Chain based routing approach to improve lifespan in wireless body area networks

Lamia Sidhoum, Mourad Hadjila, Rachid Merzougui
STIC laboratory, Department of Telecommunications, Faculty of Technology, University of AbouBakr Belkaid, Tlemcen, Algeria

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ABSTRACT

One of the most significant limitations in wireless body area network (WBAN) is the requirement for low energy usage. For this reason, several routing techniques and protocols have been put out to provide an efficient means of energy saving during communication. In this work, we propose three approaches based on the formation of a chain of sensor nodes using a matrix of distances. The first approach is based on forming a single chain using the shortest distances. The second and the third consist in changing the position of the sink by forming a single cluster using the fuzzy C-means (FCM) method and the center of the latter constitutes the new position of the sink. In comparison to RE-ATTEMPT and PSOBAN, the third proposed chain-based approach has enabled a remarkable energy savings, which may have a big impact on the network's entire lifespan.

Corresponding Author:

Lamia Sidhoum
STIC laboratory, Department of Telecommunication, Faculty of Technology
University of AbouBakr Belkaid
Chetouane, Tlemcen, Algeria
Email: lamiasidhoum8@gmail.com

1. INTRODUCTION

The increase in health problems around the world has resulted in a growing demand for health services and emergency medical response systems. Traditional diagnostic services have become insufficient to meet the needs. Remote and real-time health monitoring is one of the smart and effective solutions that make it possible to continuously identify any patient concerns [1]. Telehealth help to improve the quality of life of patients by lessening the strain on the health system and the expense of public health, reducing displacement, time spent by doctors and laboratories, and providing greater peace of mind to patients [2].

In recent years, wireless body area networks (WBANs) have gained great interest around the world with their skills in patient health monitoring services at home, in ambulances or in hospitals. Several wireless biosensor nodes that can be placed inside or on top of the patient's body make up a WBAN system. Biosensor nodes are intended to measure a range of physiological characteristics, including body temperature, blood oxygen saturation, heart rate, blood pressure (BP), and respiration rate [3]. The detected data is sent to the sink via wireless communication links on the body. The sink processes information collected by the sensor node and transfers it to an Internet cloud network for remote review by health care providers [4], [5].

Extending network lifetime is a major challenge in WBANs due to the low energy values and low battery capacity of biosensors. A small sensor node's minimal power supply is its primary drawback [6]. Sensor nodes use a significant quantity of energy allocated for patient information acquisition, processing and transmission [7]. For this, numerous energy-efficient protocols were implemented, including those based on the clustering procedure, which partitions the network into a collection of clusters with members that are regular nodes and a cluster leader [8], [9]. Cluster leaders will be responsible for assembling each member's data, doing data aggregation, and sending important data to the sink. Since the cluster head will see a concentration of data traffic loads, choosing the right cluster head is essential to lowering energy usage and extending network lifespan [4], [10].

In this work, we propose three approaches based on the formation of a chain using a matrix of distances. The first approach is based on forming a single chain using the shortest distances. The second and the third consist in changing the position of the sink by forming a single cluster using the fuzzy C-means (FCM) method and the center of the latter constitutes the new position of the sink.

Several works have been carried out in the context of routing in wireless sensor networks. A non-exhaustive list of these works is briefly described below. Wu *et al.* [11], authors proposed an improved chain-based clustering hierarchical routing (ICCHR) algorithm based on LEACH algorithm. This protocol avoids the issue of internal nodes dying too quickly by having the cluster head (CH) nodes send signals to the base station (BS) indirectly through the use of the chain technique rather than directly to the BS. The results of this study can serve as a guide for WSN networking in an intricate orchard environment. Rani *et al.* [12] proposed a protocol named E-CBCCP (energy efficient chain based routing protocol for underwater wireless sensor networks). In this protocol, the energy of cluster heads, relay nodes (RNs) and cluster coordinators (CCOs) has been taken into account in this protocol during data transmission and after a predetermined amount of time, the roles of CHs, CCOs, and RNs are changed to preserve the burden on the nodes. To transfer data from SNs to CHs, RNs are chosen using a location-independent method using hop-to-hop counting. The MATLAB simulations support the methodology that decreased the sensor nodes' communication costs and thus increased the network's lifetime. Ding *et al.* [13], for ultra-wideband (UWB) WBAN networks, the authors put forth a realistic nonlinear power consumption model. When the transmitter and receiver are on the same part of the body and there is no obvious path loss, direct communication can reduce energy consumption. However, when the transmitter and the receiver are positioned on distinct parts of the body, at an appropriate relay position and with a larger transmission distance, cooperative communication can greatly improve energy efficiency.

The researches [14], [15] looked into an energy-effective routing system for heterogeneous WBAN based on the particle swarm optimization technique. By using a particle swarm optimization technique to optimize residual energy and distance, the proposed protocol selects the relay node between the source nodes and the sink and transmits the data packets in a multi-hop manner. Results from the experiments demonstrate that the suggested protocol perfectly balances WBAN energy efficiency and lowering the number of relay nodes. Ahmad *et al.* [16], introduce RE-ATTEMPT, a thermal unaware energy-efficient multi-hop protocol for WBANs that is based on reliability enhanced-adaptive threshold. A static deployment of wireless sensors that are positioned based on energy levels forms the basis of the suggested routing protocol. While routine data uses multi-hop transmission, emergency data is provided directly. To reduce the delay factor, the RE-ATTEMPT protocol chooses the route with the fewest hops possible. To maximize network lifetime, a linear programming model is utilized, and MATLAB simulations are run to predict path loss. The simulation results show that in terms of throughput, packet loss, and network longevity, the proposed protocol outperforms the existing protocol. Arora *et al.* [17], presented an investigation approach of best placement of the central node in a WBAN, which is calculated using the reflection coefficient (S11) of an antenna mounted on the body and the path loss model IEEE 802.15.6 CM3A between communication nodes with the evaluation of link quality metrics such as signal/noise ratio (SNR), bit error ratio (BER), and received signal strength indicator (RSSI). Ullah *et al.* [18] presented the energy –efficient harvested- aware clustering and cooperative routing protocol (E-HARP) protocol which offers a new technique based on several attributes for dynamic cluster head selection and cooperative routing. This method is broken down into two stages; the first is choosing the optimal cluster head by calculating the cost factor (CF) from the sensor node's residual energy, the transmission power required, the communication link's signal-to-noise ratio (SNR), and the network's overall energy loss. The sensor nodes work together to route the data in the next stage, preventing redundant data packet transmission and saving node energy.

The remainder of the document is structured as follows: an introduction and related works are presented in section 1. Then, the network model and the energy model are described in section 2. Section 3 presents the simulation and evaluation. We talk about the comparison research in section 4. The text is finally concluded in section 5, which lists the achievements of this work.

2. METHOD

This section is designed to elaborate the proposed method which is based on forming a chain of sensor nodes using a distance matrix for energy-efficient routing in WBANs. Additionally, the network model and the energy model-which are utilized to show how well the suggested scheme works-are described in the subsections that follow. The network's efficiency in terms of throughput, residual energy, and network lifetime is optimized by the suggested model.

2.1. Network topology and model

An intelligent ambulance environment for WBAN level 1 communication is presented in this paper. The WBAN system in the ambulance will include one sink and eight biosensor nodes. Bilandi *et al*. [14] introduced this concept. In this work, we will consider that:
- After deployment, all nodes are immobile except the sink. Additionally, they are aware of vital details about themselves, such as their current position and remaining energy.
- Each node has the same calculation and detection capacity.

2.2. Energy model

For the purpose of estimating the node energy used in data transmission, the proposed work uses a first-order radio model [19], [20]. The transmission energy consumption of the nodes to relay a data packet (number of bits W) at a distance "D" can be approximated as follows using the first-order radio model:

$$E_{Tx}\,(W, D) = E_{TX-elect} \times W + E_{Amp} \times \eta \times D^{\eta} \times W \quad (1)$$

The energy usage of the nodes upon receiving a data packet containing "W" bits is also considered by the same model in the following manner:

$$E_{RX}(\,W) = E_{EX-elect}\, \times W \quad (2)$$

The energy used by the nodes to aggregate the "W" number of bits could be calculated using the same model as:

$$E_{DA}\,(W) = E_{DA}\, \times W \quad (3)$$

Here, $E_{TX-elect}$, $E_{RX-elect}$, and E_{Amp} denote the energy consumption per bit node in the operating node transmitter, receiver, and amplifier circuits, respectively. E_{DA} indicates the data aggregation energy consumption per bit. Additional path loss that is presented over the biological communication channels is represented by the path loss index. Node processing energy losses are disregarded in the suggested method since they pale in comparison to data transport [21].

3. SIMULATION AND EVALUATION

In this work, we propose three approaches based on the formation of a chain of sensor nodes using the following distance matrix (the value 99.0000 is written to avoid having a zero at the diagonal). The first approach is based on forming a single chain using the shortest distances. The second and the third consist in changing the position of the sink by forming a single cluster using the FCM method and the center of this cluster constitutes the new position of the sink. FCM is a data clustering method where an N clusters are created from a data collection [22], [23]. The FCM algorithm is utilized for the analysis that takes into account the separation between the various data points and the center of each cluster; that is, a data point close to a cluster's center will have a high degree of membership in that cluster, while a data point farther from a cluster's center will have a low degree of membership [24], [25].

$$d = \begin{bmatrix} 99.0000 & 0.3000 & 0.8443 & 0.7533 & 0.5590 & 0.5025 & 0.8757 & 0.2236 & \mathbf{0.1803} \\ 0.3000 & 99.0000 & 0.8006 & 0.7845 & 0.5025 & 0.5590 & 0.8927 & 0.1414 & \mathbf{0.1803} \\ 0.8443 & 0.8006 & 99.0000 & 0.2062 & 0.3007 & 0.3720 & \mathbf{0.1838} & 0.7035 & 0.9080 \\ 0.7533 & 0.7845 & 0.2062 & 99.0000 & 0.3081 & \mathbf{0.2508} & 0.1237 & 0.6629 & 0.8538 \\ 0.5590 & 0.5025 & 0.3007 & 0.3081 & 99.0000 & 0.2000 & 0.3992 & \mathbf{0.4031} & 0.6083 \\ 0.5025 & 0.5590 & 0.3720 & 0.2508 & \mathbf{0.2000} & 99.0000 & 0.3734 & 0.4272 & 0.6083 \\ 0.8757 & 0.8927 & 0.1838 & \mathbf{0.1237} & 0.3992 & 0.3734 & 99.0000 & 0.7765 & 0.9713 \\ 0.2236 & \mathbf{0.1414} & 0.7035 & 0.6629 & 0.4031 & 0.4272 & 0.7765 & 99.0000 & 0.2062 \\ 0.1803 & 0.1803 & 0.9080 & 0.8538 & 0.6083 & 0.6083 & 0.9713 & 0.2062 & 99.0000 \end{bmatrix}$$

The evaluation of our algorithm is carried out using a simulation model under MATLAB. The model is composed of 8 sensor nodes and 1 sink. With the exception of the sink, it is presumed that every node stays in the same location during the simulation. Table 1 provides a summary of the simulation parameters utilized in our simulation model. The process of our algorithm is as follows:

a. Choice of sink position by forming a cluster using the FCM method.
b. A distance matrix was calculated for all nodes in the network including the sink.
c. If a distance is equal to 0, i.e. the distance of a node from itself, we replace this distance by a value for example equal to 99.
d. In each row of the matrix, we extract the position of the minimum value using the indices (row index, column index). This pair indicates the link between the node represented by the line and that represented by the column.
e. Thus, we form the shortest paths between the nodes leading to the sink.

Table 1. Simulation parameters

Parameters	Values
Initial energy	0.6 J
Transmission energy	16.7 nJ/bit
Reception energy	36.1 nJ/bit
Amplification energy	1.97 nJ/bit
Data aggregation energy	5 nJ
Packet size	4000 bits
Max number of rounds	10000
Number of nodes	8
Number of Clusters	1

These three approaches are considered for the construction of a chain of 8 sensors with 1 sink within a WBAN. In the first approach, the sink remains stationary (see Figure 1). Thus maintaining its initial position throughout the operation of the network. The sink is halfway between nodes 1 and 2 but node 2 is closer to node 8. Figures 2(a) and 2(b) represent the residual energy and the number of alive nodes respectively from the first approach. Where we can notice that the order of the dead nodes is as follows: node 5(round 6812), node 4(round 6874), node 6(round 6887), node 2(round 6893), node 8(round 6900), node 7(round 6902), node 3(round 8873), and node 1 (round 8948).

The second approach introduces a dimension of mobility by moving the sink to a specific position, precisely at coordinates $x = 0.3$ and $y = 0.7$ (see Figure 3). This mobility of the sink can be exploited to optimize data collection in specific areas of the body. Thus, improving the quality of measurements and allowing targeted monitoring of vital parameters.

Figures 4(a) and 4(b) represent the residual energy and the number of alive nodes respectively from the second approach. Where we can notice that the order of the dead nodes is as follows: node 4(round 6874), node 1(round 6882), node 8(round 6886), nodes 5 and 6 (round 6888), node 2(round 6900), node 7(round 6903), and node 3 (round 8896). The third approach goes further by moving the sink to a different position, at coordinates $x = 0.4$ and $y = 0.7$ (see Figure 5). This change in position of the sink offers new perspectives in terms of residual energy consumption, network lifetime and throughput. We performed a comparison between the three approaches and two already existing routing protocols, namely Re-ATTEMPT and a novel particle swarm optimization based protocol for wireless body area networks (PSOBAN). Our observations revealed that the third approach demonstrates promising results in terms of residual energy, network lifetime and throughput.

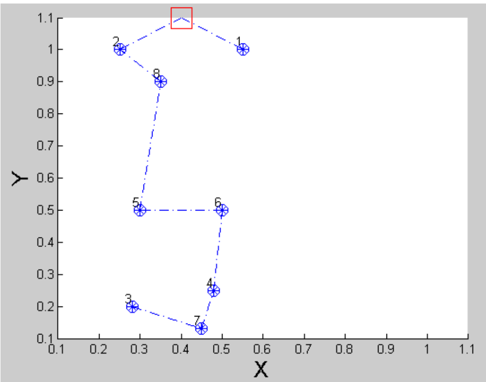
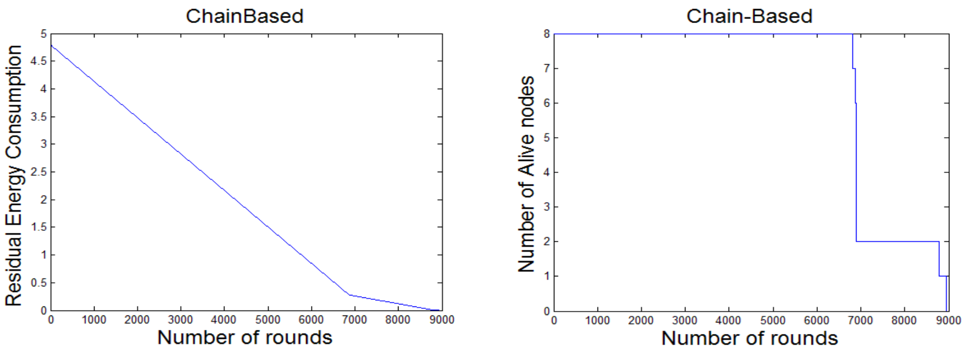


Figure 1. Chain construction without moving the sink



(a) (b)

Figure 2. First approach results in terms of: (a) residual enregy and (b) number of alive nodes

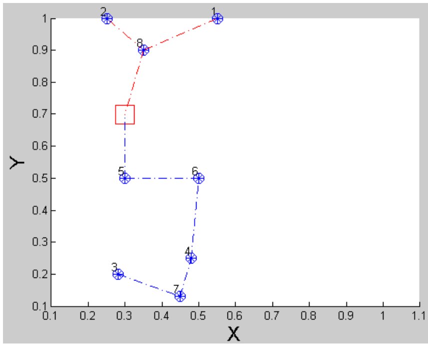
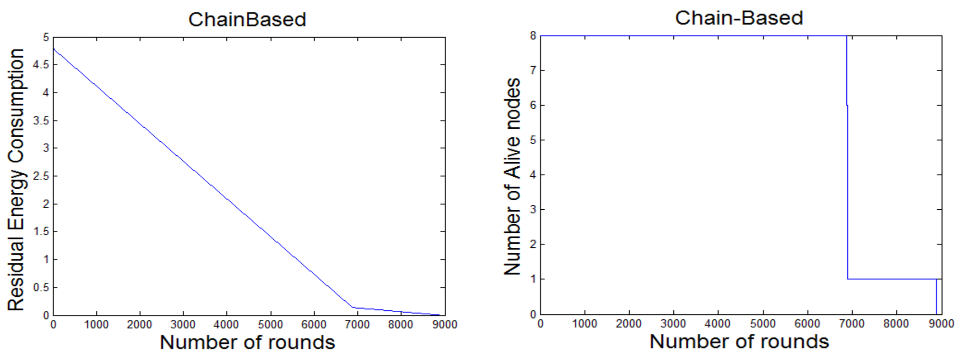


Figure 3. Chain construction by moving the sink to (0.3; 0.7)



(a) (b)

Figure 4. Second approach results in terms of: (a) residual enregy and (b) number of alive nodes

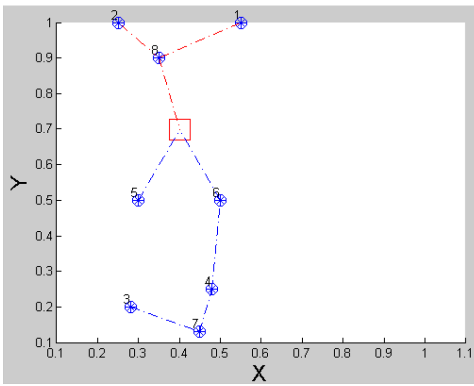


Figure 5. Chain construction by moving the sink to (0.4; 0.7)

4. COMPARATIVE STUDY

As previously mentioned, we will compare our third approach, which relies on a chain of sensors, with the PSOBAN [14], [15] and Re-ATTEMPT [16] routing protocols. The following subsections identify the key performance indicators that will be used in the comparison. Table 2 represents a comparative analysis of PROPOSED 3 and its competitors in terms of residual energy, first node died (FND), last node died (LND), and throughput.

Table 2. Comparative analysis of PROPOSED 3 and its competitors in terms of various parameters

Parameters	Protocols				
	Re-attempt	PSOBAN	Proposed1	Proposed2	Proposed3
First node died (rounds)	2480	3800	6836	6874	6836
Last node died (rounds)	8912	8995	8948	8896	8930
Throughput (packets received)	21523	30900	30189	29829	37001
Residual energy (J)					
At 2000 rounds	2.6894	3.3661	3.4849	3.4464	3.4861
At 4000 rounds	1.6029	2.2095	2.1698	2.0928	2.1722
At 6000 rounds	0.9041	1.2652	0.8547	0.7392	0.8583
At 8000 rounds	0.3359	0.3990	0.1202	0.0616	0.1239

4.1. Stability period

The first evaluation step consists in analyzing the number of dead nodes during the simulation. According to Figure 6, we notice that for PSOBAN [14], [15] and RE-ATTEMPT [16], the first node dies after a specific period of time. On the other hand, in the case of PROPOSED3, this same node dies after a different period of time and considerably later than that for RE-ATTEMPT and PSOBAN. As a result, we may conclude that the third method (PROPOSED3) has longer duration of stability than RE-ATTENT and PSOBAN.

4.2. Residual energy

The second stage of evaluation consists in analyzing the energy consumption. We measured the residual energy for each round as the simulation progresses. The simulation results shown in Figure 7 demonstrate that PROPOSED 3 conserves energy reserves during the stability period, allowing for increased transmission of data packets to the sink. This highlights the energy efficiency of PROPOSED 3 during this period, in comparison with the PSOBAN [14], [15], and RE-ATTEMPT [16] protocols.

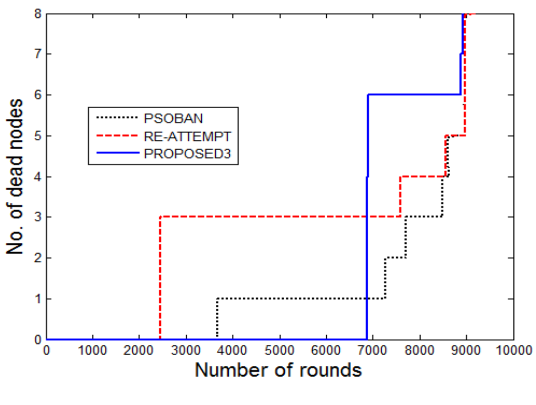


Figure 6. Number of dead nodes vs. rounds

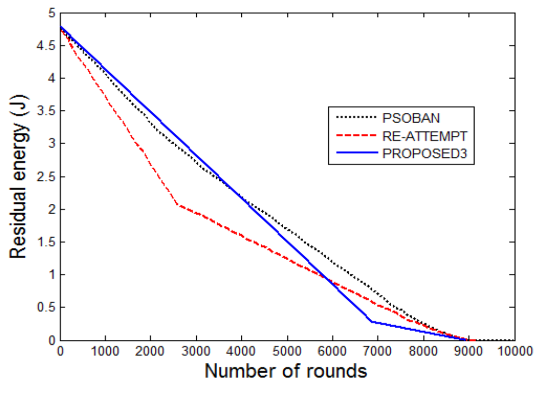


Figure 7. Residual energy vs. rounds

4.3. Throughput

The simulation results, which are clearly displayed in Table 2, show that PROPOSED3 performs admirably when compared to its rivals PSOBAN [14], [15] and RE-ATTEMPT [16]. While RE-ATTEMPT and PSOBAN managed a certain throughput over the duration of ten thousand rounds, PROPOSED3 managed a very high and remarkable throughput. These data categorically shows how well the PROPOSED3 performs in terms of efficiency and data transmission capability.

5. CONCLUSION

The primary limitation of WBAN is its requirement for low power usage. Therefore, the creation of energy-efficient protocols becomes crucial to prolong the lifetime of the network. However, their main challenge is to have effective mechanisms to achieve energy-efficient networks. Based on the aforementioned limitations, we have developed a chain-based approach for WBAN networks. The superior performance of PROPOSED3 in terms of high throughput, energy efficiency, and optimal data packet management makes it a highly competitive and relevant approach for WBANs. However, this work is only a first step toward creating ever more efficient WBAN networks. The application of the nomad algorithm (NA) as a routing algorithm in a WBAN network with a ring topology should be investigated in further research. Integrating the Nomad algorithm into our approach could improve the management of energy resources and optimize data routing.

REFERENCES

[1] T. Sundararajan, M. Sumithra, and R. Maheswar, "A Novel Smart Routing Protocol for Remote Health Monitoring in Medical Wireless Networks," *Journal of Healthcare Engineering*, vol. 5, no. 1, pp. 95–122, Mar. 2014, doi: 10.1260/2040-2295.5.1.95.

[2] A. Dumka and A. Sah, "Smart ambulance system using concept of big data and internet of things," in *Healthcare Data Analytics and Management*, Elsevier, 2019, pp. 155–176, doi: 10.1016/B978-0-12-815368-0.00006-3.

[3] T. Wu, F. Wu, J.-M. Redoute, and M. R. Yuce, "An Autonomous Wireless Body Area Network Implementation Towards IoT Connected Healthcare Applications," *IEEE Access*, vol. 5, pp. 11413–11422, 2017, doi: 10.1109/ACCESS.2017.2716344.

[4] A. Choudhary, M. Nizamuddin, and V. K. Sachan, "A Hybrid Fuzzy-Genetic Algorithm for Performance Optimization of Cyber Physical Wireless Body Area Networks," *International Journal of Fuzzy Systems*, vol. 22, no. 2, pp. 548–569, Mar. 2020, doi: 10.1007/s40815-019-00751-6.

[5] S. M. B. Al-Sabti, A. A. Abdulateef, C. Atilla, and A. H. Mohammed, "Wireless Body Region Networks Abnormality Identification And Energy Saving A Study," in *2020 4th International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT)*, Oct. 2020, pp. 1–5, doi: 10.1109/ISMSIT50672.2020.9254481.

[6] R. Cavallari, F. Martelli, R. Rosini, C. Buratti, and R. Verdone, "A Survey on Wireless Body Area Networks: Technologies and Design Challenges," *IEEE Communications Surveys & Tutorials*, vol. 16, no. 3, pp. 1635–1657, 2014, doi: 10.1109/SURV.2014.012214.00007.

[7] A.-S. Porret, T. Melly, C. C. Enz, and E. A. Vittoz, "A low-power low-voltage transceiver architecture suitable for wireless distributed sensors network," in *2000 IEEE International Symposium on Circuits and Systems. Emerging Technologies for the 21st Century. Proceedings (IEEE Cat No.00CH36353)*, 2000, vol. 1, pp. 56–59, doi: 10.1109/ISCAS.2000.857025.

[8] C. Nakas, D. Kandris, and G. Visvardis, "Energy Efficient Routing in Wireless Sensor Networks: A Comprehensive Survey," *Algorithms*, vol. 13, no. 3, p. 72, Mar. 2020, doi: 10.3390/a13030072.

[9] P. Azad and V. Sharma, "Cluster Head Selection in Wireless Sensor Networks under Fuzzy Environment," *ISRN Sensor Networks*, vol. 2013, pp. 1–8, Feb. 2013, doi: 10.1155/2013/909086.

[10] R. Zhang and J. Yu, *Energy-Efficient Algorithms and Protocols for Wireless Body Sensor Networks*. Cham: Springer International Publishing, 2020, doi: 10.1007/978-3-030-28580-7.

[11] H. Wu, H. Zhu, L. Zhang, and Y. Song, "Energy Efficient Chain Based Routing Protocol for Orchard Wireless Sensor Network," *Journal of Electrical Engineering & Technology*, vol. 14, no. 5, pp. 2137–2146, Sep. 2019, doi: 10.1007/s42835-019-00216-8.

[12] S. Rani, S. H. Ahmed, J. Malhotra, and R. Talwar, "Energy efficient chain based routing protocol for underwater wireless sensor networks," *Journal of Network and Computer Applications*, vol. 92, pp. 42–50, Aug. 2017, doi: 10.1016/j.jnca.2017.01.011.

[13] J. Ding, E. Dutkiewicz, X. Huang, and G. Fang, "Energy efficient cooperative transmission in single-relay UWB based body area networks," in *2015 IEEE International Conference on Communications (ICC)*, Jun. 2015, pp. 1559–1564, doi: 10.1109/ICC.2015.7248546.

[14] N. Bilandi, H. K. Verma, and R. Dhir, "PSOBAN: a novel particle swarm optimization based protocol for wireless body area networks," *SN Applied Sciences*, vol. 1, no. 11, pp. 1–14, Nov. 2019, doi: 10.1007/s42452-019-1514-0.

[15] P. Bedi, S. Das, S. B. Goyal, P. K. Shukla, S. Mirjalili, and M. Kumar, "A novel routing protocol based on grey wolf optimization and Q learning for wireless body area network," *Expert Systems with Applications*, vol. 210, Dec. 2022, doi: 10.1016/j.eswa.2022.118477.

[16] A. Ahmad, N. Javaid, U. Qasim, M. Ishfaq, Z. A. Khan, and T. A. Alghamdi, "RE-ATTEMPT: A New Energy-Efficient Routing Protocol for Wireless Body Area Sensor Networks," *International Journal of Distributed Sensor Networks*, vol. 10, no. 4, Apr. 2014, doi: 10.1155/2014/464010.

[17] N. Arora, S. H. Gupta, and B. Kumar, "An approach to investigate the best location for the central node placement for energy efficient WBAN," *Journal of Ambient Intelligence and Humanized Computing*, vol. 14, no. 5, pp. 5789–5800, May 2023, doi: 10.1007/s12652-020-01847-w.

[18] Z. Ullah *et al.*, "Energy-Efficient Harvested-Aware Clustering and Cooperative Routing Protocol for WBAN (E-HARP)," *IEEE Access*, vol. 7, pp. 100036–100050, 2019, doi: 10.1109/ACCESS.2019.2930652.

[19] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-efficient communication protocol for wireless microsensor networks," in *Proceedings of the 33rd Annual Hawaii International Conference on System Sciences*, 2000, vol. vol.1, p. 10, doi: 10.1109/HICSS.2000.926982.

[20] S. Ahmed *et al.*, "Co-LAEEBA: Cooperative link aware and energy efficient protocol for wireless body area networks," *Computers in Human Behavior*, vol. 51, pp. 1205–1215, Oct. 2015, doi: 10.1016/j.chb.2014.12.051.

[21] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless sensor networks: a survey," *Computer Networks*, vol. 38, no. 4, pp. 393–422, Mar. 2002, doi: 10.1016/S1389-1286(01)00302-4.

[22] S. Ghosh and S. Kumar, "Comparative Analysis of K-Means and Fuzzy C-Means Algorithms," *International Journal of Advanced Computer Science and Applications*, vol. 4, no. 4, 2013, doi: 10.14569/IJACSA.2013.040406.

[23] V. Sreenivasa Rao, "Comparative Investigations and Performance Analysis of Fcm and Mfpcm Algorithms on Iris Data," *Indian Journal of Computer Science and Engineering*, vol. 1, no. 2, pp. 145–151, 2010.

[24] J. Nayak, B. Naik, and H. S. Behera, "Fuzzy C-Means (FCM) Clustering Algorithm: A Decade Review from 2000 to 2014," in *Computational Intelligence in Data Mining-Volume 2: Proceedings of the International Conference on CIDM*, 2015, pp. 133–149, doi: 10.1007/978-81-322-2208-8_14.
[25] C. Xu, P. Zhang, B. Li, D. Wu, and H. Fan, "Vague C-means clustering algorithm," *Pattern Recognition Letters*, vol. 34, no. 5, pp. 505–510, Apr. 2013, doi: 10.1016/j.patrec.2012.12.001.

BIOGRAPHY OF AUTHORS

Lamia Sidhoum received her Master degree in Telecommunications at the University of Tlemcen, (Algeria) in 2018. Currently she is a PhD student at the same University and a member of STIC laboratory. Her doctoral research center around wireless body sensor networks and internet of things. She can be contacted at email: lamiasidhoum8@gmail.com.

Mourad Hadjila received his PhD degree in Telecommunications in 2014 at the University of Tlemcen, Algeria. Since 2002 he works as Lecturer and member of STIC laboratory at the same University. He is habilitaded to supervise research since 2019 in Telecommunications. His research interest is in: wireless sensor networks, IoT, Intrusion detection system, artificial intelligence, machine learning and deep learning. He can be contacted at email: mourad.hadjila@univ-tlemcen.dz.

Rachid Merzougui received the Dr. Eng. degree in Systems and Networks of Telecommunications from the University of Tlemcen (Algeria) in *2006*, his PhD in Telecommunication from the University of Tlemcen (Algeria) in 2011. Since 2013, he has been Assistant Professor of Communication Engineering and Telecommunication Networks. He has obtained the degree of professor in 2019.He has served on the several responsibilities: Scientific Committees of the Telecommunication Departments of the University of Tlemcen, doctoral training committee. His research interest now is development of mobile applications networks and services. He can be contacted at email: merzrachid@yahoo.fr.