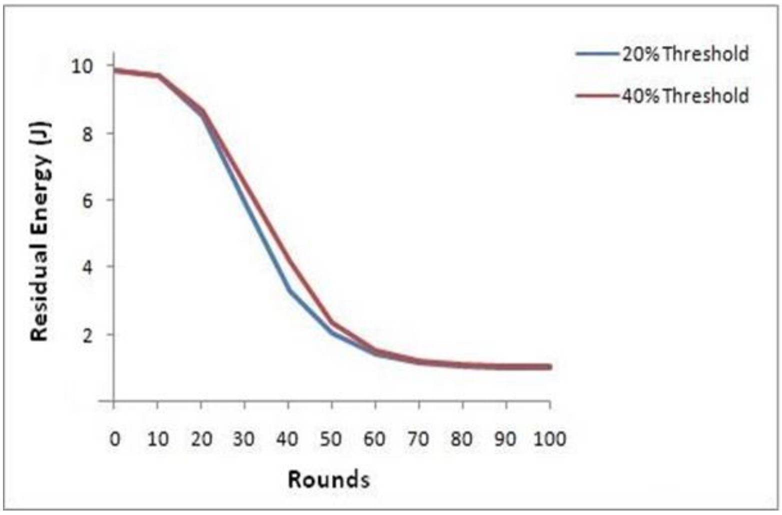

Figure 5 Comparison of Residual Energy in D-LEACH for variousEnergy thresholds

Conclusion

To effectively maximise the lifespan and immovability period of wireless sensor networks, this research presents a novel Energy Efficient adaptive clustering hierarchy Protocol based on a Genetic

Algorithm. Finding the optimal number of cluster heads and their placements based on minimising energy consumption of the sensor nodes is one of the primary goals of the evolutionary algorithm used in energy-efficient wireless sensor networks, which significantly increases the network's lifetime and stability period. Matlab simulation results shown that the proposed GENETIC ALGORITHM ENERGY EFFICIENT protocol outperformed the LEACH and LEACH-GA protocols in terms of energy efficiency and cluster process reliability across a variety of network densities and topologies. Furthermore, the GENETIC ALGORITHM ENERGY EFFICIENT protocol improves the clustering process's dependability by lengthening the stability phase and shortening the unsteadiness period.

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