An Energy-Efficient Hybrid LEACH Protocol that Enhances the Lifetime of Wireless Sensor Networks

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ABSTRACT

A Wireless Sensor Networks (WSN) comprises of little, low-power sensors, which have a low battery limit and are often utilized in unfavorable conditions. These sensors are data processing and networking devices. The battery life, processing power, communication range, and memory of sensors, which are tiny, self-contained devices, are just a few of their limits. They also have transceivers, which gather environmental data and transmit it to a base station. There are various strategies accessible to expand the existence of a WSN and diminish energy utilization. LEACH (Low Energy Adaptive Clustering Hierarchy) is a

successful and widely used method. The protocol clusters the network in order to conserve energy The cluster head, which is a single-region indicative node, receives fusion cluster data once the sensor nodes are divided into clusters. In our study, we provide a novel method for reducing sensor node energy consumption and extending network lifetime. Our research aims to increase network lifespan by reducing energy consumption based on the restrictions of the LEACH and its related algorithms.

Keywords-LEACH; WSN; sensors; energy efficiency; cluster head

I. INTRODUCTION

A Wireless Sensor Network (WSN) is an ad-hoc generated cooperative wireless network finished up of multiple sensor nodes that are spatially distributed throughout the network. WSNs are frequently employed to observe and track a desired physical state. A WSN's nodes contain sensors, transceivers, power sources, and memory, as well as numerous processing capabilities. A gateway is built as a link between the wireless network and the wired networks, while wireless communication takes place among the nodes. The number of nodes in a WSN can range from hundreds to thousands, depending on its nature and functioning [1]. Path selection and routing are critical for constructing a reliable wireless communication network. A crucial challenge of current energy-efficient ad-hoc networks is the selection of appropriate routes based on data-centric routing. To obtain the relevant data, naming uses attribute-value pairs. Instead of retrieving data from a specific node id, the sink broadcasts the attribute it is interested in. The sink receives responses from any node in the network that has information about the requested attribute. Directed Diffusion is a data-centric paradigm in which network communication is based on named data [2].

Clustering is utilized to further optimize the energy and reduce the overhead. Clustering is a common WSN technique for increasing the efficiency of routing protocols. A cluster is a collection of nodes. The Cluster Head (CH) is responsible to collect data from all other sensor nodes. The data must subsequently be transmitted to the sink by the CH [3].

A WSN is made up of a lot of low-cost small sensor nodes that have a small amount of energy, computational power, and storage. They typically concentrate on a certain area, gather data, and then communicate with the Base Station (BS). As a result of advancements in low-power digital circuits and wireless transmission, numerous WSN applications have been created and are currently being utilized for habitat monitoring, military formation, and object tracking. Energy consumption is decreased because only a portion of the nodes, the CHs, can communicate with the BS. The data delivered by each node are subsequently gathered and compressed by the CHs. After then, the data is compiled and transferred to the BS. Considering the fact that clustering can reduce energy use, it has some disadvantages. The main problem is that the CHs use the majority of the energy. The issue of how to distribute the use of energy in cluster routing has to be solved in order to fix this issue. A good example is the improved cluster head selection of the deterministic clustering LEACH algorithm [4].

When developing a protocol WSNs, a framework with reliable and fault-tolerant communication, quick routing configuration, and minimal energy utilization is expected. In addition to lacking a basis, WSNs have limited energy, space, and handling capacity, making routing more difficult. To solve these concerns, many routing protocols have been proposed, with some being more successful than others In certain scenarios with superior execution, some are more logical. In contrast, others are not appropriate in that frame of mind with massive restrictions while considering the engineering and application requests of WSNs [5-7]. Therefore, assessing routing protocols is essential.

The current study aims to develop a methodology in which the network's life expectancy increments radically. The aim is to ensure reliable data transfer between sensor nodes and the network's BS. In addition, we aim to develop a LEACH clustering algorithm with improved performance, with the ultimate goal of extending the network's life and examine how the newly designed LEACH stacks up against the current LEACH in terms of performance, lifetime, and energy dissipation.

In this study, an information combination procedure to extend the exhibition of IoT sensors is proposed. Redundant information is omitted and the energy utilization is thus limited. The proposed approach is useful when concerning node failures. We assessed the effectiveness of the proposed technique in a baseline approach.

II. RELATED WORK

Wireless sensor technology is rapidly evolving, particularly with the emergence of several new Internet of Things (IoT) applications. The limited battery life and short lifespan of sensor technologies are the main disadvantages of WSNs. As a result, the majority of the following studies discuss sophisticating these flaws and proposing various methods and techniques to address them.

W. Heinzelman proposed the LEACH methodology for WSNs [3]. The LEACH protocol chooses a CH from each of the small clusters that make up the network. After identifying its target, the sensor node provides the CH with the relevant data. After that, the CH transmits the data collected to the BS. The most crucial aspect to take into account in WSNs is energy usage [4]. Because sensor nodes have no substitutes or charging options, sensor researchers have a lot of room to experiment with how to use them optimally. As a result, authors in [4] analyzed the most efficient LEACH protocol variants and concluded that Ant Colony Optimization (ACO), which is based on energy-efficiency, produces capable outcomes. In [5], a single-hop homogeneous network was presented as a new expansion. The CH was chosen by taking into account the sensor node's initial and residual energy, as well as its distance from the BS. The resulting network lifetime and energy efficiency are comparable to LEACH's. Clusters that have already formed are fixed in Eth-LEACH [6]. Authors in [8] proposed SRCH, a WSN data aggregation technique for uniform and non-uniform networks. The Single-Round Cluster-Head (SRCH) selection algorithm is proposed and implemented. The n-tuple property determines the best CH for coordinating and managing communication from source to destination. The LEACH shared assembly routing protocol for two tightly packed sensor nodes in rectangular and circular forms was presented in [9]. Initially, the circular LEACH linked system outperformed the rectangular system in network lifetime and energy utilization. HC-LEACH [10] proposes an alternate energy harvesting mechanism for CH selection in each round to the LEACH protocl. This protocol forwards data utilizing efficient routing and low latency. Energy, delay, lifetime, and latency improved with this approach. The position of the sensor node relative to the BS and its residual energy are important parameters for MW-LEACH [11]. Like DB-LEACH, MW-LEACH sets a distance-based criterion. In [12], neighboring node average and leftover energy are considered when choosing a CH. Cluster creation begins following CH selection, as in LEACH, in all the above mentioned methods. LEACH-POS proposes many techniques, including CH node selection based on energy and probability function-based sink distance [13]. Simulations show that LEACH-POS has a longer network lifespan and lower traffic overhead than LEACH or direct transmission protocols.

In a WSN, cluster data are lost when CHs fail. Centralized protocols are more susceptible to node failure-induced topology changes. Authors in [14] studied how much energy LEACH and other routing protocols use to select a new CH when the current CH dies and proposed a more resilient and energy-efficient solution. Leach-K [15] applies K-Means to the LEACH routing protocol before CH selection to reduce energy consumption. In [16], LEACH was reliably solved by the node rank algorithm. Each CH was determined by route costs and node connectivity. This strategy eliminates the unpredictable process selection that caused CH failures in prior LEACH versions and extends network lifespan. The hybrid energy-efficient distributed data aggregating protocol optimizes sensor node energy use and cluster communication through multi-hop routing and aims to improve network energy management performance [17]. A multipath LEACH mechanism that optimizes intermediate CHs has been recently developed [18].

Intrusion Detection Systems (IDSs) are some of the most effective security measures for detecting routing threats. To combat the sinkhole threat, specification-based intrusion has been developed [19]. In terms of performance criteria such as energy use and packet delivery rate, SSLEACH exceeds the well-known current techniques MS LEACH and S-LEACH. A three-layer LEACH-based technique is proposed [20]. In BRE-LEACH, an RCH-based strategy is proposed where all the CHs send the information to the root CH rather than the immediate sink. This strategy outperforms every notable existing protocols including LEACH. All of the above-mentioned LEACH protocols show preferred execution over the fundamental LEACH, which implies they upgrade the lifetime of WSN and decrease power utilization, but there is still room for improvement in the protocol for effective energy usage, despite the fact that the aforementioned updates to LEACH have improved network reliability and decreased power consumption [22]. The goals of the current study are to reduce energy use and increase the lifespan of WSNs.

III. PROPOSED LEACH PROTOCOL

The energy dissemination of WSN sensor nodes has been diminished with the standard execution of the LEACH protocol. This clustering-driven strategy centers around making clusters and giving everyone a CH. These CHs gather information from a group's nodes, process it, and send it to the BS. These CHs are given the obligation of information assortment. Thus, the CHs are entirely dependent on impeccable information gathering. It will be hard to gather information from a group if a CH dies. Thus, a CH should have the capacity and adequate energy to communicate and gather information appropriately.

In this paper, we introduce a hybrid energy-efficient protocol with the purpose of prolonging network stability, lowering energy usage, extending lifetime, and improving throughput. The proposed protocol operates into phases. Figure 1 shows the proposed LEACH protocol. Each CH builds a routing table with network cluster distances and root cluster distances. Then the data are sorted by distance in a descending order. All CHs have numerous root clusters and choose the nearest for data transmission. The proposed method adds a VCH node as a backup. The VCH acts as the CH when the CH energy drops below a certain threshold. VCHs and standard nodes cannot send data directly to the BS, preventing overload and node energy waste.

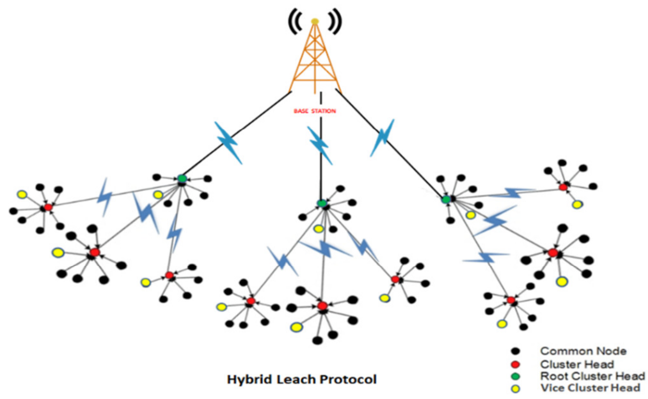

Fig. 1. The proposed architecture.

IV. THE PROPOSED ALGORITHM

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Notations:
CH: Cluster Head
R: Random Number
BS: Base station
N: Normal node
NN: Numbers of nodes
Setup phase
START
For all N
For the first Round, Every Node (N)
N select R between 0 and 1
If (R <= T(n))
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Then N becomes CH and broadcasts CH status
message
Else
N becomes Ordinary Node
N gets the adv. message sent by CH
End if
End For
For Every CH (Cluster formation stage)
N selects the CH with highest adv. message
signal strength
N becomes a member of that Cluster
End of for loop
For Every CH
a. For data transmission, each node (N)
receives a TDMA schedule.
b. N transmits the data to the CH as per
the TDMA
End of for loop

// After first round
Notations:
RCH: Root Cluster Head
VCH: Vice Cluster Head
If (first round is completed == true)
Calculate residual energy of every node
Sort nodes by residual energy highest to
lowest
If (residual energy == highest)
Select as RCH
For Every CH (Mechanism to Determine
Minimum Distance Between CH and BS)
Each CH chooses RCH with the shortest
distance to the BS.
Following the preceding phase, CH chooses
its ideal RCH.
End of for loop
Selection of VCH
For N [i] in same Cluster
N with 2nd highest energy becomes VCH
End of VCH for loop
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The new Hybrid-LEACH is based on the existing LEACH protocol. The initial round will proceed according to the standard LEACH methodology and CHs will be chosen based on the threshold value and a random integer between 0 and 1. A node will take over as CH in the initial round if this number is below the threshold. After that, TDMA scheme is constructed for all nodes, where each cluster node is allotted a fixed time slot to deliver data to its CH. After the first round, the remaining energy of all nodes is calculated and they are sorted in descending order. The node with the highest residual energy will become the Root CH (RCH) of multiple clusters. The node with the second-highest remaining energy will be chosen to serve as the VCH.

V. RESULTS AND DISCUSSION

The following results are the average outcome acquired after running 20 simulations in MATLAB. The parameters and settings used in simulations are shown in Table II.

TABLE I. SIMULATION SETTING AND PARAMETERS

Parameter	Value
Area	150 × 150 m
Total number of rounds	2000
Total nodes	150
Packet size of RCH	500 bytes
Energy of normal nodes	0.6 J
Control packet size	25 bytes
Data packet size	100 bytes
BS location	(150, 150)

A. *Result Analysis*

We investigated a homogenous network containing 150 nodes that were randomly distributed in a 150 × 150 area. Figure 2 shows the number of dead nodes over time in the network. We can see that all the nodes of the LEAD protocol died after around 1325 rounds, those running BRE LEACH died after 1541 rounds, whereas Hybrid LEACH nodes ran for almost 1946 rounds. According to these results, Hybrid LEACH increases the lifetime of the sensor nodes far better than the other two protocols.

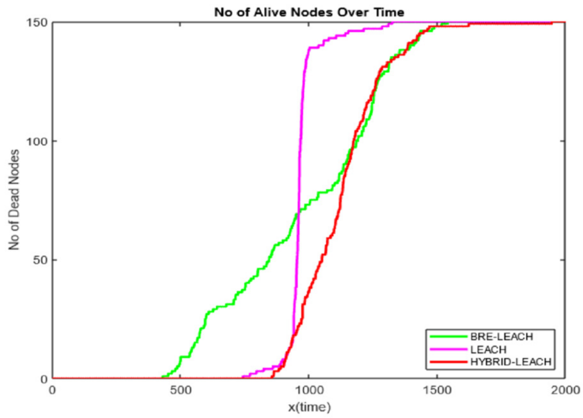

Fig. 2. Number of dead nodes over time.

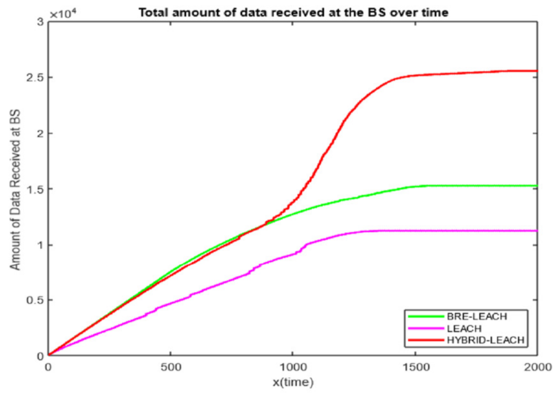

Fig. 3. Data packets received at the BS.

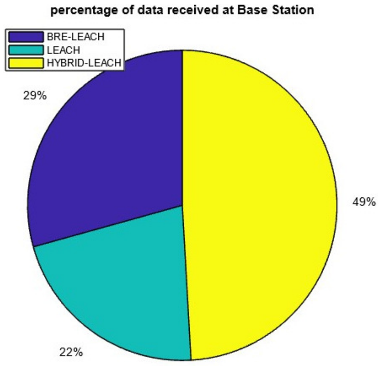

Fig. 4. Throughput of the network.

The next key parameter evaluated in this study is the throughput of the network. Figure 3 displays the total data packets transferred to the BS per round and Figure 4 shows a pie graph of the throughput. It is apparent that when compared to the proposed method has increased the volume of packets transferred to the BS. The next comparison parameter is energy usage. Figure 5 illustrates the total remaining energy in the network. It can be seen that the proposed approach utilizes a lesser amount of energy than LEACH and BRE-LEACH.

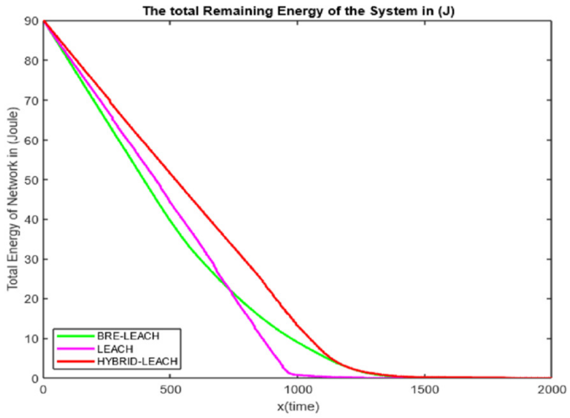

Fig. 5. Total remaining energy over time.

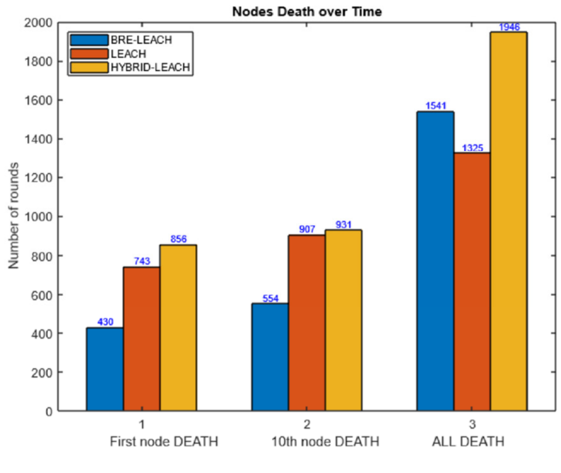

Fig. 6. Lifetime vs. rounds

Figure 5 illustrates the lifetime of the nodes in the network. For the original LEACH, the first node died after 743 rounds, while the 10th node died after 907 rounds. LEACH protocol completely shuts down after 1325 rounds. For BRE- LEACH, the first node died after 430 rounds, while the 10th node died after 554 rounds. BRE-LEACH protocol reaches 0 network energy after 1541 rounds. In the proposed algorithm, the first node died after 856 rounds, the 10th node died after 931 rounds, and the last node died after 1946 rounds, which was quite remarkable and clearly outperformed the other considered protocols.

VI. CONCLUSION

Maximizing network lifetime is a significant issue when it comes to developing an efficient wireless sensor network protocol. One of the most encouraging techniques for addressing the problem of increasing network longevity is the LEACH protocol. The CHs are the most important factors in the LEACH protocol since they control the member nodes and data routing. The LEACH has limitations, especially during the CH selection phase. So we tried to tackle the limitations of this phase and came up with a new technique called Hybrid-LEACH. In this technique, we used a mechanism of vice and root CHs. In our protocol, the remaining energy of all nodes is computed after the first round. After that, the nodes are sorted based on their energy. The node with the highest energy is selected as the root CH, while, in each cluster, the node with the second highest energy becomes the vice CH. The remaining steps follow the LEACH procedure. After running the simulation several times, we found that the proposed protocol outperformed the BRE-LEACH and basic LEACH.

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