

RASE-WSN: ADAPTIVE RED PANDA OPTIMIZED SECURE ROUTING IN WIRELESS SENSOR NETWORK

Jafar Ahmad Abed Alzubi ^{1,*}, Giovanni Pau ²

¹ Associate Professor, Department of Electronics and communications, Al-Balqa Applied University, School of Engineering, Jordan

² Associate Professor, Faculty of Engineering and Architecture, Kore University of Enna- Italy, 94100

*Corresponding e-mail: j.zubi@bau.edu.jo

Abstract – Wireless Sensor Networks (WSNs) consist of uncountable tiny sensor nodes for transmitting data, used to track and monitor various applications. Scalability and secure data transmission pose two greater challenges in WSN. In this paper, a new Redpanda Optimized Secure routing in WSN (RASE-WSN) has been proposed towards enhancing packet delivery secure routing in WSN. It uses Fuzzy K-means clustering that divides sensor nodes (SN) into groups as clusters. Each cluster will be having a Cluster Head (CH) node, selected through the goat optimization algorithm. RPO will carry out the secure and optimized routing to enhance packet delivery ratio. Finally, the confidential transmission of the data goes to the Base Station. The proposed approach (RASE-WSN) saved energy by 42% when compared against the SHO-CH, CGRP as well as HHOCFR approaches.

Keywords – Wireless Sensor Networks, Red Panda optimization, Fuzzy K-means clustering, Goat Optimization Algorithm

1. INTRODUCTION

WSN consists of small devices scattered across a geographic area, tracking various ambient physical factors at different locations, such as temperature, sound, vibration, pressure, motion, and pollution [1]. These nodes gather information about the environment in which they are installed and send it either directly or indirectly to a BS for further processing [2]. These tiny devices rely on the battery for energy and can be recharged and even replaced. Nevertheless, WSNs are facing problems such as lower energy for node and uneven network coverage, which strongly restrict their performances [3].

An efficient way to deal with these problems is through the implementation of well-designed routing protocols. Different Structured routing, including cluster-based, chain-based, and hybrid methods, have been proposed for further extending the lifetime of the network and energy efficiency. In cluster-based routing, sensor nodes are divided into clusters, and the CH is designated to merge and forward the data from clusters to the sink [4,5].

In order to strengthen WSNs against the difficulties of finite energy supplies and node malfunctions, research into

hierarchical cluster-based routing and network partitioning approaches is being conducted with the Final objective of enhancing dependability and network lifespan Trust-based techniques must be extremely resilient against malevolent nodes in order to guarantee the security of WSNs [6-8].

As a practical way to control the ability of WSNs through efficient energy management and data routing, optimization algorithms have seen significant development and expansion in the field of research [9,10]. But given the dynamic network topology's constant change, conventional optimization techniques have proven useless for dealing with multi-objective issues including energy limitations and real-time deployment difficulties. Consequently, a single intelligent framework is needed that can control large-scale, dynamic data routing under a range of network situations and coordinate rapid exploration capabilities [11-13]. The suggested work's primary contributions are as follows:

- The Key goal of the study is to provide an effective method for cluster- based routing in WSN to provide secure routing and efficient packet delivery ratio (PDR).
- The Implemented solution utilizes a Fuzzy K-means clustering that divides sensor nodes into group as clusters for time- consuming and energy efficiency.
- The CH node is the component of every cluster which is picked by using goat optimization algorithm.
- The secure and optimized routing is done by red panda optimization (RPO) which enhances packet delivery ratio.
- The effectiveness of the suggested technique is valued utilizing parameters like Network Lifetime, residual energy, PDR, Energy consumption and Throughput.

Here is the arrangement of the rest of the document. Part II provides a detailed discussion of the literature review. Part III describes the clustered routing that was developed in

WSN. Part IV presents the findings and observations from the experiment. Part V contains the conclusion and recommendations.

2. LITERATURE REVIEW

In 2024, Abose, T.A., [14] suggested an energy efficient stable election protocol (EE-SEP) and residual energy LEACH (IMP-RES-EL) to increase the effectiveness of clustering algorithms in energy savings for WSN. Additionally, the results demonstrate that the IMP-RES-EL algorithm effectively extends the lifetime of the network while reducing transmissions and energy dissipation between SN and BS.

In 2025, Prakash, V., [15] suggested an energy-efficient clustered routing method built especially for heterogeneous WSNs that makes use of the spotted hyena optimization for cluster head selection (SHO-CH). The experimental findings demonstrate that the proposed strategy increases the throughput by 173%, network lifetime by 152%, and WSN stability duration by 168%.

In 2024, Roberts, M.K., [16] suggested an enhanced dual-phased architecture for energy-efficient, cluster-based routing in WSNs to tackle the crucial problem of striking a balance between dependable energy consumption and network performance.

In 2024, Patil, V.B. and Kohle, S., [17] proposed a Genetic Routing System (CGRP), a genetic algorithm-based routing mechanism, as an efficient way to boost WSN scalability. The results generated by this setup can provide insights into the potential performance of the protocol in real-world scenarios, which may lead to additional modifications and enhancements.

In 2024, Rekha and Garg, R., [18] proposed a hybrid K-means and Lion optimization approach for energy-efficient

clustering-based routing (K-LionER), which increases network lifetime and energy efficiency. The proposed K-LionER protocol increases the network lifespan by 10 to 48 percent.

In 2025, Rawat, P., [19] proposed An energy-efficient Cluster Routing Protocol for Heterogeneous Network (CPHN) to improve the lifespan of the wireless sensor network, and it is used to select the most energy-efficient node to act as the cluster head. The outcome demonstrates that the suggested protocol performs better than a number of current clustering methods in terms of stability period, throughput, and network longevity.

In 2024, Rao, A.K., [20] suggested a blockchain-enabled, optimized, secure cluster-based routing system for smart agriculture that guarantees strong security measures, extended network lifetime, and effective resource use. The suggested method shows a much faster rate of convergence and a greater detection rate, between 75% to 90%.

3. PROPOSED METHODOLOGY

In this portion, a novel RASE-WSN approach has been proposed to optimized secure routing in WSN. Initially the datas are gathered from sensor nodes that can collaboratively monitor and transmit information. A Fuzzy K-means clustering divides sensor nodes into several independent groups, referred as clusters. Each cluster consists of a CH node and several Candidate nodes. Nodes that have the greatest Fitness Parameter among the candidates such as residual energy, node degree and mobility are selected as cluster heads (CHs) accountable for managing and transmitting data within each cluster. CH selection is based on Goat Optimization rules inspired by agility, terrain climbing ability and leader-following behavior. The secure and optimized routing is done by red panda optimization. Finally, the data is securely transmitted to the BS.

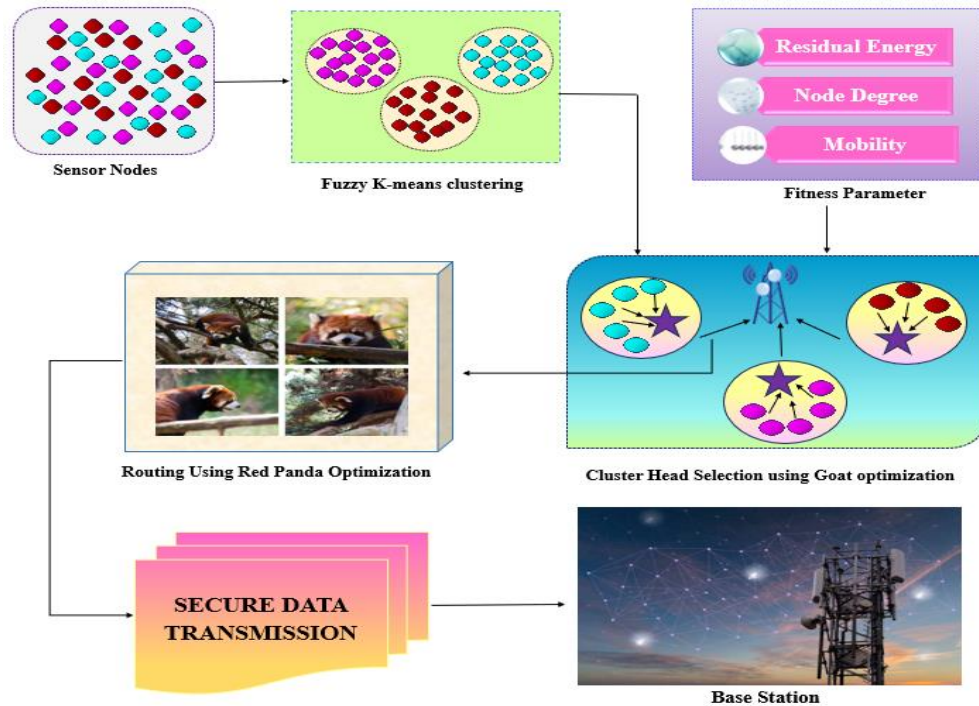


Figure 1. Proposed RASE-WSN Methodology

3.1. Data collection

WSN are composed of wirelessly connected SN. GPS, cameras, and radar are some of the places that SN collects data. However, the electromagnetic frequency, memory, and battery power of SNs are limited. It serves as a conduit between SNs and end users.

3.2 Fuzzy K-means Clustering

A viable way to minimize node energy consumption and increase longevity of networks is through clustering tactics. It is commonly known that clustering, which groups nodes into clusters, is an effective routing technique in WSNs. Here, Fuzzing K-means Clustering is used to grope the cluster nodes. In order to assign memberships to each sample for clustering, FKM algorithms employ a Euclidean distance measure, which can only produce good clustering results free of outliers.

$$A = \sum_{j=1}^K \sum_{i=1}^N t_{ij}^v s_{ij} \quad (1)$$

Where m is the fuzzifier parameter, k is the number of clusters, N is the number of data points, and s_{ij} is the squared Euclidean distance between data point X_i and cluster representative.

3.3 Cluster Head Selection using Goat optimization

A coordinator node or CH, oversees each cluster and is chosen based on particular fitness criteria such as residual energy, node degree and mobility using GOAT optimization inspired metaheuristic optimization technique inspired by goats' adaptive foraging, strategic movement, and parasite avoidance. All cluster's sensors send the pertinent data to CHs on a regular basis or following an incident. After that, CHs send the data either directly or via a series of hops to a BS.

3.3.1 Exploration Phase (Adaptive Foraging Strategy)

Each goat explores the search space in this phase by randomly moving in different directions, inspired by its foraging behavior. The new position of each goat is updated using:

$$Z_i^{s+1} = Z_i^s + \alpha \cdot P \cdot (UB - LB) \quad (2)$$

Where, Z_i^s is the position of goat i at iteration s , α is the exploration coefficient, controlling the intensity of random movements. P is a random variable drawn from a Gaussian distribution $N(0,1)$, ensuring randomness in movement. $(UB - LB)$ Scales the movement according to the size of the search space. This equation ensures that goats randomly explore different regions before committing to a specific grazing spot.

3.3.2. Exploitation Phase (Movement Towards the Best Goal)

To refine solutions, goats gradually move toward the best solution so far, mimicking the tendency of goats to migrate toward optimal grazing areas. The exploitation phase is defined as:

$$Z_i^{s+1} = Z_i^s + \beta \cdot (Z_{best}^s - Z_i^s) \quad (3)$$

Where, Z_{best}^s is the best-performing goat at iteration s , β is the exploitation coefficient, regulating movement strength toward the best solution. This equation ensures that goats converge toward promising solutions while maintaining diversity.

3.4 Routing via Red Panda Optimization

Routing approach can assist address the primary issue of dependable energy-aware data transmission in WSN. In this approach, a new technique RPO is used to select the routing in the best possible way. This bio-inspired metaheuristic algorithm that imitates how red pandas behave in the wild. The suggested RPO method is mathematically represented in two stages: Red pandas' feeding behavior is simulated by exploration, and their movement as they climb trees is simulated by exploitation.

$$X_i^{ql} : X_{ij}^{ql} = X_{ij} + M \cdot (FSF_{ij} - V \cdot X_{ij}) \quad (4)$$

where, the new location of the i th candidate has been displayed by X_i^{ql} , its j th dimension has been indicated by X_{ij}^{ql} , the selected source of nutrition for the i th candidate has in its j th dimension has been displayed by FSF_{ij} .

3.5. Secure Data Transmission

The Goat Optimization Algorithm is used to pick the CH after fuzzy K-means clustering is finished, while the Red Panda Optimization Algorithm is used to route the data. After these procedures are finished, the collected data is safely sent to the BS for additional processing.

4. RESULT AND DISCUSSION

The suggested model has been solved and put into practice. To assess the effectiveness of the suggested strategy, experiments were carried out. The outcomes were compared to the SHO-CH, CGRP, and HHOCFR approaches that are currently in use.

4.1. Evaluation Metrics

This section explains the measures that were utilized to assess the recommended strategy. Utilizing residual energy, throughput, packet delivery ratio, energy consumption and network lifetime. The efficacy of the suggested approach has been assessed.

$$\text{Residual Energy } ff_2 = \sum_{i=1}^D \frac{1}{E_{SCH_i}} \quad (5)$$

$$\text{Energy Consumption } E_{re}(l) = lE_{elec} \quad (6)$$

4.2. Performance Analysis

According to the experimental results, the suggested APPROACH technique has been compared with current techniques for secure data transmission to BS, including SHO-CH, CGRP and HHOCFR.

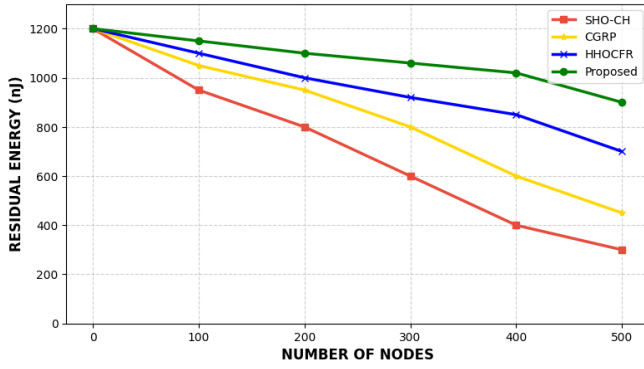


Figure 2. Residual Energy

To balance the CH energy consumption, on the other hand, the suggested RASE-WSN approach can choose the best RN to share the data transmission work of CH in various scenarios. Because multi-hop routing between relay nodes lessens the likelihood that an RN would send data straight to the BS, RN energy consumption is also reduced Figure 2.

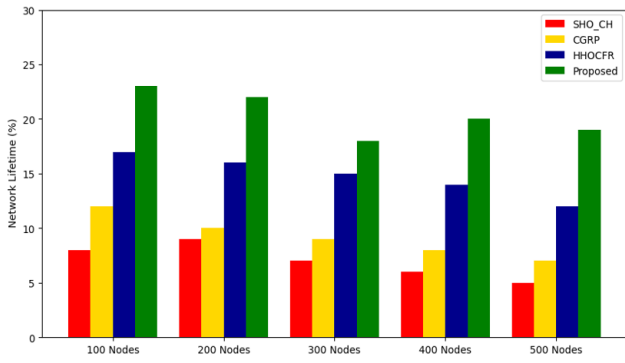


Figure 3. Network lifetime

The suggested model's network lifespan improvement as a percentage is displayed in Figure 3. A comparison is made between the suggested model and the most advanced SHO-CH and hybrid models. With increases of 27%, 24%, and 21% for 100, 200, 300, 400, and 500 nodes, respectively, the suggested RASE-WSN methodology greatly increased network longevity.

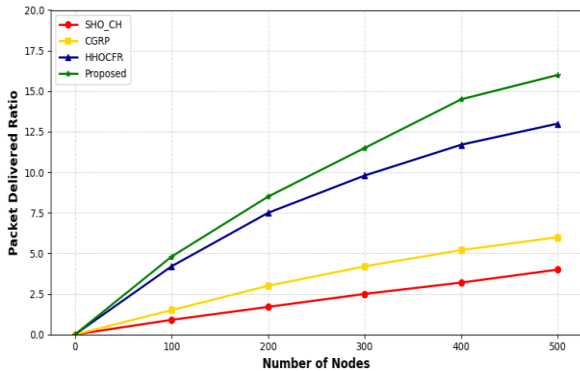


Figure 4. Packet delivery ratio

Figure 4 illustrates how a high PDR is commonly accepted and favored as a crucial evaluation criterion for measuring the reliability of the network and the general effectiveness of WSNs by ensuring that data packets are delivered to their destination without errors. When compared to SHO-CH, CGRP, and HHOCFR, the suggested RASE-WSN technique consistently improves PDR for a range of node count densities.

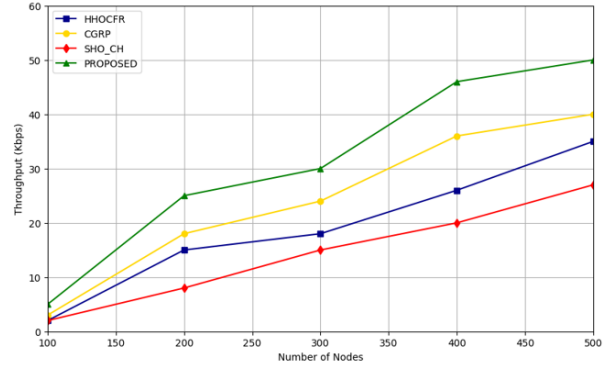


Figure 5. Throughput

To improve their reach and viability for managing large data loads, many WSN systems today demand high throughput. In comparison to SHO-CH, CGRP, and HHOCFR, the suggested RASE-WSN methodology consistently delivers superior throughput for different node counts, according to the overview of data given in Fig. 5.

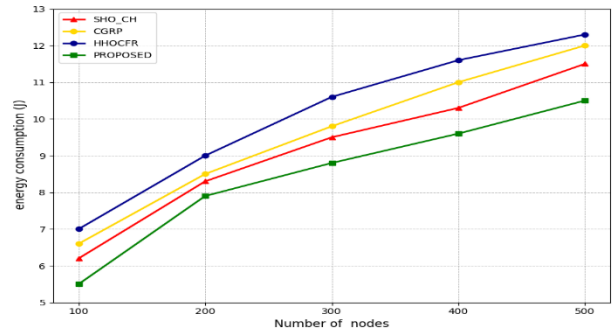


Figure 6. Energy Consumption

The duration of the sensor nodes in WSNs is greatly reliant on their limited-energy batteries, which make data computation, transmission, and reception difficult. When compared to SHO-CH, CGRP, and HHOCFR, the suggested RASE-WSN technique consistently produces reduced energy consumption.

5. CONCLUSION

This paper presents RASE-WSN approach, a novel clustering and routing protocol aimed at enhancing the secured routing path in WSN. The suggested RASE-WSN approach effectively increase the network energy conservation and extending the life of networks. A Fuzzy K-means clustering divides sensor nodes into group as clusters. Each cluster consists of a CH node. CH selection is based on Goat Optimization. Each cluster's sensor provides CH with

the pertinent data then either directly or over a series of hops, CHs send the data to a BS. The secure and optimized routing is done by red panda optimization and the data is securely transmitted to the BS. Network lifetime, packet delivery, residual energy, network throughput, and energy consumption were among the performance indicators utilized to assess the suggested approach. The tested model outperformed the SHO-CH model by 450%, the CGPR model by 33%, and the HHOCFR procedure by 27%, according to the experimental data. More sensor density and intricate propagation models will be added in the future

CONFLICTS OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

FUNDING STATEMENT

Not applicable.

ACKNOWLEDGEMENTS

The author would like to express his heartfelt gratitude to the supervisor for his guidance and unwavering support during this research for his guidance and support.

REFERENCES

- [1] B. Zeng, S. Li, and X. Gao, "Threshold-driven K-means sector clustering algorithm for wireless sensor networks", *EURASIP Journal on Wireless Communications and Networking*, vol. 2024, no. 1, pp. 68, 2024. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [2] N. Sha. "Basketball technical action recognition based on a combination of capsule neural network and augmented red panda optimizer", *Egyptian Informatics Journal*, vol. 29, pp. 100603, 2025. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [3] D.A. Elalfy, E. Gouda, M.F. Kotb, V. Bureš, and B.E. Sedhom, "Frequency and voltage regulation enhancement for microgrids with electric vehicles based on red panda optimizer", *Energy Conversion and Management*, vol. 25, pp. 100872, 2025. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [4] H. Wang, X. Huang, and Y. Wu, "GD3N: Adaptive clustering-based detection of selective forwarding attacks in WSNs under variable harsh environments", *Information Sciences*, vol. 665, pp. 120375, 2024. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [5] H. Meng, X. Liu, R. Liu, Y. Zheng, A. Hou, S. Liu, W. He, Y. Wang, A. Wang, Q. Guo, and J. Peng. "Decellularized laser micro-patterned osteochondral implants exhibit zonal recellularization and self-fixing for osteochondral regeneration in a goat model", *Journal of Orthopaedic Translation*, vol. 46, pp.18-32, 2024. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [6] T.A. Abose, V. Tekulapally, K.T. Megersa, D.C. Kejela, S.T. Daka, and K.A. Jember, Improving wireless sensor network lifespan with optimized clustering probabilities, improved residual energy LEACH and energy efficient LEACH for corner-positioned base stations. *Heliyon*, vol. 10, no. 14, 2024. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [7] P. Divya, and B. Sudhakar, "Route Optimization and Optimal Cluster Head Selection for Cluster-Oriented Wireless Sensor Network Utilizing Circle-Inspired Optimization Algorithm", *International Journal of Computational Intelligence Systems*, vol. 17, no. 1, pp. 302, 2024. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [8] A.R. Gaidhani, and A.D. Potgantwar. A review of machine learning-based routing protocols for wireless sensor network lifetime. *Engineering Proceedings*, vol. 59, no. 1, pp. 231, 2024 [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [9] M. Singh, S. Kaur, and A. Gaba, "An Efficient Cluster Based Routing Scheme for Delay and Packet Loss Reduction in WSN". [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [10] R. Shyamsundar, and M. Harshavathan, "A clustered routing for maximizing the lifetime of underwater wireless sensor network using gravitational search algorithm", *Results in Engineering*, vol. 25, pp. 104470, 2025. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [11] A. Hossan, and J. Islam, "Secondary cluster head-based SEP in heterogeneous WSNs for IoT applications", *IET Communications*, vol. 18, no. 11, pp. 679-688, 2024. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [12] A. Kumar, N. Gaur, and A. Nanthaamornphong. "Wireless optimization for sensor networks using IoT-based clustering and routing algorithms", *PeerJ Computer Science*, vol. 10, p.e2132, 2024. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [13] S.B. Shalu, and M.V.R. Sarobin, "An optimized clustering approach for wireless sensor networks using improved squirrel search algorithm (ISSA)", *IEEE Access*, 2024. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [14] T.A. Abose, V. Tekulapally, D.C. Kejela, K.T. Megersa, S.T. Daka, and K.A. Jember. "Optimized Cluster Routing Protocol with Energy-Sustainable Mechanisms for Wireless Sensor Networks", *IEEE Access*, 2024. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [15] V. Prakash, S. Pandey, and B.M. Sahoo, "Enhanced energy-efficient cluster-based routing with spotted hyena optimization in heterogeneous WSNs", *EURASIP Journal on Wireless Communications and Networking*, vol. 2025, no. 1, pp. 1-24, 2025. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [16] M.K. Roberts, J. Thangavel, and H. Aldawsari, "An improved dual-phased meta-heuristic optimization-based framework for energy efficient cluster-based routing in wireless sensor networks", *Alexandria Engineering Journal*, vol. 101, pp. 306-317, 2024. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [17] V.B. Patil, and S. Kohle. A high-scalability and low-latency cluster-based routing protocol in time-sensitive WSNs using genetic algorithm. *Measurement: Sensors*, vol. 31, pp. 100941, 2024. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [18] R. Rekha and Garg, "K-LionER: meta-heuristic approach for energy efficient cluster-based routing for WSN-assisted IoT networks", *Cluster Computing*, vol. 27, no. 4, pp. 4207-4221, 2024. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [19] P. Rawat, G.S. Rawat, H. Rawat, and S. Chauhan. Energy-efficient cluster-based routing protocol for heterogeneous wireless sensor network. *Annals of Telecommunications*, vol. 80, no. 1, pp. 109-122, 2025. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [20] A.K. Rao, K.K. Nagwanshi, and M.K. Shukla. An optimized secure cluster-based routing protocol for IoT-based WSN structures in smart agriculture with blockchain-based integrity checking. *Peer-to-Peer Networking and Applications*, vol. 17, no. 5, pp. 3159-3181, 2024 [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]

AUTHORS



Jafar A. Alzubi is an associate professor at Al-Balqa Applied University, School of Engineering, Jordan. Received Ph.D. degree in Computer Engineering - Computer Networks Security from Swansea University, Swansea - UK (2012). Master of Science degree (Hons.) in electrical and computer engineering from New York Institute of Technology, New York - USA (2005). And Bachelor of Science degree (Hons.) in Electrical Engineering, majoring in Electronics and Communications, from the University of Engineering and Technology, Lahore - Pakistan (2001). Jafar works and researches in multi and interdisciplinary environment involving Cyber Security, Machine Learning, classifications and detection of Web scams, Internet of Things, Wireless Sensor Networks, , Networks Security, Cryptography. A cumulative research experience for over ten years, resulted in publishing more than seventy papers in highly impacted journals. Currently, he is senior IEEE member and serving as an editor and editorial board member and reviewer in many prestigious journals in computer engineering and sciences field. Jafar is listed among the top 2% of scientists in the world according to the recently released list by Stanford University in 2022.



Giovanni Pau is an Associate Professor at the Kore University of Enna, Faculty of Engineering and Architecture, where he specializes in the field of Information Engineering (SSD ING-INF/05 - 09/H1). He holds a Ph.D. in Technologies and Management of Aeronautics Infrastructures (XXVII Cycle, 2015) from Kore University of Enna. His academic background includes a Master's Degree (2010) and a Bachelor's Degree (2008) in Telematic Engineering, earned from Kore University of Enna and the University of Catania, respectively. Since 2011, Professor Pau has held multiple academic and research roles at Kore University, progressing from Research Fellow to Adjunct Professor, then Assistant Professor, and currently Associate Professor since 2020. In addition to his academic activities, Giovanni Pau is a licensed professional engineer (Information sector), registered with the Engineers' Professional Order of Enna (n. 735).

Arrived: 14.05.2025

Accepted: 19.06.2025