International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 7
DOI: https://doi.org/10.17762/ijritcc.v11i7.7919
Article Received: 01 May 2023 Revised: 18 June 2023 Accepted: 10 July 2023

Energy Optimization Efficiency in Wireless Sensor Networks for Forest Fire Detection: An Innovative Sleep Technique

Manar Khalid Ibraheem[1], Mbarka Belhaj Mohamed[2], Ahmed Fakhfakh[3]
[1]Laboratory of signals, systems, artificial intelligence and networks (SM@RTS), Digital Research Center of Sfax (CRNS), National School of Engineers of Sfax (ENIS)
University of Sfax
Sfax, Tunisia
manar.ibraheem.1979@gmail.com
[2]Laboratory of signals, systems, artificial intelligence and networks (SM@RTS), Digital Research Center of Sfax (CRNS), National School of Engineers of Gabes (ENIG)
University of Sfax
Gabes, Tunisia
mbarkaenig@gmail.com
[3]Laboratory of signals, systems, artificial intelligence and networks (SM@RTS), Digital Research Center of Sfax (CRNS), National School of Engineers of Sfax (ENIS)
University of Sfax
Sfax, Tunisia
ahmed.fakhfakh@enetcom.usf.tn

Abstract—Wireless Sensor Networks (WSNs) have the potential to play a significant role in forest fire detection and prevention. However, limited resources, such as short battery life pose challenges for the energy efficiency and longevity of WSN-based IoT networks. This paper focused on the energy efficiency aspect and proposed the ECP-LEACH protocol to optimize energy consumption in forest fire detection cases. The proposed protocol consists of two main components: a threshold monitoring module and a sleep scheduling module. The threshold monitoring module continuously monitors energy consumption and triggers sleep mode for nodes surpassing the predetermined threshold. The ECP-LEACH protocol offers a promising solution for improving energy efficiency in WSN-based IoT networks for forest fire detection. By optimizing sleep scheduling and duty cycles, the ECP-LEACH protocol enables significant energy savings and extended network lifetime.

Keywords- Wireless Sensors Network; MAC protocols; Fire detection; Sleeping algorithms; OMNET++.

I. INTRODUCTION

The potential of WSN-based IoT (Internet of Things) for fighting forest fires is enormous [1]. It consists of a network of tiny, battery-operated sensors spread out over the forest, all working together to accomplish certain goals. Various sensors for detecting crucial aspects like temperature, humidity, pressure, and air quality are now available in WSN-based IoT [2] thanks to developments in embedded systems and MEMS technology. These sensors gather information in the field and send it wireless to a hub, also known as a base station or gateway [3]. WSN-based IoT may be broken down into "event-driven" and "time-driven" categories when considering its use in fire forest applications, respectively.

Limited resources, such as short battery life, sluggish connectivity, and low memory capacity [4], are one of the main obstacles in WSN-based IoT for forest fire application. The longevity of a sensor network is inversely proportional to the amount of energy its nodes use. Therefore, extending the lifespan of the WSN-based IoT network and improving its efficacy in forest fire applications necessitates a key research emphasis on boosting the energy efficiency of the sensor nodes.

II. SLEEP SCHEDULING STRATEGIES IN WIRELESS SENSOR NETWORKS

A. Time-Scheduling Methods for Sleep

A crucial aspect of energy management in wireless sensor networks (WSNs) used to detect forest fires is sleep scheduling. By coordinating the sleep and waking hours of a network of sensor nodes, sleep scheduling algorithms aim to decrease power consumption while preserving the needed performance of the network. This introduction provides a background on sleep scheduling techniques and their importance in achieving energy efficiency in WSNs.

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 7
DOI: https://doi.org/10.17762/ijritcc.v11i7.7919
Article Received: 01 May 2023 Revised: 18 June 2023 Accepted: 10 July 2023

1) Synchronized Sleep Scheduling

The practice of coordinating each sensor node's sleep schedule across a network is referred to as "synchronized sleep scheduling." In this approach, nodes are organized into clusters, and each cluster has a cluster head that controls the wake-up and sleep cycles of the nodes inside the cluster. With the help of this synchronization, it is ensured that, at any one time, only a small portion of nodes are actively processing data, with the remainder entering a power-saving sleep state.

The LEACH mechanism is a well-liked method for synchronizing the sleep schedules of various devices. LEACH employs dynamic cluster head selection and cluster head role rotation to minimize energy spikes and make sure that resources are used effectively throughout the network. This technique has been used in scenarios involving the monitoring of forest fires, effectively reducing energy consumption and extending network lifetime.

2) Asynchronous Sleep Scheduling

Asynchronous sleep scheduling, sometimes referred to as duty cycle, allows nodes to operate independently without the need for central coordination. Using either its own internal data or a set of duty cycle parameters, each node establishes its own timetable for when it goes to sleep and when it wakes up. With the help of this technique, nodes may save energy in a manner that best meets their requirements and adjusts to the dynamic nature of networks.

Asynchronous sleep scheduling that uses adaptive duty cycling dynamically adjusts the duty cycle in response to outside factors and the need for data collection. To better balance data quality and energy efficiency. By adjusting their sleep and active cycles, nodes may conserve energy when they are not in use and yet react swiftly to emergencies.

3) Hybrid Sleep Scheduling

Hybrid sleep scheduling solutions combine synchronized and unsynchronized processes to optimize energy utilization in WSNs. Utilizing the best elements of both strategies, this hybrid solution maximizes energy savings while preserving network responsiveness.

For instance, hierarchical sleep scheduling mixes decentralized scheduling for individual nodes with synchronized sleep scheduling across clusters. While individual nodes within a cluster establish their own schedules for when to sleep and wake up, cluster leaders coordinate their sleep cycles. This technique reduces energy consumption by regulating the frequency of node activation and optimizes communication between them.

WSNs for detecting forest fires mainly depend on sleep scheduling techniques to extend network lifetime and use less energy. By carefully choosing when to sleep and when to wake up, these techniques enable sensor nodes to save energy during periods of low activity while still reacting to fire events. The choice of sleep scheduling approach should take into account factors including network structure, data collection requirements, and the desired trade-off between energy use and network responsiveness. to greatly improve energy efficiency in detecting forest fires.

B. Routing Protocols

Massive networks of sensor nodes that communicate wirelessly with one another and a base station or sink node in order to gather and transmit data about the sensing environment are known as Wireless Sensor Networks (WSNs). Through the use of WSN routing algorithms, information may be sent from sensor node to node.

The goal of WSN routing protocols is to minimize power consumption by sensors by determining the most efficient route between a source and a sink node. The routing protocol determines the optimal path for transmitting packets taking into consideration energy, distance, and the quality of the communication channel.

A common routing protocol in WSNs is LEACH. WSNs are a form of network which contain a large number of tiny, low-power devices called sensors. These sensors may be used to monitor a wide range of environmental and physical parameters.

Because sensors in WSNs often run on small, disposable batteries, the LEACH protocol was developed to help minimize their power usage. The protocol does this by grouping the sensors into "clusters," with one node serving as the "cluster head" and relaying the information gathered by the other nodes to the "sink node" or base station. An energy-efficient probabilistic technique is used to choose which node in the cluster will serve as the system's leader.

C. Medium Access Control

Wireless communication protocols include MAC layer. To reduce interference and collisions between numerous nodes transmitting data simultaneously, the MAC layer manages access to the shared wireless communication medium.

TunableMAC is a medium access control protocol designed for WSNs, which provides a tunable tradeoff between energy consumption and network performance. It achieves this by dynamically adjusting the duty cycle of nodes, which determines the percentage of time a node spends in active (transmitting or receiving) mode and the percentage of time it spends in sleep mode.

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 7
DOI: https://doi.org/10.17762/ijritcc.v11i7.7919
Article Received: 01 May 2023 Revised: 18 June 2023 Accepted: 10 July 2023

When used in conjunction with LEACH, TunableMAC can further improve the energy efficiency of the network. TunableMAC can reduce the consumed energy of nodes while maintaining the required level of network performance.

The combination of LEACH and TunableMAC allows for a hierarchical network structure, with clusters formed by LEACH and nodes in each cluster using TunableMAC for medium access control.

In this approach, the cluster head node in each cluster is responsible for coordinating the communication within the cluster and with the sink node, using LEACH. The other nodes in the cluster use TunableMAC to adjust their duty cycles and reduce energy consumption. This enables the nodes to stay in sleep mode for longer periods of time, thereby reducing energy consumption, while still ensuring timely and efficient data transmission.

Overall, using TunableMAC with LEACH can result in significant energy savings and improved network performance in WSNs, making it a promising solution for many applications. However, it is important to carefully tune the parameters of both protocols to achieve a trade off between consumed energy and performance, depending on the specific requirements of the application.

Sensor nodes in a WSN could use a lot of energy in a single round due to various reasons, such as transmitting large amounts of data, being involved in high-traffic communication, or performing complex computations. This can cause the node to drain its battery quickly and may result in network failure or reduced network lifetime.

To address this issue, several techniques can be used to reduce the energy consumption of the nodes and improve the overall network lifetime. The most popular approach is to use sleep scheduling algorithms, which can help to reduce the active time of the nodes and increase the time they spend in sleep mode. By reducing the active time of the nodes, the energy consumption of the nodes can be significantly reduced, as most of the energy is consumed when the nodes are active.

D. Sleep Mode and Duty Cycle

In a Wireless Sensor Network (WSN), sleep mode and duty cycle are two important concepts related to energy efficiency.

Sleep mode is a low-power state in which a sensor node can conserve energy by turning off or reducing the power to non-essential components, such as the radio or the processor, while keeping the essential components, such as the sensor and the memory, active. In sleep mode, the node consumes very little power, which makes it an effective way to conserve energy. However, it also means that the node is not able to communicate with other nodes or the sink node while in sleep mode.

Duty cycle, on the other hand, refers to the percentage of time a node spends in active mode compared to the total time. In other words, it determines the fraction of time that a node is transmitting, receiving, or processing data compared to the time it is in sleep mode. By adjusting the duty cycle, a node can control the amount of energy it consumes while still participating in the network.

In practice, sleep mode and duty cycle are often used together to achieve energy-efficient operation of sensor nodes in WSNs. By setting an appropriate duty cycle, the nodes can adjust their active time to match the requirements of the application while minimizing energy consumption. For example, if the application requires high data rates, the nodes may need to have a higher duty cycle to ensure timely and efficient data transmission. On the other hand, if the application has low data rates, the nodes can have a lower duty cycle to conserve energy.

Sleep scheduling algorithms can be used to determine the optimal duty cycle for each node, based on factors such as data rate, traffic patterns, and energy consumption. These algorithms can also be used to coordinate the sleep schedules of the nodes in a way that reduces interference and improves overall network efficiency. Sleep mode and duty cycle are important concepts in WSNs, and effective use of these concepts can lead to significant energy savings and improved network performance.

III. RELATED WORK

Wireless sensor networks (WSNs) are a relatively new technology that has attracted a lot of interest because of the many different fields in which they may be used. The restricted energy resources of the sensor nodes make it especially difficult to maximize the energy efficiency of WSNs. As a result, several strategies have been suggested to reduce the consumed energy of WSNs, with the sleeping strategy being one among them [5].

In order to save power, several WSNs use the "sleeping" method. In this strategy, sensor nodes are placed into a power-saving sleep mode at regular intervals. Application needs and network circumstances are often used to define the sleep intervals and sleep state length. The sensor nodes reduce their power usage by stopping all data processing, transmission, and reception when in the sleep mode. This method allows sensor nodes to reduce power consumption and increase their operational time between charges.

An adaptive duty-cycle strategy for TR-MAC based on preamble sampling was proposed by the authors of [6].

The TBEMAC protocol is described in [7], and it comprises two stages: the duty cycle adjustment stage, and the wakeup

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 7
DOI: https://doi.org/10.17762/ijritcc.v11i7.7919
***Article Received**: 01 May 2023 **Revised**: 18 June 2023 **Accepted**: 10 July 2023*

scheduling stage. In reaction to variations in traffic loads, buffer status, and power reserves at sensor nodes, TBEMAC adjusts the duty cycle. Based on their remaining battery life and the volume of traffic, the protocol divides the nodes into groups for the waking phase. Nodes will go into a sleep state if they do not communicate with one another throughout the active period.

The traffic adaptive synchronous (TAS) MAC protocol was created by the authors of [8] to complement the duty cycle technique. It provides high throughput with low latency and low power consumption. Since TASMAC employs TDMA, a cutting-edge traffic adaptive allocation technique, it only allots time slots to nodes that are on active routes. In order to remove delay in the transmission of data from its source, this protocol proactively modifies the wakeup timings of all the nodes along the pathways of receiving data. TASMAC divides the process of traffic notification and data transmission scheduling into two distinct stages.

Energy consumption, packet loss rate, and WSN lifespan were all investigated by the authors of [9]. The authors created the READC protocol to address the higher energy needs of the sink's immediate vicinity.

In [10], the authors propose a strategy for adjusting the duty cycle of WSNs. The authors began by developing a packet prediction model, then a multi-objective optimization function for power use and latency, and finally an effort to determine the optimum time spent sleeping. The authors of [11] published a novel approach to managing the duty cycle used in MAC layer for WSNs. The first half of the duty cycle is reserved for sending or receiving data from a neighboring node in this setup.

Based on the idea of individual duty cycle optimization, the EAMP-AIDC protocol was established for EH-WSNs in [12].

E-ECAB protocol was developed by the authors of [13] to achieve optimal efficiency and meet the requirements of a wide variety of applications. The E-ECAB relies on many criteria and a duty-cycle approach.

In order to deal with latency and energy-awareness in WSNs, the authors of [14] suggested using the multi-mode sensor MAC (MMSMAC), a multi-mode medium access protocol. The MMSMAC protocol may function in synchronous, asynchronous, or hybrid configurations.

Taking cues from the cooperative nature of biological things, the authors of [15] devised a technique they called E-MAC. In contrast to the IEEE 802.11 CAMA/CA standard, the author asserts that the E-MAC protocol yields superior outcomes.

In order to reduce power consumption in WSNs, the AI-HMAC protocol is suggested by the authors of [16]. This tactic, which is based on a combination of TDMA and CSMA-based traffic, is used by the AI-HMAC protocol. Adapting IH-MAC's link scheduling to take advantage of congestion windows is the major goal of this protocol.

IV. THE PROPOSED ECP-LEACH PROTOCOL

In a Wireless Sensor Network (WSN), the nodes only have access to a finite amount of energy resources; therefore, it is essential to conserve energy in order to lengthen the network's lifetime. When nodes are not required for data transmission or sensing, it is possible to save energy by putting them into a sleep state so that they do not consume any power. Nevertheless, the difficulty is in determining the appropriate time to put the nodes into sleep mode.

In order to overcome this obstacle, the ECP-LEACH protocol have been developed for the WSN. The methodology of ECP-LEACH protocol is described in Fig. 1. This protocol makes use of a threshold in order to establish when it is appropriate to put the nodes into sleep mode. At each point in the round, the consumed energy of the nodes is compared to the threshold, which is a figure that has been predetermined and is utilized for comparison. The protocol puts a node into sleep mode if it detects that the node's energy usage is higher than the threshold value.

The protocol is comprised of two primary components, the first of which is a threshold monitoring module and the second of which is a sleep scheduling module.

In order to overcome this obstacle, the ECP-LEACH protocol have been developed for the WSN. The methodology of ECP-LEACH protocol is described in Figure 1. This protocol makes use of a threshold in order to establish when it is appropriate to put the nodes into sleep mode. At each point in the round, the consumed energy of the nodes is compared to the threshold, which is a figure that has been predetermined and is utilized for comparison. The protocol puts a node into sleep mode if it detects that the node's energy usage is higher than the threshold value.

The protocol is comprised of two primary components, the first of which is a threshold monitoring module and the second of which is a sleep scheduling module.

The threshold-monitoring module is in charge of keeping track of the energy that is being consumed by the nodes at each point throughout the round. It examines how each node's energy consumption stacks up against the predetermined threshold value. The module will send a signal to put a node to sleep if it detects that the node's energy usage is higher than the threshold. The equation to calculate the spent energy as a percentage of the initial energy of each round is

$$Spent\ Energy\ Percentage = \frac{E_i - E_r}{E_r} * 100 \qquad (1)$$

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 7
DOI: https://doi.org/10.17762/ijritcc.v11i7.7919
***Article Received**: 01 May 2023 **Revised**: 18 June 2023 **Accepted**: 10 July 2023*

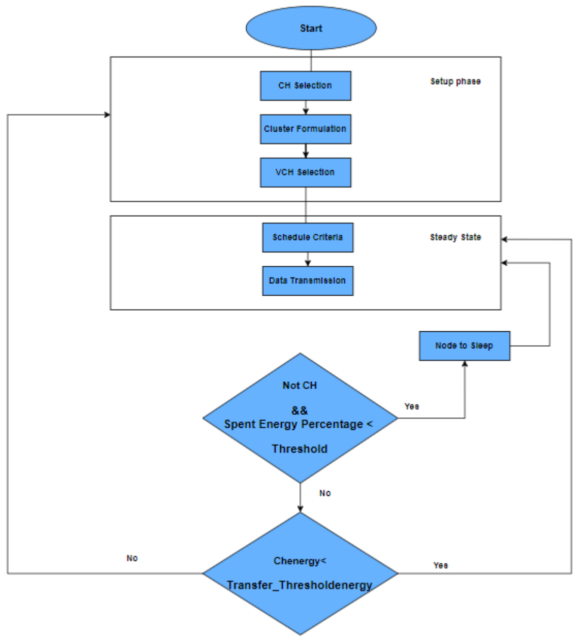

Figure 1. The proposed ECP-LEACH protocol.

Where:

- Ei is the amount of energy available to the node at the beginning of its round.
- Er is the current Energy of the node.

It is the responsibility of the sleep scheduling module to schedule the nodes' sleep modes in accordance with the sleep signals that are transmitted by the threshold-monitoring module. In order to decide which nodes should be put into sleep mode until the end of the round, it employs a scheduling algorithm. In order to arrive at the best possible conclusion, the algorithm takes into account a variety of elements, including the levels of the energy in the nodes and the communication history between them.

The protocol is able to successfully preserve energy and keeping the network lifetime by utilizing a threshold that sends nodes into sleep mode. Reducing the number of active nodes at any one point also helps to lower the overall energy consumption of the network. This may be especially helpful in applications where maximizing energy efficiency is of the utmost importance, such as environmental monitoring and the detection of forest fires.

It is important to note that the threshold and sleep scheduling method that were developed is only supposed to be used for non-cluster head nodes in the network. The management of network traffic and the distribution of data across nodes is the responsibility of the cluster head nodes. It's possible that putting the cluster head nodes into sleep mode will cause connectivity problems and mess up the operation of the network.

We can ensure that the network connectivity is maintained while still conserving energy by using the threshold and sleep scheduling strategy solely for the nodes in the network that are not cluster heads. This strategy helps to avoid congestion on the network and ensures that it functions smoothly and effectively.

In general, the implementation of a threshold and sleep scheduling method in a Wireless Sensor Network can result in the delivery of significant benefits. You may save the lifetime of the network, enhance efficiency, and reduce energy consumption, all without sacrificing network connectivity or performance if you carefully manage the energy consumption of the nodes.

V. SIMULATION AND RESULTS

We used OMNET++ version 4.6 as a simulator with CASTALIA framework version 3.3 to evaluate the performane of ECP-LEACH Protocol. We made three scenarios as follow: Scenario one for 50 nodes, Scenario two for 100 nodes and Scenario three for 150-nodes.The network parameters are described in Table 1.

For the three scenarios, two routing protocols have been implemented. The first routing protocol is LEACH protocol and the second one is ECP-LEACH, with different values of duty cycle (0.2, 0.4, 0.6, and 0.8) to evaluate the consumed power and the network lifetime for the two routing protocols.

TABLE I. THE NETWORK PARAMETERS

Parameter	Value
Initial Energy	18720 Jol
Round Length	12 seconds
Simulation Time	2000 ms
Nodes	50, 100 ,150
Field Range	200 * 200 square meter
Mac protocol	Tunble Mac
Routing protocol	LEACH

A. Scenario one

In this Scenario, 50 nodes were deployed. The results as shown in Fig. 2 indicate that the consumed power has been reduced in the proposed ECP-LEACH protocol as compared with default LEACH protocol. Where the consumed power for ECP-LEACH reduced with 3.47755 jol in duty cycle 0.2, 10.65959 jol in duty cycle 0.4, 16.33945 jol in duty cycle 0.6 and 21.8639 jol in duty cycle 0.8.

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 7
DOI: https://doi.org/10.17762/ijritcc.v11i7.7919
***Article Received**: 01 May 2023 **Revised**: 18 June 2023 **Accepted**: 10 July 2023*

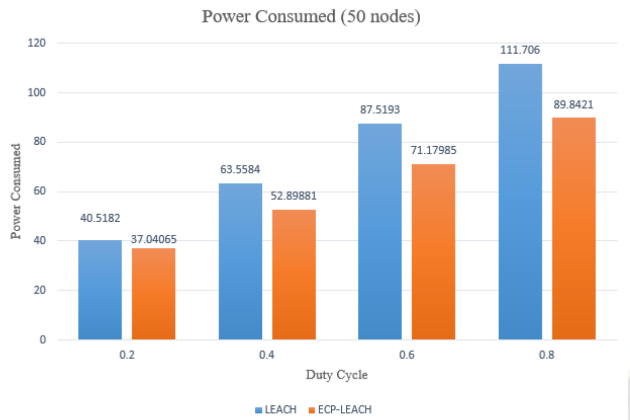

Figure 2. Power Consumed for different duty cycle in Scenario 1 (50 nodes).

The ECP-LEACH protocol exhibited an improvement in network lifetime, as shown in Fig. 3, which present the results for the network lifetime of the LEACH protocol and the ECP-LEACH protocol. The increase in the network lifetime was relatively small and the highest increase was 0.6458 days for duty cycle value 0.2. Whereas, the smallest increase was 0.00091 days for duty cycle value 0.8.

B. Scenario two

In Scenario Two, we expanded the network to include 100 nodes to further evaluate the performance of the LEACH and ECP-LEACH protocols. The results for consumed energy and network lifetime for both protocols are presented below.

The results revealed a significant reduction in consumed energy when employing the ECP-LEACH protocol compared to the LEACH protocol. As indicated in Fig. 4, the ECP-LEACH protocol rduced the average consumed energy values by 8.89654, 18.9423, 29.43365 and 32.83419 for duty cycle values of 0.2, 0.4, 0.6, and 0.8, respectively.

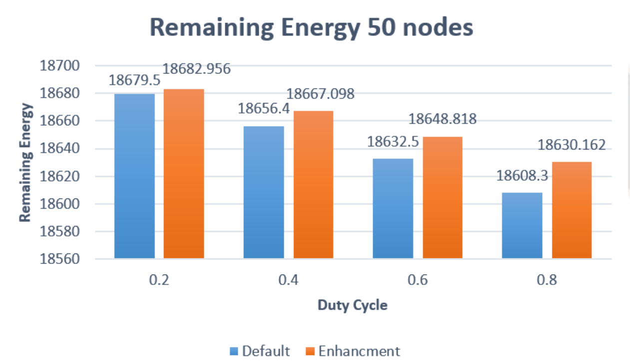

Figure 3. Network Lifetime for different duty cycle in Scenario 1 (50 nodes).

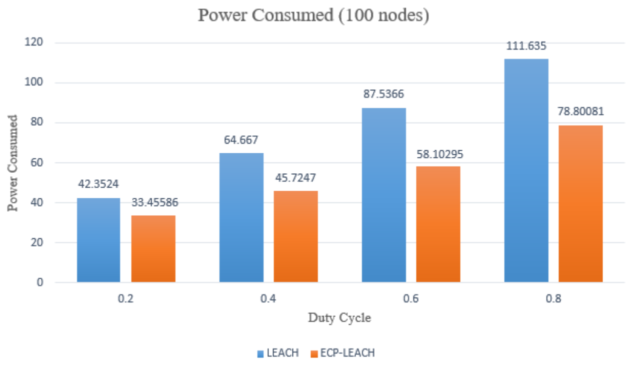

Figure 4. Power Consumed for different duty cycle in Scenario 2 (100 nodes).

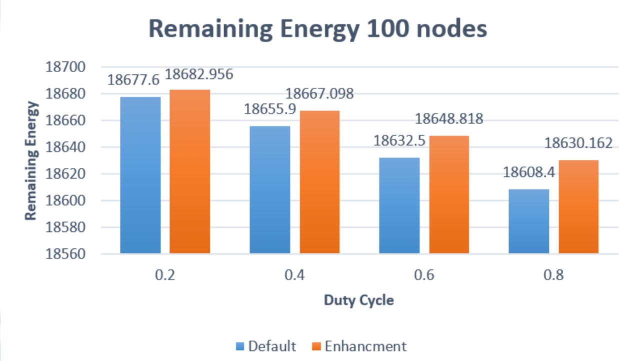

Figure 5. Network Lifetime for different duty cycle in Scenario 2 (100 nodes).

On the other hand, the network life time increased by using the ECP-LEACH protocol compared to the LEACH protocol as shown in Fig. 5. The increase in network life time for the ECP-LEACH protocol compared to the LEACH protocol for different values of the duty cycle was as follows: 0.1874 days for duty cycle 0.2, 0.00065 days for duty cycle 0.4, 0.0014 days for duty cycle 0.6 and 0.00049 days for duty cycle 0.8.

C. Scenario three

In Scenario Three, with 150 nodes in the network, the ECP-LEACH protocol maintained its superiority over LEACH. The simulation results revealed a sustained reduction in average energy consumption for the ECP-LEACH protocol.

Fig. 6 shows significant reduction in consumed energy at ECP-LEACH by 14.4759482 for duty cycle 0.2, 23.5297 for duty cycle 0.4, 34.66787 for duty cycle 0.6 and 41.93921 for duty cycle 0.8.

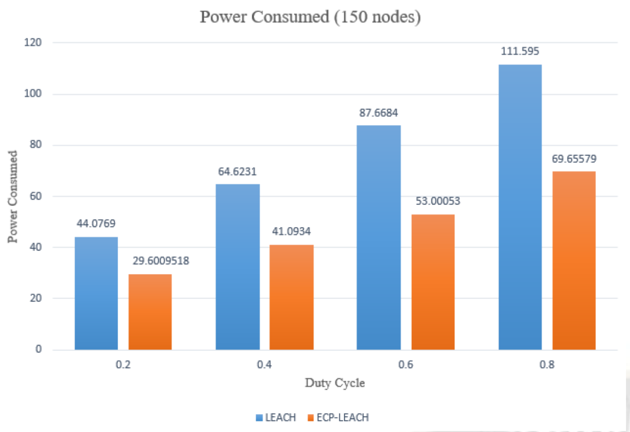

Figure 6. Power Consumed for different duty cycle in Scenario 3 (150 nodes).

Fig. 7 demonstrate that the ECP-LEACH protocol maintains a comparable network lifetime to the LEACH protocol, indicating its effectiveness in optimizing energy consumption without compromising the overall network performance.

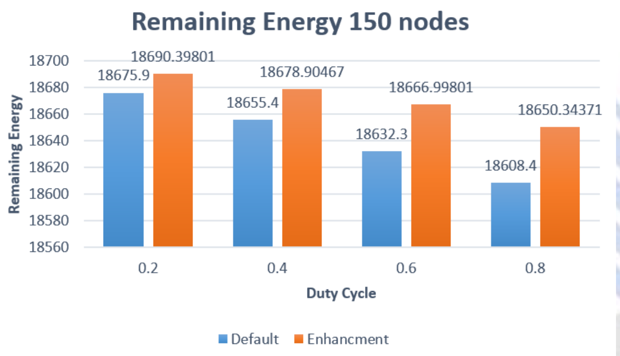

Figure 7. Network Lifetime for different duty cycle in Scenario 3 (150 nodes).

The simulation results clearly demonstrated that the proposed ECP-LEACH protocol achieved a reduction in consumed power compared to the LEACH protocol in all three scenarios. This reduction ranged from 3.47755 jol to 41.93921 jol, depending on the duty cycle and the number of nodes in the network. The findings highlight the energy efficiency improvements offered by the ECP-LEACH protocol, making it a promising solution for energy-constrained forest fire wireless sensor networks.

In addition, the simulation results also indicated that the ECP-LEACH protocol exhibited an increase in network lifetime compared to the LEACH protocol in all three scenarios. While the increase was relatively small, ranging from 0.00091 days to 0.6458 days, it signifies the potential of the ECP-LEACH protocol to extend the operational lifespan of the network, leading to improved network sustainability and longevity.

VI. CONCLUSION

In this paper, we presented a proposed ECP-LEACH protocol for energy-constrained forest fire wireless sensor networks based on the Leach routing protocol, which aims to reduce the energy consumed in nodes and extend the life of the network.

The simulation-based evaluation of the proposed ECP-LEACH protocol in three different scenarios highlighted the superiority of the ECP-LEACH protocol in terms of consumed power and network lifetime. The ECP-LEACH protocol consistently demonstrated reduced consumed power, offering energy savings ranging from 3.47755 jol to 41.93921 jol compared to the LEACH protocol. Moreover, the ECP-LEACH protocol exhibited a slight increase in network lifetime, ranging from 0.00091 days to 0.6458 days, across the scenarios.

Resuls emphasize the significant benefits of the ECP-LEACH protocol in terms of energy efficiency and network longevity. The protocol's ability to reduce power consumption while maintaining network performance makes it a promising solution for wireless sensor networks, particularly in resource-constrained environments.

Future research directions may include further performance analysis of the ECP-LEACH protocol under different network conditions and parameters, investigating its robustness against various network challenges, and exploring its applicability in other types of wireless networks.

ACKNOWLEDGMENT

Appreciation and thanks to everyone who contributed to the completion of this work.

REFERENCES

[1] Sangaiah AK, Javadpour A, Ja'fari F, Zavieh H, Khaniabadi SM. SALA-IoT: Self-reduced Internet of Things with learning automaton sleep scheduling algorithm. IEEE Sensors Journal. 2023.

[2] Belhaj Mohamed M, Meddeb-Makhlouf A, Fakhfakh A, Kanoun O. Wireless body sensor networks with enhanced reliability by data aggregation based on machine learning algorithms. Advanced Sensors for Biomedical Applications. 2021;67-81.

[3] Del-Valle-Soto C, Velázquez R, Valdivia LJ, Giannoccaro NI, Visconti P. An energy model using sleeping algorithms for wireless sensor networks under proactive and reactive protocols: A performance evaluation. Energies. 2020;13(11):3024.

[4] Alzahrani E, Bouabdallah F, Almisbahi H. State of the art in quorum-based sleep/wakeup scheduling MAC protocols for ad hoc and wireless sensor networks. Wireless Communications and Mobile Computing. 2022.

[5] Radhika S, Rangarajan P. Fuzzy based sleep scheduling algorithm with machine learning techniques to enhance energy efficiency in

wireless sensor networks. Wireless Personal Communications. 2021;118:3025-3044.

[6] Reena S. Satpute, Avinash Agrawal. (2023). A Critical Study of Pragmatic Ambiguity Detection in Natural Language Requirements. International Journal of Intelligent Systems and Applications in Engineering, 11(3s), 249–259. Retrieved from https://ijisae.org/index.php/IJISAE/article/view/2681

[7] Soni G, Selvaradjou K. Performance evaluation of wireless sensor network MAC protocols with early sleep problem. International Journal of Communication Networks and Distributed Systems. 2020;25(2):123-144.

[8] Annabel LSP, Murugan K. Traffic-based energy efficient MAC protocol for wireless sensor networks. International Journal of Information and Communication Technology. 2016;8(2/3):249.

[9] Liu C, Huang PEI, Xiao LI. TAS-MAC: a traffic-adaptive synchronous MAC protocol for wireless. 2016;12(1):1.

[10] Xie R, Liu A, Gao J. A residual energy aware schedule scheme for WSNs employing adjustable awake/sleep duty cycle. Wireless Personal Communications. 2016;90(4):1859-1887.

[11] Ana Oliveira, Yosef Ben-David, Susan Smit, Elena Popova, Milica Milić. Machine Learning for Forecasting and Predictive Modeling in Decision Science. Kuwait Journal of Machine Learning, 2(3). Retrieved from http://kuwaitjournals.com/index.php/kjml/article/view/199

[12] Luo H, He M, Ruan Z, Chen F. A duty-cycle MAC algorithm with traffic prediction for wireless sensor networks. In: 2017 4th International Conference on Information Science and Control Engineering (ICISCE). IEEE; 2017. pp. 16-19.

[13] Prof. Sharayu Waghmare. (2012). Vedic Multiplier Implementation for High Speed Factorial Computation. International Journal of New Practices in Management and Engineering, 1(04), 01 - 06. Retrieved from http://ijnpme.org/index.php/IJNPME/article/view/8

[14] Usha NS, Hassen M, Saha S. Efficient duty cycle management for reduction of energy consumption in wireless sensor network. In: 2017 2nd International Conference on Electrical & Electronic Engineering (ICEEE). IEEE; 2017. pp. 1-4.

[15] Bouachir O, Ben MA, Touacti F, Crescini D. EAMP-AIDC – energy-aware MAC protocol with adaptive individual duty cycle for EH-WSN. In: 2017 13th International Wireless Communications and Mobile Computing Conference (IWCMC). IEEE; 2017. pp. 2021-2028.

[16] Jemili I, Ghrab D, Belghith A, Mosbah M. Context-aware broadcast in duty-cycled wireless sensor networks. International Journal on Semantic Web and Information Systems. 2017;13(3):48-67.

[17] Guerroumi M, Pathan AK, Derhab A, Badache N, Moussaoui S. MMSMAC: a multi-mode medium access control protocol for wireless sensor networks with latency and energy-awareness. Wireless Personal Communications. 2017;96(4):4973-5010.

[18] Mickus T, Mitchell P, Clarke T. The emergence MAC (E-MAC) protocol for wireless sensor networks. Engineering Applications of Artificial Intelligence. 2017;62(1):17-25.

[19] Haqbeen JA, Ito T, Otsuka T, Arifuzzaman M. Traffic adaptive hybrid MAC with QoS driven energy efficiency for WSNs through joint dynamic scheduling mode. In: 2018 19th IEEE/ACIS International Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing (SNPD). IEEE; 2018. pp. 252-258.