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Original scientific paper

AEETMS: An Attribute-Based Energy Efficient Scheduling Scheme for Enhanced Performance and Longevity in Wireless Sensor Networks

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Abstract: Wireless Sensor Networks (WSNs) are gaining increasing popularity due to their ability to provide comprehensive coverage through sensor nodes that span across an entire infrastructure. These networks are widely employed in military applications, where node mobility and recovery are critical for tasks such as program searching and data prioritization. The performance of WSNs heavily depends on the adoption of efficient scheduling techniques to address energy constraints and communication challenges. In this context, we propose an Attribute-based Energy Efficient Traffic Minimization Scheduling (AEETMS) scheme to enhance network performance and extend its lifetime. Our approach begins by estimating the initial energy of nodes before scheduling transmission channels, thereby improving network longevity. The network topology is first transformed into a mixed graph model, which helps to reduce interference and energy consumption among communication nodes through multitasking table techniques. Next, the initial scheduling is performed using Energy-Aware Data Aggregation (EADA). Unused nodes are efficiently identified and managed to conserve energy and minimize time complexity. The proposed method estimates the Packet Loss Rate (PLR) at each node, prioritizing packet transmission based on importance. High-priority packets are allocated time slots and transmitted continuously, superseding lower-priority data packets. To further optimize data aggregation, selecting an appropriate parent node for packet transmission is crucial. Once data aggregation is optimized, nodes transmit fewer packets, significantly reducing energy consumption. Performance metrics such as energy consumption, throughput, and delivery ratio are analyzed to evaluate the effectiveness of the AEETMS scheme. Comparisons with existing methods demonstrate that AEETMS outperforms them in terms of energy efficiency and network throughput.

Keywords: Attribute based Energy Efficient Traffic Minimization Scheduling (AEETMS); Energy Aware Data Aggregation (EADA); energy consumption; Packet Loss Rate (PLR); Wireless Sensor Networks (WSNs)

1 INTRODUCTION

Wireless technology plays an integral role in modern applications. Advances in research on Wireless Sensor Network (WSN) technology, including its applications in environmental monitoring, military operations, robotics, commercial systems, human-centered applications, medical surveillance, home and industrial automation, and logistics, have led to the development of several innovative protocols, particularly aimed at optimizing energy usage in WSNs. These advancements ensure that data can be accessed anytime and anywhere. Data transfer is a crucial aspect, involving the time-lapse delay in obtaining information from any part of the world. A network can be viewed as a collection of devices connected through various mediums. Each device, known as a node, is capable of sending and receiving data generated by other nodes within the network. The communication path, which connects these nodes, forms the foundation of the network [1-3].

The proposed method focuses on energy control mechanisms for small sensor nodes in wireless networks. By combining various components, this approach enhances energy efficiency at the terminal level when needed, allows the selection of specific components for particular applications, and, most importantly, facilitates the overall optimization of network energy consumption. This optimization is achieved by adjusting combinations of energy consumption components based on the specific application's requirements and conditions [4-6]. The method emphasizes reducing and integrating energy consumption through a generalized model for WSN stabilization and development, ensuring efficient energy usage across the network.

1.1 Problem Statement

The problem statement can be summarized as follows: In WSN, idle energy consumed by the unused nodes should be reduced to conserve energy. There is a tradeoff between to reducing the interference and energy consumption during communication, which need to be resolved.

1.2 Novelty and Contributions of the Work

Novelty and contributions of the work are listed below:

In Energy-Aware Data Aggregation (EADA), unused nodes are efficiently identified and managed to conserve energy.

The proposed method estimates the PLR at each node, prioritizing packet transmission based on importance.

In order to minimize the overhead and data transmission along the high cost nodes, the proposed method minimizes the amount of data redundancy at the aggregator node.

1.3 Organization of Manuscript

This paper is organized as follows: Section 2 deals with the related works along with research gaps. Section 3 presents the proposed methodology. Section 4 presents the results and discussion. Finally, section 5 concludes the paper.

2 RELATED WORKS

Dedicated Energy harvesting (EH) algorithm deals with radio frequency energy harvesting technology. It can provide the lowest energy sensor nodes for a lifetime. In each region, the process-related activity is rated by SN (Sensor Node) and the noise signal is measured using one of the timeless-ensemble entities PCA-SBL [7].

This work considers, but only by selecting a Cluster Head (CH), that the energy efficiency data transfer sensor is the center of energy remaining. Improved Deep Convolutional Neural Network (IDCNN) then identifies the Malicious Node Detection (MND) phase and separates them into malicious list boxes. The Actor-Critic Algorithm used in the unnoticed way of the search strategy is proposed to improve the quality of the project [8].

The path is established, the ZScore method uses the network layer to propose intelligent link quality information from the MAC layer to the Mac layer and conflict information to help intelligent routing results [9]. Multi-Armed Bandit-Based Routing Algorithm (MABRA) transmits battery and data information and its data depending on its neighbor in which each node has the best next hop [10].

Multi-hop co-operative caching of The Information-Centric Networking (ICN) has been explored. By using the cache memory, the delay in fetching the data can be reduced [11]. A novel VariationBayesian Based Event-Triggered Sequential Measurement Fusion (VB-ESMF) evaluator was proposed to create new wireless sensor networks, using the variable Bayesian method to predict pseudo-measurement noise [12].

WSN was used for the global continuous connection state prediction problem of the cluster. Of these, the wireless sensor network for frequent data communication, which significantly increases energy consumption and communication load, should be considered [13]. Energy efficiency is acheived by choosing a CH to show that the data transfer sensor is centered on the rest of the energy [14].

Towards a specific deployment of the optimal maintenance strategy and new sensors, in this article, they have proposed to use the Network Damage Spectrum (D-Spectrum), the purpose of which is to compute the balance between cost and reliability [15]. Dynamic Chain-Based Collaboration (DCBC) based on target movement, which is beyond the target levels and monitoring the chain intersections off certain nodes added to the input node range to adjust the target, the chain can be switched to the target shift position [16].

Exploring Cooperative Opportunities, Reducing Latency and Prolong Network Lifetime algorithm (CORL2), aims to extend the lifespan of the network to improve network longevity and reduce data collection waiting time [17]. On-line monitoring of transformers has been proposed based on genetic algorithm-based analysis of the characteristics of different types of outliers, rapid analysis and anti-line monitoring data detection data system multiple-time sequence flow and contact analysis [14].

Prior knowledge of centralized rating Generalized Eigen Value Decomposition (GEVD) of specific signals at wireless sensor network terminals is introduced on the basis of Multiple-Channel Wiener Filters (MWFs), where nodes are required to have the original guidance matrix [18]. WSNs are an improvement from the traditional Depth-Based Routing (DBR) algorithm for an Energy-Efficient Probabilistic Depth-Based Routing (EEPDBR) guide [19].

In data Collection scheme based on Denoising Autoencoder (DCDA), the data measurement team has used computational and historical perceived data [20] for data restoration. A novel Quorum Time Slot Adaptive Condensing (QTSAC) based MACprotocol has been proposed for Wireless Sensor Networks (WSN) to achieve delay or mitigation and energy efficiency [21].

WSN to reduce network latency has been part of the tank to select Quorum Time Slots (QTSs) rather than protocol based on energy consumption [22]. Using Ant Colony Algorithm improved formula function, and considering the transmission distance, transmission direction, and the rest of the node contact energy, the target node can find the best path to the source node [23].

2.1 Research Gaps

From the existing works, the following research gaps are identified:

The tradeoff between reducing the interference and energy consumption among sensor nodes, was not handled in most of the works.

Most of the scheduling techniques did not consider the priority of packet transmission based on importance.

3 PRPOSED METHODOLOGY

An effective energy management strategy must be designed at the sensor node only after the network level to extend network life as much as possible. Some energy management plans have been proposed to reduce energy consumption due to radio wave levels. As the colliding packets are discarded, the packet reciprocating energy causes further loss. In some cases, energy can be conserved by using external environment, such as using an energy source. However, the behavior of the external energy supply is discontinuous; therefore, the battery needs a backup load. Since the network life cycle is an important aspect of WSN evaluation, the proposed method reduces energy consumption and increases the network life.

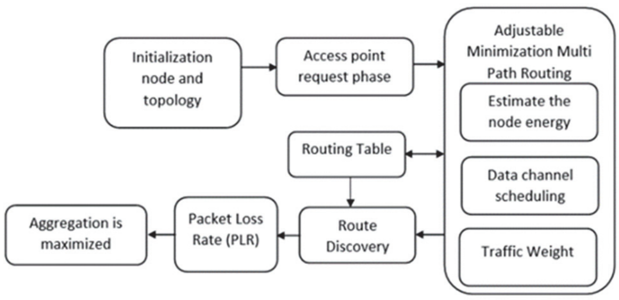

Figure 1 Proposed Diagram

In Fig. 1, the transmission data was collected based on the first energy level which reduces the occurrence of traffic congestion. By designing a diverse network the node formation will differ from a homogeneous network. The specific amount of energy and time channels used for listening in this network are equal to the synchronization period. If a node has not heard timetables from other nodes, the wait period will expire.

3.1 Energy Aware Data Aggregation (EADA)

The data aggregation by the sink should be predefined. The sink aggregates the data sensed by the sensor nodes through the aggregation points. Data aggregation is classified into two types, (i) planned and (ii) unplanned data aggregation. Planned aggregation is the regular data aggregation done by the sink at frequent interval and will not have any impact on the energy consumption of the sensor nodes as it is already defined.

Algorithm:

Step 1: initialize the data as D_i and denote the number of nodes= $\{n_1, n_2, \ldots, n_n\}$

Step 2: Initialize the time interval for data aggregation Da

Step 3: Using counter C, analyze the time interval based energy level to identify $C = 0$

Step 4: Calculate the aggregation level

While (True)

If(C = Da)

Perform data aggregation Da

Else

Increment C

If(interference=True)

Rlocate the data aggregation

Else if (interference = false)

Eliminate the aggregation

End if

End if

Step 5: Transmit the D_i to the processing center or neighbor node, increase the scalability of the network.

If (distance $D > E$) // first node failed (1)

(center distance $D_c == E_c$)

Best Node = n_n

Reduce the unbalanced energy consumption in the network

End if

End if

End while

Unplanned data aggregation takes place only if there is a request by any of the senor nodes. If a particular sensor node has low energy, it responds positive to the broadcast message sent by the sink. The sink relocates itself to the nearest point to aggregate the data from that particular node.

3.2 Data Channel Scheduling and Packet Loss Rate (PLR) Routing Using AEETMS

In order to minimize the overhead data transmission along the high cost nodes, the proposed method minimizes the amount of data redundancy at the aggregator node [24-26]. To minimize the data transmitted by the sensors to the aggregator, each node attempts to send at their alloted slots through the parent nodes. Thus the pieces of information are as follows: (a) Number of incoming packages (ii) Type for each incoming packet.

In this method to estimate the priority of scheduling over the data collection channel, expected PLR is estimated.

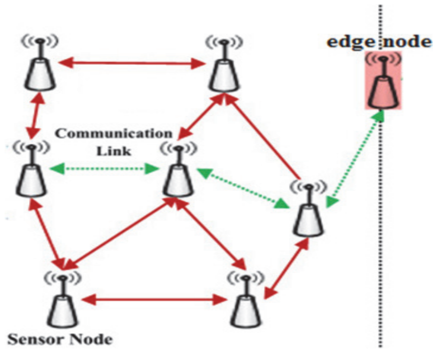

Figure 2 Channel estimatiionmethod

Algorithm:

Input: Routing table, Node ID (n_{id}), Energy (n_{energy})

For each node n

Categorize n based on n_{energy} , and node threshold th_n ,

Compute the sequence edge support $\left(n_{\text{SES}}\right)$.

Compute the channel traffic weight $\left(n_{\text{CTW}}\right)$.

Compute the transmit channel support ($\left(n_{TCS}\right)$.

If ($n_{energy} > th_n$) then

$$n_{SES} = \arg\max\left\{\sum_{i=o}^{n}\frac{\sigma^n + \sigma^{n+1}}{2}\right\} \tag{2}$$

$$n_{CTW} = \frac{\int_{i=1}^{size(Mcc)} \sum Mcc\left(n\left(i\right)\right).Mobility < NMTh}{size\left(Mcc\right)} \tag{3}$$

The transmit channel support is computed based on time-variant data and amount of bandwidth utilized.

$$n_{TCS} = \frac{\oint_{i=0}^{id} \alpha\left(t\right) e^{n(i).\varphi(t)} + n\left(b\right)}{2\pi} \tag{4}$$

End:

$$\text{Packet loss rate} = n_{SES} \times n_{CTW} \times n_{TCS} \tag{5}$$

Packet loss rate , it is equal to $n_{id}\left(n_{\text{CTW}}\right)/p$, where p is the packets sent, n_{id} is the packets received, CTW is the recycled packets (including data packets).

If (EECS < th)

Allot the channel and include the route into the routing table.

End.

The decrease in traffic load will give maximized network lifetime and the proposed MER algorithm will decrease the energy usage. Based on the relevant data, the data will be gathered and then send it to the destination. It will help to lower the transmission energy and consume it. The proposed multi-way feature concept is towards transmission of traffic load across t multiple routes.

4 RESULTS AND DISCUSSION

In this experimental analysis, the wireless sensor network's operation and performance are analyzed with the proposed Attribute based Energy Efficient Traffic Minimization Scheduling (AEETMS) method. In this method the developed java platform and 250 nodes are used.

Table 1 Simulation parameters

Parameters	Value
Platform	NS2
Number of nodes	250
Traffic mode	CBR (Constance Bit Rate)
Simulation Time	10 min

Tab 1 shows the proposed method simulation parameters.

The sensor nodes are deployed over a region of 500 m × 500 m with a 3 second pause. In this proposed method, AEETMS is used to evaluate the metric Packet Delivery Ratio (PDR), Throughput (TH), Energy consumption and scheduling performance.

$$Th = \frac{\text{PacketsReceived (n)} \times \text{Packetsize}}{200} \tag{6}$$

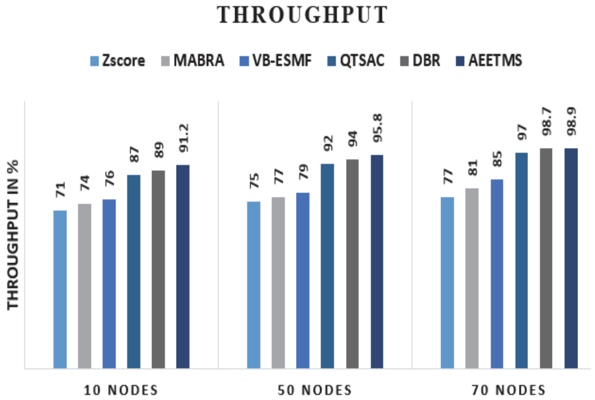

Figure 3 Comparison results of throughput

Fig. 3 shows comparison results of the techniques Zscore [22], Multiarmed Bandit-based Routing Algorithm MABRA [23], Variational Bayesian based Event-triggered Sequential Measurement Fusion VB-ESMF [24], etc, with the proposed AEETMS.

Table 2 Results of Throughput

Method	10 Nodes	50 Nodes	75 Nodes
	Throughput / %		
ZScore	71	75	77
MABRA	74	77	81
VB-ESMF	76	79	85
QTSAC	87	92	97
DBR	89	94	98.7
AEETMS	91.2	95.8	98.9

The proposed method attains throughput of 98.7% for 250 number of nodes, and the methods ZScore, MABRA, VB-ESMF attain 77%, 81%, and 85%, respectively.

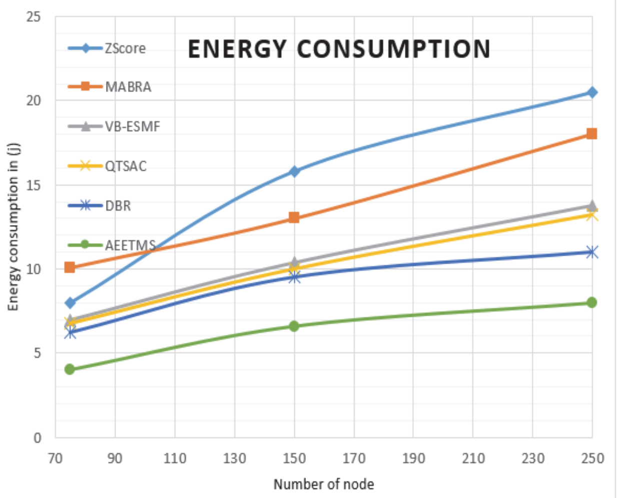

Figure 4 Comparison of Energy Consumption

The results of average energy consumption for different nodes for each 10-50 seconds are shown in Fig. 4. Compared to the ZScore, MABRA, VB-ESMF, and QTSAC, DBR schemes, the proposed AEETMS scheme has the lowest energy consumption of around 4.5 to 8 Joules whereas the energy consumption of ZScore is around 6 - 22 Joules, MABRA is around 10 - 17 Joules, VB-ESMF is 6 - 13 Joules, QTSAC is around 6 - 12 Joules, DBR is around 5.5 to 9 Joules.

Table 3 Results of network life time

Method	75 Nodes	150 Nodes	250 Nodes
	Life time / %		
ZScore	14	17	21
MABRA	16	20	25
VB-SMF	18	22	29
QTSAC	45	60	70
DBR	53	69	78
AEETMS	64	72	89

The AEETMS algorithm attains higher lifetime when compared to the other methods, as shown in Tab. 3.

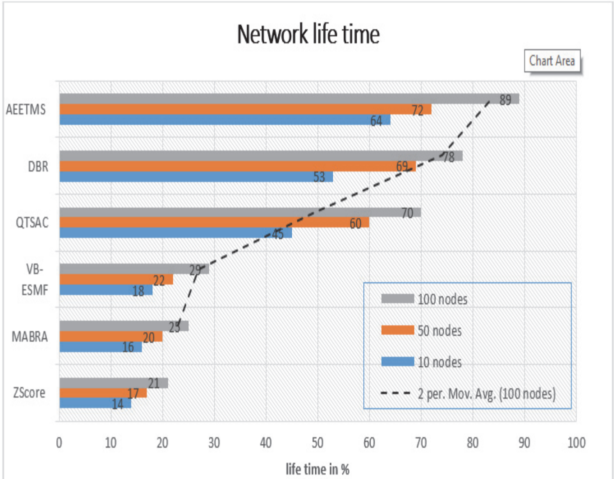

Figure 5 Comparison of network lifetime

Average network lifetimes of existing and proposed methods are shown in Fig. 5. As seen from the figure, the proposed method attains average network lifetime of 89% and the existing methods ZScore, MABRA, VB-ESMF schemes attain 21%, 29%, and 70% of network lifetime.

5 CONCLUSION

This paper addresses the challenges of congestion in load distribution networks and seeks to enhance data rate output in Wireless Sensor Networks (WSNs) by adopting the AEETMS algorithm. The proposed Attribute-based Energy Efficient Traffic Minimization Scheduling (AEETMS) scheme significantly improves the network's lifetime by efficiently managing energy consumption and optimizing data dissemination. By utilizing the remaining energy of sensor nodes and selecting the optimal path with minimal hops, the AEETMS scheme enhances the packet reception rate and eliminates buffering delays. The most notable feature of the proposed AEETMS scheme is its ability to distribute data dissemination tasks to nodes with higher residual energy, effectively preventing packet loss due to energy depletion. This method ensures that the energy of individual nodes is preserved, which contributes to minimizing the energy termination factor and extends the overall network lifespan. In contrast to traditional methods, this energy-aware approach improves the stability and reliability of data transmission in WSNs. Performance analysis of the AEETMS scheme reveals significant improvements in key metrics, including throughput, energy consumption, and network lifetime. The throughput level achieved by the AEETMS is 98.9%, ensuring high data delivery efficiency. Additionally, the energy consumption per node is optimized, with energy use measured at 8 seconds for a 250 J energy capacity. The network's operational lifetime is also extended by 89%, demonstrating the effectiveness of the proposed scheme in mitigating energy-related issues and enhancing overall network performance. In conclusion, the AEETMS algorithm offers a robust solution for improving WSN efficiency, ensuring both energy conservation and sustained network operation.

Future work: There are chances of various kind of faults which may occur during data aggregation. Hence the future works deals with designing a fault tolerant data aggregation for WSN.

6 REFERENCES

[1] Muthulakshmi, K., Balaji, S. P., Stephe, S., & Vijayalakshmi, J. (2024). Adaptive wind driven optimization-based energy-aware clustering scheme for wireless sensor networks. *Technical Gazette*, *31*(2), 466-473. https://doi.org/10.17559/TV-20230610000715

[2] Verma, G. & Sharma, V. (2021). A novel RF energy harvester for event-based environmental monitoring in wireless sensor networks. *IEEE Internet of Things Journal*. http://dx.doi.org/10.1109/JIOT.2021.3097629.

[3] Gupta, V. & De, S. (2021). Energy-efficient edge computing framework for decentralized sensing in WSN-assisted IoT. *IEEE Transactions on Wireless Communications*. http://dx.doi.org/10.1109/TWC.2021.3062568.

[4] Chandrasekaran, K. & Chinnasamy, K. (2023). Query-based location aware energy-efficient secure multicast routing for wireless sensor networks using fuzzy logic. *Tehnički vjesnik*, *30*(6), 1791-1798. https://doi.org/10.17559/TV-20230307000418

[5] Zhu, B., Bedeer, E., Nguyen, H. H., Barton, R., & Henry, J. (2021). UAV trajectory planning in wireless sensor networks for energy consumption minimization by deep reinforcement learning. *IEEE Transactions on Vehicular Technology*. https://doi.org/10.1109/TVT.2021.3102161.

[6] Muthu, T. & Kalimuthu, V. K. (2023). Seagull Optimization-based Feature Selection with Optimal Extreme Learning Machine for Intrusion Detection in Fog Assisted WSN. *Tehnički Vjesnik*, *30*(5). https://doi.org/10.17559/TV-20230130000295

[7] Patel, N. R., Kumar, S., & Singh, S. K. (2021). Energy and collision aware WSN routing protocol for sustainable and intelligent IoT applications. *IEEE Sensors Journal*. https://doi.org/10.1109/JSEN.2021.3076192

[8] Zhao, T., Wang, L., Chin, K., & Yang, C. (2020). Routing in energy harvesting wireless sensor networks with dual alternative batteries. *IEEE Systems Journal*. https://doi.org/10.1109/JSYST.2020.3007166

[9] Yang, Y. & Song, T. (2021). Energy-efficient cooperative caching for information-centric wireless sensor networking. *IEEE Internet of Things Journal*. https://doi.org/10.1109/JIOT.2021.3088847

[10] Younus, M. U., Khan, M. K., & Bhatti, A. R. (2021). Improving the software-defined wireless sensor networks routing performance using reinforcement learning. *IEEE Internet of Things Journal*. https://doi.org/10.1109/JIOT.2021.3102130.

[11] Yang, F., Shi, L., & Zheng, L. (2021). Event-triggered globally sequential fusion estimation for clustered wireless sensor networks with variational Bayesian. *IEEE Sensors Journal*. https://doi.org/10.1109/JSEN.2021.3092888.

[12] Kumar, M., Mukherjee, P., Verma, K., Verma, S., & Rawat, D. B. (2021). Improved deep convolutional neural network based malicious node detection and energy-efficient data transmission in wireless sensor networks. *IEEE Transactions on Network Science and Engineering*. https://doi.org/10.1109/TNSE.2021.3098011.

[13] Boardman, N. T. & Sullivan, K. M. (2020). Time-based node deployment policies for reliable wireless sensor networks. *IEEE Transactions on Reliability*. https://doi.org/10.1109/TR.2020.3047757

[14] Premkumar, M., Sundararajan, T. V. P., & Vinoth Kumar, K. (2019). Various defense countermeasures against DoS attacks in wireless sensor networks. *International Journal of Scientific and Technology Research*, *8*(10).

[15] Feng, J. & Zhao, H. (2021). Dynamic nodes collaboration for target tracking in wireless sensor networks. *IEEE Sensors Journal*. https://doi.org/10.1109/JSEN.2021.3093473

[16] Wen, W., Chang, C. Y., Wu, S. J., & Roy, D. S. (2021). CORL2: Exploring cooperative opportunities, reducing latency, and prolonging network lifetime for data collection using mobile sinks in wireless sensor networks. *IEEE Sensors Journal*. https://doi.org/10.1109/JSEN.2021.3091545

[17] Gurumoorthy, K. B., Gopinath, S., & Vinoth Kumar, K. (2019). Ant colony optimization and genetic algorithm integrated load balancing approach for MANET. *International Journal of Innovative Technology and Exploring Engineering*, *8*(5), 399-405.

[18] Chen, X., Hu, Y., Dong, Z., Zheng, P., & Wei, J. (2021). Transformer operating state monitoring system based on wireless sensor networks. *IEEE Sensors Journal*. https://doi.org/10.1109/JSEN.2021.3050763

[19] Vanrompaey, R. & Moonen, M. (2021). Distributed adaptive signal estimation in wireless sensor networks with partial prior knowledge of the desired sources steering matrix. *IEEE Transactions on Signal and Information Processing over Networks*. https://doi.org/10.1109/TSIPN.2021.3098941

[20] Balakrishnan, S. & Kumar, K. V. (2023). Hybrid Sine-Cosine Black Widow Spider Optimization based Route Selection Protocol for Multihop Communication in IoT Assisted WSN. *Tehnički Vjesnik*, *30*(4), 1159-1165. https://doi.org/10.17559/TV-20230201000306

[21] Zhang, M. & Cai, W. (2020). Energy-efficient depth-based probabilistic routing within 2-hop neighborhood for underwater sensor networks. *IEEE Sensors Letters*, *4*(6),

1-4. https://doi.org/10.1109/LSENS.2020.2995236

[22] Li, G., Peng, S., Wang, C., Niu, J., & Yuan, Y. (2019). An energy-efficient data collection scheme using denoising autoencoder in wireless sensor networks. *Tsinghua Science and Technology*, *24*(1), 86-96. https://doi.org/10.26599/TST.2018.9010002

[23] Feng, Y., Guo, L., Fu, X., & Liu, N. (2019). Efficient mobile energy replenishment scheme based on hybrid mode for wireless rechargeable sensor networks. *IEEE Sensors Journal*, *19*(21), 10131-10143. https://doi.org/10.1109/JSEN.2019.2928169

[24] Kalimuthu, V. K. & Muthu, T. (2023). Oppositional Coyote Optimization based Feature Selection with Deep Learning Model for Intrusion Detection in Fog-Assisted Wireless *Sensor Network. Acta Montanistica Slovaca*, *28*(2). https://doi.org/10.46544/AMS.v28i2.18

[25] Lim, S. J. & Shin, B. M. (2024). A novel chain formation scheme for balanced energy consumption in WSN-based IoT network. *Tehnički vjesnik*, *31*(2), 525-533. https://doi.org/10.17559/TV-20220706031646

[26] Vellingiri, E., Kalimuthu, V. K., & Samydurai, G. (2021). Fuzzy logic based DSR trust estimation routing protocol for MANET using evolutionary algorithms. *Tehnički Vjesnik*, *28*(6).

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