Energy-efficient routing protocol for wireless sensor networks based on progressive and concentric clusters

Adil Hilmani[1], Mohamed Koundi[2], Yassine Sabri[3], Abderrahim Maizate[1]
[1]RITM, ESTC/CED-ENSEM, University Hassan II, Casablanca, Morocco
[2]ASE-Lab, École Nationale des Sciences Appliquées, Ibn Tofail University, Kenitra, Morocco
[3]Laboratory of Metrology and Information Processing (LMTI), Faculty of Sciences, Ibn Zohr University, Agadir, Morocco

Article Info

Article history:

Received Jan 20, 2023
Revised Apr 28, 2023
Accepted Jun 30, 2023

Keywords:

Clustering
Energy efficiency
Internet of things
Multi-hop communication
Power consumption
Routing protocol
Wireless sensor network

ABSTRACT

Smart parking is common in contemporary cities. These smart parking lots are outfitted mostly with wireless sensor networks (WSNs), which are used to detect, monitor, and collect data on the availability status of all existing parking spaces in a given area. Sensors make up WSN, which may gather, process, and transmit informations to the sink. However, the power and communication limitations of the sensors have an effect on the performance and quality of the WSNs. The decrease in the battery and the energy of the nodes causes a decrease in the life of the nodes and also of the entire WSN network. In this article, we present a routing protocol that implements an efficient and robust algorithm allowing the creation of clusters so that the base station can receive data from the entire WSN network. This protocol adopts a reliable and efficient algorithm allowing to minimize the energy dissipation of the sensors and to increase the lifetime of the WSN. In comparison to alternative parking lot management protocols already in use, the simulation results of the proposed protocol are effective and robust in terms of power consumption, data transmission reliability, and WSN network longevity.

Corresponding Author:

Adil Hilmani
RITM, ESTC/CED-ENSEM, University Hassan II
El Jadida Street, B.P. 8012 Oasis Casablanca, Morocco
Email: adilhilmani@gmail.com

1. INTRODUCTION

With numerous applications in various facets of daily life, such as industrial control, environmental sensing, military operations, and parking management, the internet of things (IoT) has become a highly advanced and deployed technology in recent years [1]–[6]. The poor management of parking spaces in busy areas such as city centers, offices, and institutions has contributed to severe traffic congestion problems in many cities worldwide. To solve this problem, smart parking solutions have been implemented using wireless sensor networks (WSN) to detect available parking spaces and transmit the information to the sink (BS or sink) using either a direct transmission or multi-hop communication. These WSNs comprise wireless sensor nodes deployed within a parking area to collect and transmit necessary information.

The use of wireless communication in wireless sensor nodes can reduce their performance, quality, and lifespan due to energy consumption when the battery is low [7]–[9]. To solve this problem, clustering is the most popular and effective technique to increase the lifetime of the WSN. Clustering dramatically reduces network energy consumption and increases node lifetime by alternating the role of the cluster head (CH) among its cluster members [10]–[12].

The rest of the paper is structured as follows: an overview of related work is provided in section 2. In section 3, we give an overview of the suggested system. We describe in section 4 the characteristics of the proposed protocol, including these different parts. In section 5, we present the simulation of the suggested protocol and an analysis of its effectiveness. In the final section, the conclusions are represented.

2. RELATED WORK

In recent years, several algorithms and several protocols have been developed allowing sensors to create a cluster topology in order to minimize energy dissipation and increase the lifetime of the WSN network [13]–[15]. Energy-efficient-low energy adaptive clustering hierarchy (EE-LEACH) [16] is a routing protocol that allows sensor data to be aggregated and sent to the base station with the object of reducing power dissipation and increasing node lifetime and of the network. All sensor nodes in this article have the same capacity and similar properties.

Schaffer and Buttyán [17] proposes a new routing protocol named panel, allowing to geographically divide the network into several clusters. This protocol chooses the cluster heads (CH) in each cluster in order to group and send all information from all cluster nodes to the sink node or base station. Hatamian *et al*. [18] presented a protocol based on the onion approach named centralized genetic clustering protocol (CGC) which reduces the energy consumption of CHs by dividing the entire network into several onion layers. Lamine [19], the communication modes of the single-hop and multi-hop wireless sensor network are used by the author to propose a hybrid routing strategy, which makes it possible to create a tree network topology whose sensors can send their data to the base station.

Wang *et al*. [20] proposed a clustering routing based on energy-efficient compressive detection (EECSR). The phases of cluster formation, spanning tree construction, and data collecting are all included in the EECSR. The process of choosing group leaders and joining member nodes to those leaders is carried out during the grouping phase. An exterior gateway routing protocol (EGRP) routing protocol algorithm based on mobile sinks has been proposed by the authors of the article [21]. This protocol uses two mobile sinks to receive all the data from the sensors available in the WSN network. The mobile sinks move in two overlapping orbits and stop to acquire data in intervals predetermined by the sensors.

The authors of the article [22] proposed a two-level cluster-based routing approach. There are two phases in the process. In the first phase, two types of nodes are chosen CH and bitcoin cash (BCH) according to their residual energy, their concentric placement, the distance to the BS. Clustering overhead is reduced by using BCHs. In the second phase of the protocol, each CH chooses its next hop to the base station taking into account the remaining energy, the number of existing clusters and the distance to the base station. Moon *et al*. [23], the authors propose a routing protocol that uses an algorithm that implements a star network topology so that nodes can send their data directly to the base station. Sharma *et al*. [24] proposed an efficient and robust mode-switched routing algorithm (MSGR) for wireless sensor networks that allows to partition the detection area into virtual grids of the same size in order to reduce the power consumption.

3. SYSTEM OVERVIEW

3.1. Network and radio models

To implement our routing protocol, we designed a WSN composed of M homogeneous sensors with a gateway serving as sinks deployed in a capture area. The sensors are denoted s_i, where i is between 1 and N, and are collectively called $S = \{s\_1, s\_2, \ldots\ldots, s\_M\}$. The following are the network model's primary attributes: i) the nodes are inexpensive and don't require a lot of money to deploy; ii) the sensor nodes have limited energy resources; iii) power control can be utilized by nodes during data transmission; iv) the sensor nodes are immobile; and v) GSM or long-range communication systems are not integrated into the nodes for direct location transmission to the BS.

3.2. Energy consumption models

In WSNs, two transmission models are commonly used: free-space transmission and two-ray ground transmission [25]–[27]. Free space transmission occurs when the transmitter and receiver nodes are in a straight line of sight. However, when there isn't a direct way for transmission between the nodes and the electromagnetic wave must travel via multiple paths and at various times to reach the receiver, the two-ray ground transmission model is use [28]–[30]. Our proposed algorithm allows the base station to receive data from all network nodes by consuming different amounts of energy according to the proposed energy model, which is a revised version of [27]. The model includes the energy consumed to transmit data and the energy consumed to receive data by the sensors. Further, the threshold distance is calculated using (3).

$$E_{Tx}((l,d)=\begin{cases} l \times (e_t + \in_{fs} \times d^2)\ d \le d_{th} \\ l \times (e_t + \in_{amp} \times d^4)\ d \le d_{th} \end{cases} \quad (1)$$

$$E_{Rx}(l,d) = l \times e_r \quad (2)$$

$$d_{th} = \sqrt{\frac{\in_{fs}}{\in_{amp}}} \quad (3)$$

Where, l is data packet length, d is the node distance, e_t is the transmission energy, e_r is the energy consumed during the reception, $\in_{fs}$ is the energy consumed during transmission in free space, $\in_{amp}$ is the energy consumed during the amplification of the transmitted signal. d_th is the threshold distance illustrated in the following equation.

4. PROPOSED PROTOCOL

Our suggested protocol consists of three phases: i) collection of node positions and formation of clusters, ii) selection of cluster heads, and iii) data aggregation and transmission. These phases ensure efficient communication in the network by organizing nodes into clusters, optimizing energy consumption, and aggregating data for transmission.

4.1. Collection of node positions and formation of clusters

The network of sensors is divided into several concentric circular layers (L1, L2, ...) in the initial phase, all of which are centered on the base station. These levels are built up gradually, with the base station constituting the initial layer (Layer 1). To accomplish this, the base station (BS) sends a hello message to each node inside its boundary in an effort to transmit their coordinates. The BS divides Layer 1 into a number of sections (clusters) after obtaining these coordinates depending on the angular value i for each node and the quantity of clusters in each predetermined and changeable level during simulation. The following formula is used by the BS to get the corresponding angular value for each node in Layer 1.

$$\theta_i = \begin{cases} \arctan\left(\frac{y_i - y_{BS}}{x_i - x_{BS}}\right)\ y_i - y_{BS} > 0, x_i - x_{BS} > 0 \\ 180 - \arctan\left|\frac{y_i - y_{BS}}{x_i - x_{BS}}\right|\ y_i - y_{BS} > 0, x_i - x_{BS} < 0 \\ 180 + \arctan\left|\frac{y_i - y_{BS}}{x_i - x_{BS}}\right|\ y_i - y_{BS} < 0, x_i - x_{BS} < 0 \\ 360 - \arctan\left|\frac{y_i - y_{BS}}{x_i - x_{BS}}\right|\ y_i - y_{BS} < 0, x_i - x_{BS} > 0 \end{cases} \quad (4)$$

Then the BS starts dividing the first layer into clusters α, whose parameter α is the number of clusters in each layer using (5). from this moment, the BS sends a message to all nodes of the first layer which contains the cluster identifier so that each node knows in which cluster it belongs.

$$Cluster_i \in [(i-1) \times \beta, i \times \beta]\ i \in \{1,2,\dots,\alpha\} \quad (5)$$

$$\beta = \frac{360}{\alpha}$$

Where, α it is the number of sections in each layer.

The proposed algorithm ensures that all nodes must belong to a cluster and a determined localization level. For this, the BS selects an intermediate node in each cluster of each level, which is the most distant node of each cluster, in order to collect the coordinates and the locations of the sensors. Then, the intermediate sensor then transmits a "hello" packet to all the sensors in its perimeter, asking them to send their coordinates. These nodes are those that are not part of any level or cluster and are chosen based on the strength of the received signal. After collecting all the positions, the intermediate node transmits them to its respective intermediate node which is in the lower location level to send them to the BS. When receiving new positions, the BS initiates the same process by sending messages to the newly discovered sensors with an incremented location layer value and the same section number as their corresponding intermediate sensor.

4.2. Selection of cluster head

Data transmission in the proposed algorithm is organized into clusters, where a CH is selected in each cluster to collect data from other sensors in the same cluster and forward it to the base station or another CH in a lower layer. Each sensor transmits a "hello" message with its ID, residual power, cluster ID, and position in order to choose the CH. The receiving nodes store this information in a neighborhood table and use it to calculate a parameter $Conc_i$ that determines the node's concentric location in the cluster with respect to its neighbors, using (6).

$$Conc_i = \frac{\sum_{i=1}^{q} \sqrt{(x-x_i)^2+(y-y_i)^2}}{q} \tag{6}$$

Where,
- q=the number of neighbors.
- (x, y)=node coordinates.
- (x_i, y_i)=the coordinates of neighboring nodes, respectively.

Once the concentric locations have been determined, candidate nodes within each cluster exchange their weight values. In the current round, the highest weight is an essential parameter for the selection of the CH. Meanwhile, non-candidate sensors enter a low-power sleep state to conserve energy, awaiting a message from the CH indicating when it is time to begin transmitting data. The weight of each node is calculated using (7).

$$Weight_{Node_i} = \frac{Energy_{Current}}{Energy_{Max}} + \left(1 - \frac{Conc_i}{q \times d_{max}}\right) \tag{7}$$

Where,
- $Energy_{Current}$ are the residual energy of the node
- $Energy_{Max}$ are the maximum energy of the node when the battery is fully charged
- d_{max} is the distance to the farthest node
- q is the number of neighbors and
- $Conc_i$ is the concentric location.

4.3. Data aggregation and transmission

Once CHs have been selected, data transmission to the base station can begin. Communication between nodes in each cluster and their associated CHs is scheduled via the time division multiple access (TDMA) protocol within predetermined time windows. The base station or a lower-level intermediate CH node receives the data that has been collected and has been aggregated by the CHs. In order to maximize node energy layers, we developed an energy-efficient multi-hop communication technique for intercluster data transfer, taking into account residual energy and distances between nearby CH nodes and the BS. All nodes, including the CHs, are near to the sink for the first layer of localisation. Single-hop communication is used for the first level of these nodes' communication to reduce energy usage.

There are a variety of pathways between close-by CHs and the base station on other layers via intercluster multi-hop communication. Each higher-level CH transmits a message with its location level and CH-id in order to choose the best paths. In response to this transmission, lower-level CHs relay their CH-id, position, level, and remaining energy. Formula (8) is used by CH nodes to calculate the weight of each neighboring CH in order to select the best neighboring CH for the following hop. The CH node selects the next closest CH with the highest weight and which belongs to the lower location level in order to send all the data of its cluster to the node sink.

$$Weight_{CH_j} = \frac{E_{CH_j}}{E_{avg}} + \frac{d(S_i, S_{BS})}{d(S_i, S_{BS}) + d(S_i, S_j)} \; Level_i > Level_j \tag{8}$$

$$E_{avg} = \frac{\sum_{i=1}^{M} Energy_i}{M}$$

Where,
- M is the number of neighboring CHs.
- $Energy_i$ is the residual energy of each neighboring CH.
- $d(S_i, S_{BS})$ is the distance between the CH and the base station.
- $d(S_i, S_j)$ is the distance between the CH and the neighboring CH.

5. SIMULATION AND DISCUSSION

In this section, we will simulate our proposed protocol and also the results obtained. The proposed method was simulated using the NS2 network simulation software on an Ubuntu-Linux operating system and compared to the CGC method [18] and the MSGR method [24] taking into account the metrics and performance criteria, energy consumption, network lifetime and packet delivery rate, which are the most used parameters to evaluate and compare routing algorithms in wireless sensor networks. To concretize the comparison and obtain reliable and solid results, we evaluated all the protocols under the same conditions, see Table 1.

Table 1. Simulation parameter

Parameter	Value
Network area	200 x 200
Number of nodes	50-400
BS location	50 x 50
Initial energy of sensor nodes	2j
Data packet size	500 bytes
Simulation time	600s
Communication range of each sensor node	30m
α (Number of clusters per level)	8

Figure 1 simulation results show that the proposed algorithm uses less power on average than the CGC and multi-scale grid clustering (MSGC) methods. In fact, a CH is chosen in each sector of the area of interest utilizing progressively concentric layers. Power consumption is decreased since the data is transmitted directly to the cluster heads CHs, which are near to the nodes. The data is subsequently sent to the base station by the CHs utilizing multi-hop transmission. There is no need to waste time or effort looking for routes because the paths for information flow have already been defined.

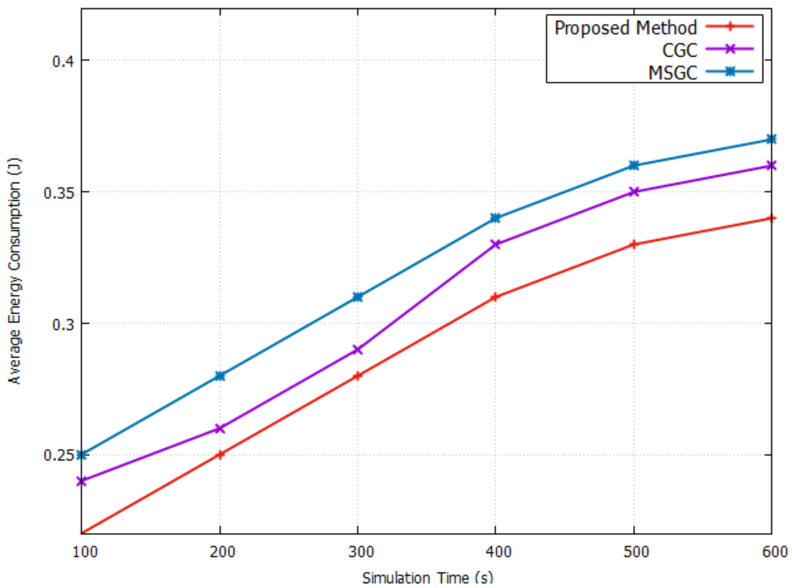

Figure 1. Average energy consumption at different times

The rate of packet delivery rises as the ratio of packets sent to packets received rises. Figure 2 displays the packet delivery rates for the proposed, CGC, and MSGC techniques. Comparing the suggested method to the other ways, the figure demonstrates a notable rise in packet delivery rate as the number of nodes grows. This is due to the network's stratification and sector division, which allows for the redetermination of the pathways and the structured, gradual transmission of data across the location levels and clusters to the base station. Without the requirement for route discovery, data is routinely routed to the base station along preset paths, reducing the likelihood of packet collision and significantly increasing packet delivery rate.

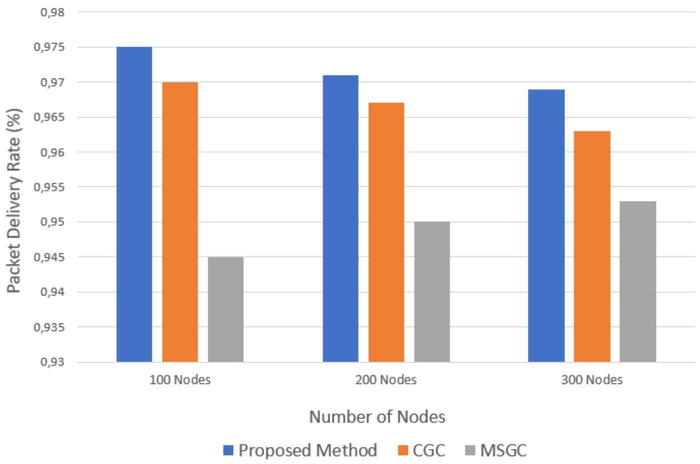

Figure 2. Packet delivery rate in proportion to different node numbers

As shown in Figure 3, the suggested method has been demonstrated to enhance the number of active nodes in the network when compared to the CGC and MSGC methods. In order to reduce the power consumption of member nodes, CHs, and intermediary nodes while also boosting load balancing and extending network lifetime, clustering, load balancing, and merging techniques are used. The suggested algorithm's results show how well it works to keep power consumption levels constant between different nodes, extending the period until the first node fails and lengthening the lifespan of the network as a whole. Based on the simulation and the outcomes of the suggested method. The packet delivery rate, average power consumption, and number of active sensors of the suggested algorithm were better than those of existing methods.

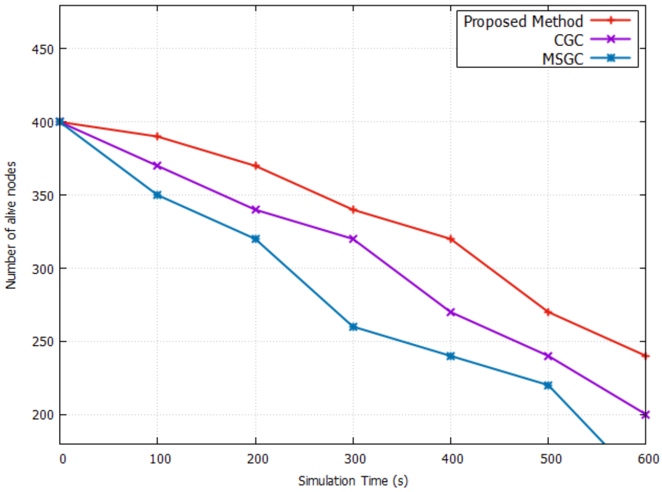

Figure 3. Number of alive nodes

6. CONCLUSION

The main objective of routing protocols is to choose an energy-efficient path in order to transmit all the data from the wireless sensor network to the base station. Our algorithm solves this problem by dividing the network into several concentric circular levels around the base station, each level of which there are eight clusters of the same size. In terms of the performance metrics and criteria employed in our paper, the proposed protocol could be further improved by incorporating energy-efficient communications technologies such as long range (LoRa) by implementing dynamic clusters that respond to node density at each location level to produce a flexible and dynamic structure for large-scale WSN networks. Our approach allows to organize the network in levels, which facilitates its extension according to growing needs. If the network needs expansion, just add a new level of circular clusters around the base station. In addition, the division into concentric levels offers increased redundancy and resilience. If one cluster or tier is affected by a failure, other clusters and tiers can continue to operate without interruption, ensuring continued connectivity and improved network reliability. In a future work, we will carry out a more in-depth study to determine the optimal size of the clusters in each circular level. This can be based on criteria such as node density, traffic requirements, and resource constraints. A well-optimized cluster size can improve communication efficiency and resource management for large WSN networks.

REFERENCES

[1] H. Yetgin, K. T. K. Cheung, M. El-Hajjar, and L. Hanzo, "A survey of network lifetime maximization techniques in wireless sensor networks," *IEEE Communications Surveys and Tutorials*, vol. 19, no. 2, pp. 828–854, 2017, doi: 10.1109/COMST.2017.2650979.

[2] Y. Rahayu and F. N. Mustapa, "A secure parking reservation system using GSM technology," *International Journal of Computer and Communication Engineering*, pp. 518–520, 2013, doi: 10.7763/ijcce.2013.v2.239.

[3] H. C. Yee and Y. Rahayu, "Monitoring parking space availability via Zigbee technology," *International Journal of Future Computer and Communication*, vol. 3, no. 6, pp. 377–380, Dec. 2014, doi: 10.7763/ijfcc.2014.v3.331.

[4] L. Xu, R. Collier, and G. M. P. O'Hare, "A survey of clustering techniques in WSNs and consideration of the challenges of applying such to 5G IoT scenarios," *IEEE Internet of Things Journal*, vol. 4, no. 5, pp. 1229–1249, Oct. 2017, doi: 10.1109/JIOT.2017.2726014.

[5] M. Chen and T. Chang, "A parking guidance and information system based on wireless sensor network," in *2011 IEEE International Conference on Information and Automation, ICIA 2011*, Jun. 2011, pp. 601–605, doi: 10.1109/ICINFA.2011.5949065.

[6] J. Yang, J. Portilla, and T. Riesgo, "Smart parking service based on wireless sensor networks," in *IECON Proceedings (Industrial Electronics Conference)*, Oct. 2012, pp. 6029–6034, doi: 10.1109/IECON.2012.6389096.

[7] S. B. Alla, A. Ezzati, and A. Mohsen, "Gateway and cluster head election using fuzzy logic in heterogeneous wireless sensor networks," in *Proceedings of 2012 International Conference on Multimedia Computing and Systems, ICMCS 2012*, May 2012, pp. 761–766, doi: 10.1109/ICMCS.2012.6320203.

[8] L. Li and D. Li, "An energy-balanced routing protocol for a wireless sensor network," *Journal of Sensors*, vol. 2018, pp. 1–12, 2018, doi: 10.1155/2018/8505616.

[9] Ramesh and Somasundaram, "A comparative study of clusterhead selection algorithms in wireless sensor networks," *International Journal of Computer Science & Engineering Survey*, vol. 2, no. 4, pp. 153–164, Nov. 2011, doi: 10.5121/ijcses.2011.2411.

[10] A. Mansura, M. Drieberg, A. A. Aziz, V. Bassoo and S. Sarang, "An energy balanced and nodes aware routing protocol for energy harvesting wireless sensor networks," *Peer-to-Peer Networking and Applications* vol. 15, pp. 1255–1280, 2022, doi: 10.1007/s12083-022-01292-w.

[11] O. Younis and S. Fahmy, "HEED: A hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks," *IEEE Transactions on Mobile Computing*, vol. 3, no. 4, pp. 366–379, Oct. 2004, doi: 10.1109/TMC.2004.41.

[12] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-efficient communication protocol for wireless microsensor networks," in *Proceedings of the Hawaii International Conference on System Sciences*, 2000, vol. vol.1, p. 223, doi: 10.1109/hicss.2000.926982.

[13] A. Hilmani, A. Maizate, and L. Hassouni, "Hierarchical protocol based on recursive clusters for smart parking applications using internet of things (IoT)," *Wireless Communications and Mobile Computing*, pp. 1–21, Jul. 2020, doi: 10.1155/2020/9179530.

[14] Z. Hajipour and H. Barati, "EELRP: energy efficient layered routing protocol in wireless sensor networks," *Computing*, vol. 103, no. 12, pp. 2789–2809, Dec. 2021, doi: 10.1007/s00607-021-00996-w.

[15] S. Firdous, N. Bibi, M. Wahid, and S. Alhazmi, "Efficient clustering based routing for energy management in wireless sensor network-assisted internet of things," *Electronics*, vol. 11, no. 23, p. 3922, Nov. 2022, doi: 10.3390/electronics11233922.

[16] G. S. Arumugam and T. Ponnuchamy, "EE-LEACH: development of energy-efficient LEACH Protocol for data gathering in WSN," *Eurasip Journal on Wireless Communications and Networking*, vol. 2015, no. 1, pp. 1–9, Dec. 2015, doi: 10.1186/s13638-015-0306-5.

[17] P. Schaffer and L. Buttyán, "Position-based aggregator node election in wireless sensor networks," *International Journal of Distributed Sensor Networks*, vol. 2010, no. 1, p. 679205, Jan. 2010, doi: 10.1155/2010/679205.

[18] M. Hatamian, H. Barati, A. Movaghar, and A. Naghizadeh, "CGC: centralized genetic-based clustering protocol for wireless sensor networks using onion approach," *Telecommunication Systems*, vol. 62, no. 4, pp. 657–674, Aug. 2016, doi: 10.1007/s11235-015-0102-x.

[19] M. M. Lamine, "Gestion d'un parking par un Réseau de Capteurs Sans Fils," in *Conference: Proceedings of the First National Conference on Computer Science and Information and Communication Technologies*, 2012, vol. 942, pp. 29–32.

[20] Q. Wang, D. Lin, P. Yang, and Z. Zhang, "An energy-efficient compressive sensing-based clustering routing protocol for WSNs," *IEEE Sensors Journal*, vol. 19, no. 10, pp. 3950–3960, May 2019, doi: 10.1109/JSEN.2019.2893912.

[21] M. Naghibi and H. Barati, "EGRPM: energy efficient geographic routing protocol based on mobile sink in wireless sensor networks," *Sustainable Computing: Informatics and Systems*, vol. 25, p. 100377, Mar. 2020, doi: 10.1016/j.suscom.2020.100377.

[22] A. Mosavifard and H. Barati, "An energy-aware clustering and two-level routing method in wireless sensor networks," *Computing*, vol. 102, no. 7, pp. 1653–1671, Jul. 2020, doi: 10.1007/s00607-020-00817-6.

[23] J. Moon, M. Yoon, and T. K. Ha, "A wireless sensor network protocol for a car parking space monitoring system," *World Academy of Science, Engineering and Technology International Journal of Computer and Information Engineering*, vol. 8, no. 6, pp. 957–960, 2014, doi: 10.5281/zenodo.1337251.

[24] S. Sharma, D. Puthal, S. Tazeen, M. Prasad, and A. Y. Zomaya, "MSGR: a mode-switched grid-based sustainable routing protocol for wireless sensor networks," *IEEE Access*, vol. 5, pp. 19864–19875, 2017, doi: 10.1109/ACCESS.2017.2746676.

[25] S. V. Purkar and R. S. Deshpande, "Energy efficient clustering protocol to enhance performance of heterogeneous wireless sensor network: EECPEP-HWSN," *Journal of Computer Networks and Communications*, vol. 2018, pp. 1–12, 2018, doi: 10.1155/2018/2078627.

[26] M. Dohler and T. Nakamura, *5G Mobile and Wireless Communications Technology*. Cambridge University Press, 2016, doi: 10.1017/CBO9781316417744.
[27] S. S. Wagh, A. More, and P. R. Kharote, "Performance evaluation of IEEE 802.15.4 protocol under coexistence of WiFi 802.11b," *Procedia Computer Science*, vol. 57, pp. 745–751, 2015, doi: 10.1016/j.procs.2015.07.467.
[28] T. O. Olasupo, C. E. Otero, L. D. Otero, K. O. Olasupo, and I. Kostanic, "Path loss models for low-power, low-data rate sensor nodes for smart car parking systems," *IEEE Transactions on Intelligent Transportation Systems*, vol. 19, no. 6, pp. 1774–1783, Jun. 2018, doi: 10.1109/TITS.2017.2741467.
[29] K. Shuaib, M. Alnuaimi, M. Boulmalf, I. Jawhar, F. Sallabi, and A. Lakas, "Performance evaluation of IEEE 802.15.4: Experimental and simulation results," *Journal of Communications*, vol. 2, pp. 29–37, Jun. 2007, doi: 10.4304/jcm.2.4.29-37.
[30] S. Goto, S. Saito, H. Kang, and K. Iwamura, "New secure LEACH protocol using hierarchy-based preshared key scheme," in *Lecture Notes in Electrical Engineering*, vol. 330, 2015, pp. 99–106, doi: 10.1007/978-3-662-45402-2_15.

BIOGRAPHIES OF AUTHORS

Adil Hilmani received his diploma as much as a Network and Telecommunication engineer from the superior engineering school, from the University of Seville in Spain. In 2021, he had his doctorate in computer engineering at the National School of Electricity and Mechanics (ENSEM) in Casablanca-Morocco. Currently, he is a professor at the office of professional training and job promotion (OFPPT) Kénitra, Morocco. And also, he is a temporary professor in the IT department of Ibno Tofail University (UIT), Kénitra, Morocco. His research interests include mobile networks and computing, wireless sensor networks, and embedded systems software for IoT. He can be contacted at email: adilhilmani@gmail.com.

Mohamed Koundi received his B.S. in Experimental Sciences and the M.S. in Electrical Engineering from Hassan II University of Casablanca, in 2007, 2014 respectively. Since 2014, he was an Electrical Engineering Professor in OFPPT, Morocco. He is currently pursuing the Ph.D. in Electrical Engineering at the Ibn Tofail University, Kénitra, Morocco. His main research area includes fuel cell electric vehicles, PEM electrolyser system, P2X technology and nonlinear control of power converters. He has co-authored several journal and conference papers. He can be contacted at email: mohamed.koundi.mk@gmail.com.

Yassine Sabri was born on October 28th, 1984 in Rabat, Morocco. He received his fundamental licence (B.Sc.), in the fields of science and technology and mathematics, from the Mo-hamed 5 University of Rabat, Morocco, in 2006. He completed his Master of Science (M.Sc.), in the field of Engineering, from the Universiti Chouaib Douakaly in 2008 and then joined the Laboratory of Science and Technology to continue his studies to become a Doctor of Technology (Ph.D.) in the field of WSN technology. In 2013, he joined the Laboratory of Metrology and Information Processing-LMTI-Faculty of Sciences, Ibn Zohr University, Agadir, Morocco as an assistant professor. His research interests include wireless sensor networks, evolu-tionary computation, the internet of things (IoT) and mobile computing in recent years, he has focused on the processing of cloud computing, big data, artificial intelligence, machine learning, evolutionary algorithms, and software frameworks. He has collaborated actively with researchers in several other disciplines of science and technology. He can be contacted at email: sabriyassino@gmail.com.

Abderrahim Maizate received his Engineering Diploma in Computer Science from the Hassania School of Public Works since 2004 and DESA degree from ENSIAS in 2007. He received with honors the Ph.D. degree in Computer Networks and Telecommunications from Chouaib Doukalli University in El Jadida in 2014. Since October 2014 he has been working as a Professor at the Computer Engineering Department at the Higher School of Technology of Casablanca (ESTC-UH2C). He is currently the Deputy Director of the Network, Computer, Telecommunications and Multimedia Laboratory at the same School and member of the research center TIC-DEV. He is also an IEEE member. His research interests include fields such as wireless communications, WSN, smart cities, NDN, big data, cloud computing and security. He is also a TPC member and a reviewer for many international conferences. He is a member of the publishing committee of the Mediterranean Telecommunication Journal and member of the organizing committee of the international conferences SysCo 16 and CMT 2018. He can be contacted at email: maizate@hotmail.com.