Energy-efficient multilevel inverter for electric vehicles using wireless sensor network monitoring

Nishalini Delcy[1], Francis Thomas Josh[1], Kannadhasan Suriyan[2]
[1]Department of Electrical and Electronics Engineering, Karunya Institute of Technology and Sciences, Coimbatore, India
[2]Department of Electronics and Communication Engineering, Study World College of Engineering, Coimbatore, India

Article Info

ABSTRACT

This research presents a unique energy-efficient routing strategy aimed at optimizing energy consumption and prolonging network longevity using an innovative clustering probability. Cluster-based routing algorithms facilitate versatile configurations and extend the network's lifetime until the last node ceases operation. This study introduces an energy-efficient hierarchical clustering algorithm for wireless sensor networks (WSNs), enhancing the low-energy adaptive clustering hierarchy (LEACH) algorithm. The objective of this algorithm is to reduce power consumption by the strategic selection of new cluster heads (CH) in each data transfer round and to prevent network conflicts. This objective is accomplished by employing an efficient function to identify the optimal CH nodes in each cycle, considering the current energy levels of the sensors. The suggested technique enhances the cluster formation process by utilizing the reduced distance to the base station. This study findings will enhance packet scheduling algorithms for data aggregation in WSNs to minimize the number of packets transmitted from sensors to CH. Simulation findings validate the system's efficacy in comparison to alternative compression techniques and non-compression scenarios utilized in LEACH and multi-hop LEACH.

Corresponding Author:

Nishalini Delcy
Department of Electrical and Electronics Engineering, Karunya Institute of Technology and Sciences
Karunya Nagar, Coimbatore, Tamilnadu, India
Email: nishaheshwanth@gmail.com

1. INTRODUCTION

Wireless sensor networks (WSNs) are increasingly capable of managing complicated functions. WSNs are increasingly capable of managing sophisticated functions. In-network processing, including data gathering, information fusion, calculation, and transmission, mandates that these sensors utilize energy efficiently to prolong their operational lives. Sensor nodes are sensitive to energy depletion and malfunction, and their battery supply may be non-replaceable; thus, new sensors are deployed. Consequently, the continual re-energization of WSNs, when aged sensor nodes fail and due to the irregular terrain of the monitored area, could result in energy imbalances or heterogeneity among the sensor nodes. If the network system fails to adequately utilize and harness the increased energy, it could significantly damage its stability and performance. These networks, which are distributed embedded systems, consist of a diverse range of short-range sensor nodes that collaborate to monitor a system or environment. These nodes will detect and gather information from the environment or system and transfer the data to the base station. The nodes comprise a sensor module that detects environmental conditions, a processor and memory that execute local computations on the detected data and store information, a transceiver that facilitates communication with neighboring nodes, and a power supply unit that provides energy to the node. The primary aim of load-

balanced clustering is to prolong the network's longevity; nevertheless, heuristics alone cannot provide optimum outcomes. Prior research has sought to enhance network longevity by selecting more energy-efficient cluster heads (CH) and optimizing packet transmission from CH to base stations, as well as reducing total energy usage. This study compares center-located and corner-located base stations (BSs) using several existing algorithms and presents two new ones. Regarding energy efficiency, one of the suggested algorithms beat all preceding models, especially in the length from network inception to the demise of the last node (LND). This research analyzes the efficacy of clustering algorithms for reducing power consumption in WSNs employing various sensor types. In this sensor network, a CH supports each node's connection to the base station by transmitting sensing data to the base station, which is located either in the middle of the network or at one of its corners [1]-[5].

A key objective of the aforementioned WSNs is to transfer the observed data from sensors to the sink for subsequent analysis. The efficacy of such WSNs is dependent upon data collection methods, sensor architecture, and the volume of data crossing the network, among other considerations. To mitigate various constraints such as node failure, communication problems, computing resource crises, energy shortages, traffic congestion, and delays, topology management is essential. As a result, choosing the right topology is essential to maximizing network properties. One important factor that greatly affects how well WSN operate is energy usage. Data from all nodes within a group is gathered and relayed to the base station by cluster leaders, picked at regular intervals using designated clustering algorithms, and end-users then use this collected information. A probable reason for the higher efficiency is that the sensor networks were reactivated to extend their longevity. The implementation residue EL node (IMP-RES-EL) approach is introduced for uniform sensor networks. These networks are divided into two groups of nodes depending on their initial energy levels [6]-[10].

The research indicates that the proposed strategy has superior resilience in managing the extensive energy use of refined nodes compared to low-energy adaptive clustering hierarchy (LEACH). WSNs garner significant interest in contemporary IoT-enabled industrial and residential applications, using either homogeneous or heterogeneous sensors to collect information of purpose. WSNs are designed to function with self-powered sensor nodes because to their application in geographically crucial environments. Such nodes must facilitate energy efficiency to enhance network lifespan. The selection of CH is a critical phase in a WSNs design, primarily aimed at minimizing energy consumption within the network [11]-[15].

This paper concentrates on the design and execution of an energy-efficient clustering hierarchy algorithm for WSNs. The suggested algorithm is meant to address the shortcomings of the LEACH algorithm. The proposed technique enhances the selection of CH nodes by considering the remaining power of the sensors, hence balancing power consumption among the cluster nodes through the exact selection of nodes designated as CH. Information technology has significantly transformed human society in transportation, industrial production, administration, technological advancements, entertainment, and various other domains. Numerous issues are challenging to resolve by conventional methods. The traditional process exhibits specific constraints, such as structure-oriented bindings, partial predictability, and computability within restricted time and space parameters [16]-[20]. A multitude of clustering protocols have been developed, with the LEACH protocol and the stable election protocol (SEP) heterogeneous protocol serving as prime examples; nonetheless, certain restrictions persist. This research presents a novel technique to enhance network longevity and optimize storage capacity during transmission, hence augmenting the network's ability to identify optimal CH among nodes in comparison to LEACH and [21]-[25].

2. RESEARCH METHOD

WSNs may be structured on an ad-hoc basis, consisting of an adequate quantity of sensor nodes. The primary design aspects assessed in the formation of a network clustering are cluster size, intracluster communication, sensor, and CH movement, sensor diversity and location, multiple levels, and overlaps. The paramount concerns of clustering encompass connectivity, rotation of CH responsibilities, design of the medium access control layer, management of sensor duty cycles, optimal cluster sizing, and coordination among sensor nodes. The data amassed in the CH is refreshed with every transition between nodes. Energy efficiency is very sensitive to WSNs, particularly for industrial applications in large-scale remote environments or in harsh environments where the nodes are set up. The primary issue in determining the optimal CH placement is its inconsistency, as the CH location varies with each instance from the initial position is shown in Figure 1. The clustering strategy also presents additional obstacles, including the difficulty of determining the locations of neighbouring nodes and their energy levels after designating a CH.
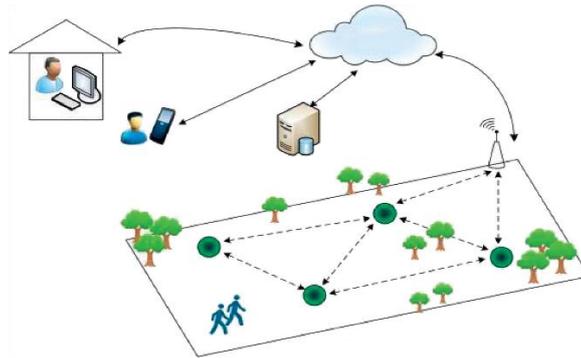
Figure 1. WSN methodology

The internet of things (IoT) network gathers diverse data types, necessitating distinct methods of data processing. All data must be processed at the edge or in the cloud upon the booking of asset needs. The asset requirements can be delimited by tasks, and the edge network can successively meet these demands. Subsequently, it detects the appropriate cloud assets and allows their utilization by IoT networks for increased processing. Distributed computing resources must be integrated into edge computing within IoT networks as a component of a complete asset planning strategy. Planning needs to take scalability and asset elasticity into account. When assets in the cloud are spread over edge networks, their scalability and flexibility are transformed, as the majority of these assets are either virtual or physical. The edge must take these criteria into account when allocating assets for IoT networks because various applications have distinct asset requirements. This is because different applications require different registration assets.

WSNs include small, battery-operated sensors with limited energy resources. The primary advantage of the sensor network is the incorporation of power usage constraints for sensor nodes, facilitated by battery life considerations. The sensor nodes are often inaccessible to the user; hence, replacing the energy source or battery is impractical. Consequently, energy efficiency is a primary design consideration that must be enhanced to prolong the lifespan of the sensor network. To prolong the lifespan of sensor nodes, energy consumption and route design considerations are addressed. This research presents and implements an extended energy efficient clustering algorithm for WSNs. A thorough examination of many methodologies presented in the literature on clustering-based strategies aimed at enhancing network longevity, with a primary emphasis on the LEACH and hybrid energy-efficient distributed clustering (HEED) algorithms. The primary advantages of the proposed technique are the optimized energy usage and the extended network lifespan. WSNs provide real-time data collection and transmission, enabling astute resource management and improving energy efficiency across diverse industries is shown in Figure 2. WSNs significantly influence the operation and administration of smart grids and the monitoring of renewable energy sources. Smart grids use advanced communication and information technologies to enhance traditional electricity networks. This shift employs WSNs to improve energy efficiency and bolster grid dependability.
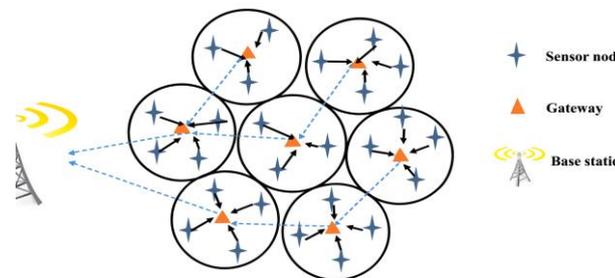

Figure 2. Clustering techniques in WSN

Inverters convert direct current (DC) electricity from batteries to alternating current (AC) to accelerate or decrease the vehicle speed and to control the motor speed and torque. The pulse width

modulation (PWM) approach is used to adjust the output frequency of the inverters, which changes necessary speed of the drive. The inverters necessary so are to be highly efficient and reliable. Inverters are pricey component of EV power conversion system and also it is the important factor in terms of overall system dependability and operation. Waveforms of square waves, quasi-sine waves, modified sine waves, or pure sine waves can be found in the AC output generated by the inverter. When compared to other output kinds, pure sine wave inverters are favored due to their superior power quality and great efficiency. The total harmonic distortion (THD) of the inverter output is regulated by the shape of the distorted wave.

The whole WSN is structured into hexagonal clusters. Each cluster has a head located at the convergence point of the hexagon, which is further optimized for computing efficiency and has an extensive radio broadcast range. A CH is equipped with a transmitter capable of communicating with several CH. The transmission range of a CH is often considered to be twice that of a sensor, corresponding to the maximum distance of the hexagon. The transmission range of the CH determines the extent of the hexagonal coverage. The distribution of sensor dispersion follows a Poisson distribution. Partial Poisson scattering may be represented in a d-dimensional space. However, we anticipate that the nodes inside the cluster will conform to a spatial Poisson distribution in a one-dimensional space. The density of node distribution signifies the average quantity of nodes that may be accommodated within a unit length. A higher density allows for the placement of more nodes. An analytical model examining the relationship between cluster size and the number of transmissions required for data delivery. They proposed and indicated that square-based clusters are ideal in size for achieving efficient transmissions and energy saving in WSNs. This paper asserts that employing a square cluster model may increase the number of inter-cluster transmissions for data delivery to the sink compared to the proposed hexagonal cluster model, as the coverage area of the square is smaller than that of the hexagonal cluster, resulting in a greater number of clusters in the square model. Consequently, it is said that the current square-type cluster model enhances inter-cluster transmission frequency. In contrast to the square model, the hexagonal cluster model exhibits an equal transmission range to the CH situated at the clusters center position.

3.   RESULTS AND DISCUSSION

The setup phase is the initial and crucial operation in the LEACH protocol, during which the CH is identified and clusters are produced. The selection process of CH nodes in the LEACH protocol is predicated on probabilistic principles, which results in an inadequate distribution of energy consumption among all nodes, leading to an imbalance in energy utilization across the network nodes. The selection of the CH nodes disregards the remaining energy levels, resulting in instances where a CH node is selected despite insufficient energy, ultimately causing premature and inconsistent node failures. To enhance the equilibrium of power consumption in the WSN, the identification of appropriate CH nodes will be executed in the suggested algorithm. In this part, we evaluate the efficacy of the proposed technique. We evaluate our suggested strategy against LEACH and HEED. We develop our simulation environment with ASP.Net. The premises are as Figure 3 demonstrate that the proposed methodology enhances the lifetime of the sensor node compared to the LEACH and HEED algorithms. Specifically, Figure 4 indicates that the first dead node in the sensor network comprising 100 sensors occurs after 945 rounds with the proposed method, signifying a reduction in the number of nodes required for transmission and thereby extending the network's lifetime.

Figure 3 illustrates that energy usage increases with the number of cycles in clustering data transmission in the proposed approach compared to existing technologies. The superfluity in data collection might result in considerable energy waste. In light of this fact, adaptive sampling techniques and data compression strategies were employed to minimize transmission costs and hence enhance the lifespan of the WSN. Compressive sensing (CS) based approaches have been devised to address these constraints. In recent years, the efficacy of CS strategies in data compression and their applicability in WSN have garnered significant attention. The characteristics of the cluster structure, including traffic-load balancing, and fault tolerance, confer competitive advantages to CS-based clustering and data gathering techniques compared to alternative methods. Utilizing the CS approach can lead to a large reduction in the redundancy of temporally and geographically correlated data, hence enhancing the efficiency of WSN.

The lifetime of a WSN is measured in rounds from the initiation of network operations until the demise of the first sensor node (FND), which is crucial for numerous vital applications requiring dependable responses from the WSN. This provides an understanding of the network's performance in sustaining stability from the initial round to the demise of the first node. The Figure 5 demonstrates that the proposed cluster-based hierarchical routing protocol based on cuckoo search (CBHRP-CS) protocol significantly extends the lifespan of the WSN in comparison to alternative protocols. CBHRP-CS exhibited superior network stability compared to the other three protocols by employing a mix of the CS approach and CH-set. To understand how maximum power point tracking (MPPT) works, let's first investigate the operation of a traditional (non-MPPT) charge controller. A traditional controller just connects the modules straight to the

battery while charging a drained battery. Because of this, the modules must run at battery voltage, which is usually not the optimal operating voltage at which the modules are able to produce their maximum possible power.
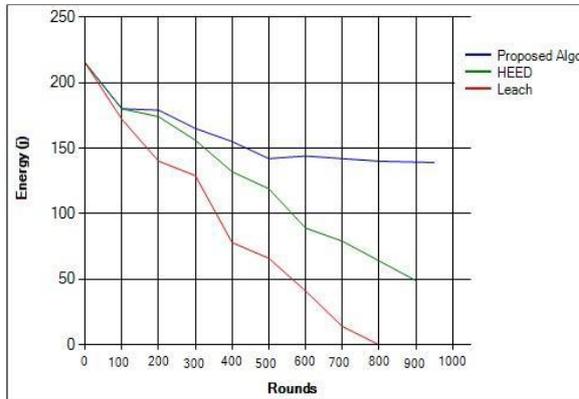

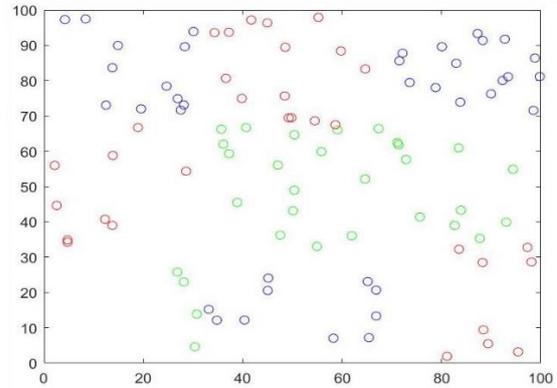Figure 3. Energy efficiency of the proposed work

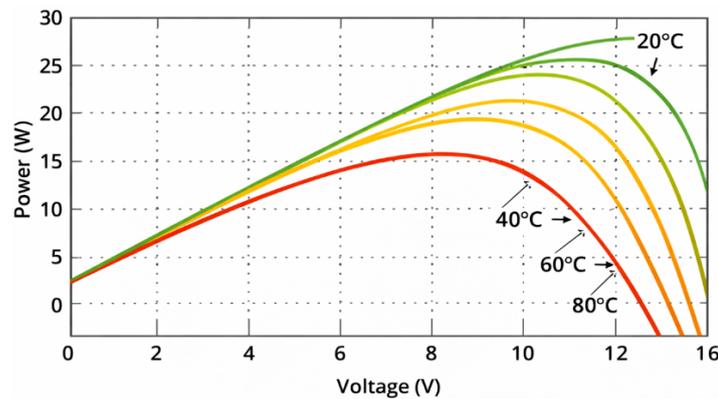Figure 4. Deployment node of the proposed network

Figure 5. Multilevel inverter with EV applications using sensor networks

Furthermore, four critical characteristics may affect network performance. These characteristics include the distance between the sink and the CH, the residual energy of the CH node, the distance between the CH and sensor nodes, and the degree of the CH. The suggested approach excels in network longevity and economical energy use. A novel clustered routing protocol (CQRP) for distributed WSNs. The authors use challenges such as connection failure and resilience in WSNs in their method. The network attained quality of service (QoS) requirements with the effective selection of CH. The suggested CQRP approach effectively enhances network efficiency while reducing packet loss rates in both mobile and stable settings. Nonetheless, the suggested approach does not provide much increase in energy efficiency. This approach enabled an improved packet delivery rate despite the movement of CH. A novel sleep-oriented clustering methodology aimed at reducing energy usage. This method employs binary particle swarm optimization to cluster base stations exhibiting elevated interference values. A sleep mechanism has been implemented for base stations, and orthogonal spectrum sources have been allocated to smaller base stations within the cluster. Although the developed approach decreases energy usage, it fails to enhance other QoS metrics. Moreover, the suggested protocol employs a multi-metric fitness function for next-hop selection. The subsequent hop placements are optimized according to node status, and packet delivery to crowded lines is avoided. The experimental findings indicate that the suggested approach substantially enhances network longevity, energy efficiency, and throughput. WSNs include small, battery-operated sensors with limited energy resources. The primary advantage of the sensor network is its incorporation of electricity. Utilization limitation for sensor nodes based on battery longevity. The sensor nodes are often inaccessible to the user; hence, replacing the energy source or battery is impractical. Consequently, energy efficiency is a primary design consideration that seeks

enhancement to prolong the lifespan of the sensor network. To prolong the lifespan of sensor nodes, energy consumption and route design considerations are addressed. This research presents and implements an extended energy efficient clustering algorithm for WSNs. A thorough examination of many methodologies presented in the literature on clustering-based strategies aimed at enhancing network longevity, with a primary emphasis on the LEACH and HEED algorithms. The primary advantages of the proposed technique are the optimized energy usage and the extended network lifespan.

4.   CONCLUSION

This research presents a novel methodology to enhance the energy efficiency of WSNs by strategically positioning base stations to reduce the squared Euclidean distances between sensors to these stations. We have used the Hessian matrix from multivariable calculus to enhance energy efficiency and determine optimal base station sites to decrease energy usage. The suggested technique is substantiated by problem formulation and requisite evidence. The suggested mathematical design will significantly enhance and optimize low-energy networks. The connection-based decentralized clustering model emphasizes the quantity of hops and the message weight used in data transmission. Choosing the appropriate relay node may contribute to energy conservation. Ultimately, the multi objective genetic algorithm (MOGA) is used for energy efficiency and reconstruction error optimization. The simulation results unequivocally demonstrate that our proposed CBHRP-CS protocol significantly reduces energy consumption, enhances the lifespan of the WSN, and permits a greater number of frames to be broadcast every iteration compared to other existing protocols. The A-LEC exhibits greater robustness, making it adaptable to variations in data patterns. The experimental results compare the proposed method to hybrid CS with an optimal tree structure, hybrid CS with square clusters, and clustering without CS. It reports a reduction in the number of transmissions by approximately 30%, 40%, and 60% on average for compressive ratios of 10 and 5, relative to the existing hybrid CS methods, across varying node counts. The field is examined to ascertain the impact and optimization of cluster size. Moreover, the future implementation of the hybrid CS with a hexagonal cluster would aim to enhance the wireless body sensor network by conserving energy during electroencephalography (EEG) signal collecting, with outcomes comparable to the current pure CS technology used in the wireless body sensor network. In the near future, a novel and enhanced cluster-based routing protocol may be presented to extend network longevity and optimize node energy levels for improved CH selection.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Nishalini Delcy	✓	✓	✓	✓	✓	✓			✓	✓				✓
Francis Thomas Josh		✓				✓			✓	✓				✓
Kannadhasan Suriyan	✓		✓	✓					✓					✓

C : **C**onceptualization	I : **I**nvestigation	Vi : **Vi**sualization
M : **M**ethodology	R : **R**esources	Su : **Su**pervision
So : **So**ftware	D : **D**ata Curation	P : **P**roject administration
Va : **Va**lidation	O : Writing - **O**riginal Draft	Fu : **Fu**nding acquisition
Fo : **Fo**rmal analysis	E : Writing - Review & **E**diting	

CONFLICT OF INTEREST STATEMENT

No conflict of interest.

DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

REFERENCES

[1] D. Airehrour, J. A. Gutierrez, and S. K. Ray, "SecTrust-RPL: A secure trust-aware RPL routing protocol for Internet of Things," *Future Generation Computer Systems*, vol. 93, pp. 860–876, 2019, doi: 10.1016/j.future.2018.03.021.
[2] A. Hamzah, M. Shurman, O. Al-Jarrah, and E. Taqieddin, "Energy-efficient fuzzy-logic-based clustering technique for hierarchical routing protocols in wireless sensor networks," *Sensors*, vol. 19, no. 3, 2019, doi: 10.3390/s19030561.
[3] S. Sharma and A. Kaur, "Survey on Wireless Sensor Network, Its Applications and Issues," *Journal of Physics: Conference Series*, vol. 1969, no. 1, 2021, doi: 10.1088/1742-6596/1969/1/012042.
[4] T. M. Behera *et al.*, "Energy-Efficient Routing Protocols for Wireless Sensor Networks: Architectures, Strategies, and Performance," *Electronics*, vol. 11, no. 15, 2022, doi: 10.3390/electronics11152282.
[5] A. A. Hayajneh, M. Z. A. Bhuiyan, and I. McAndrew, "A novel security protocol for wireless sensor networks with cooperative communication," *Computers*, vol. 9, no. 1, 2020, doi: 10.3390/computers9010004.
[6] K. Haseeb, K. M. Almustafa, Z. Jan, T. Saba, and U. Tariq, "Secure and energy-aware heuristic routing protocol for wireless sensor network," *IEEE Access*, vol. 8, pp. 163962–163974, 2020, doi: 10.1109/ACCESS.2020.3022285.
[7] A. Kumar and I. Sharma, "Enhancing Cybersecurity Policies with Blockchain Technology: A Survey," in *Proceedings of 5th International Conference on Contemporary Computing and Informatics, IC3I 2022*, 2022, pp. 1050–1054, doi: 10.1109/IC3I56241.2022.10072588.
[8] H. Kuhlani, X. Wang, A. Hawbani, and O. Busaileh, "Heuristic data dissemination for mobile sink networks," *Wireless Networks*, vol. 26, no. 1, pp. 479–493, 2020, doi: 10.1007/s11276-019-02154-9.
[9] G. V. Gurram, N. C. Shariff, and R. L. Biradar, "A Secure Energy Aware Meta-Heuristic Routing Protocol (SEAMHR) for sustainable IoT-Wireless Sensor Network (WSN)," *Theoretical Computer Science*, vol. 930, pp. 63–76, 2022, doi: 10.1016/j.tcs.2022.07.011.
[10] Y. Liu, Q. Wu, T. Zhao, Y. Tie, F. Bai, and M. Jin, "An improved energy-efficient routing protocol for wireless sensor networks," *Sensors*, vol. 19, no. 20, 2019, doi: 10.3390/s19204579.
[11] S. K. Gupta and S. Singh, "Survey on energy efficient dynamic sink optimum routing for wireless sensor network and communication technologies," *International Journal of Communication Systems*, vol. 35, no. 11, 2022, doi: 10.1002/dac.5194.
[12] H. Landaluce, L. Arjona, A. Perallos, F. Falcone, I. Angulo, and F. Muralter, "A review of iot sensing applications and challenges using RFID and wireless sensor networks," *Sensors*, vol. 20, no. 9, 2020, doi: 10.3390/s20092495.
[13] P. Zhongmin, D. Zhidong, Y. Bo, and C. Xiaoliang, "Application-oriented wireless sensor network communication protocols and hardware platforms," in *Proceedings of the IEEE International Conference on Industrial Technology*, 2008, doi: 10.1109/ICIT.2008.4608532.
[14] A. Khalifeh, K. A. Aldahdouh, K. A. Darabkh, and W. Al-Sit, "A survey of 5G emerging wireless technologies featuring LoRaWAN, Sigfox, NB-IoT and LTE-M," in *2019 International Conference on Wireless Communications, Signal Processing and Networking, WiSPNET 2019*, pp. 561–566, 2019, doi: 10.1109/WiSPNET45539.2019.9032817.
[15] A. Ikpehai *et al.*, "Low-power wide area network technologies for internet-of-things: a comparative review," *IEEE Internet of Things Journal*, vol. 6, no. 2, pp. 2225–2240, 2019, doi: 10.1109/JIOT.2018.2883728.
[16] K. Mekki, E. Bajic, F. Chaxel, and F. Meyer, "A comparative study of LPWAN technologies for large-scale IoT deployment," *ICT Express*, vol. 5, no. 1, pp. 1–7, 2019, doi: 10.1016/j.icte.2017.12.005.
[17] C. Nakas, D. Kandris, and G. Visvardis, "Energy efficient routing in wireless sensor networks: A comprehensive survey," *Algorithms*, vol. 13, no. 3, 2020, doi: 10.3390/a13030072.
[18] G. Sahar, K. A. Bakar, S. Rahim, N. A. K. K. Khani, and T. Bibi, "Recent Advancement of Data-Driven Models in Wireless Sensor Networks: A Survey," *Technologies*, vol. 9, no. 4, 2021, doi: 10.3390/technologies9040076.
[19] P. Guo, J. Cao, and X. Liu, "Lossless In-Network Processing in WSNs for Domain-Specific Monitoring Applications," *IEEE Transactions on Industrial Informatics*, vol. 13, no. 5, pp. 2130–2139, 2017, doi: 10.1109/TII.2017.2691586.
[20] M. Wu, L. Tan, and N. Xiong, "Data prediction, compression, and recovery in clustered wireless sensor networks for environmental monitoring applications," *Information Sciences*, vol. 329, pp. 800–818, 2016, doi: 10.1016/j.ins.2015.10.004.
[21] R. Zagrouba and A. Kardi, "Comparative Study of Energy Efficient Routing Techniques in Wireless Sensor Networks," *Information*, vol. 12, no. 1, 2021, doi: 10.3390/info12010042.
[22] Z. Al Aghbari, A. M. Khedr, and W. Osamy, "Routing in Wireless Sensor Networks Using Optimization Techniques: A Survey," *Wireless Personal Communications*, vol. 111, pp. 2407–2434, 2020, doi: 10.1007/s11277-019-06993-9.
[23] D. Sharma and G. S. Tomar, "Comparative energy evaluation of LEACH protocol for monitoring soil parameter in wireless sensors network," *Materials Today: Proceedings*, vol. 29, no. 2, pp. 381–396, 2020, doi: 10.1016/j.matpr.2020.07.292.
[24] Y. Bektaş, "Real-time control of Selective Harmonic Elimination in a Reduced Switch Multilevel Inverter with unequal DC sources," *Ain Shams Engineering Journal*, vol. 15, no. 6, 2024, doi: 10.1016/j.asej.2024.102719.
[25] H. Shu, S. Lei and X. Tian, "A New Topology of Modular Multilevel Converter With Voltage Self-Balancing Ability," *IEEE Access*, vol. 7, pp. 184786-184796, 2019, doi: 10.1109/ACCESS.2019.2958857.

BIOGRAPHIES OF AUTHORS

Nishalini Delcy 🔗 is a lecturer in Department of Electrical Engineering at the Study World College of engineering and research scholar in Department of Electrical and Electronic Engineering, Karunya Institute of Technology and Sciences. She received the B.Eng. degree in electrical engineering from Vellalar College of Engineering and Technology, Erode since 2010 and M.Eng. degree in power electronics, from C.S. She college of engineering since 2014 respectively and pursuing Ph.D. degree in Electrical Engineering from Karunya Institute of Technology and Sciences. Her research interests include the field of power electronics, electric vehicle motor drives, industrial applications, and industrial electronics. She can be contacted at email: nishaheshwanth@gmail.com.

Francis Thomas Josh 🆔 ⑧ SC ◖ is a lecturer in Department of Electrical and Electronic Engineering, Karunya Institute of Technology and Sciences since Nov 2011, and he has been a senior lecturer since 2005. He received the B.Eng. degree in electrical engineering from Madura Kamarajar Universitysince 2000 and M.Eng. degree in power electronics, from Bharathidasan University since 2002 respectively, and Ph.D. degree in Electrical Engineering from Anna University, Chennai since 2014. His research interests include the field of power electronics, motor drives, industrial applications, industrial electronics, photovoltaic power systems, battery energy management techniques, AI for renewable energy, IoT for food and agri applications, and modern electric drives for EV. He can be contacted at email: josh@karunya.edu.

Kannadhasan Suriyan 🆔 ⑧ SC ◖ is working as an Assistant Professor in the Department of Electronics and Communication Engineering in Study World College of Engineering, Coimbatore, Tamilnadu, India. He is completed the Ph.D. in the field of Smart Antenna for Anna University in 2022. He is twelve years of teaching and research experience. He obtained his B.E in ECE from Sethu Institute of Technology, Kariapatti in 2009 and M.E. in Communication Systems from Velammal College of Engineering and Technology, Madurai in 2013. He obtained his M.B.A in Human Resources Management from Tamilnadu Open University, Chennai. He has published around 45 papers in the reputed indexed international journals indexed by SCI, Scopus, Web of Science, major indexing, and more than 146 papers presented/published in national, international journal and conferences. Besides he has contributed a book chapter also. He also serves as a board member, reviewer, speaker, session chair, advisory, and technical committee of various colleges and conferences. He is also to attend the various workshop, seminar, conferences, faculty development programme, STTP, and online courses. His areas of interest are smart antennas, digital signal processing, wireless communication, wireless networks, embedded system, network security, optical communication, microwave antennas, electromagnetic compatability and interference, wireless sensor networks, digital image processing, satellite communication, cognitive radio design, and soft computing techniques. He is member of SMIEEE, ISTE, IEI, FIETE, CSI, IAENG, SEEE, IEAE, INSC, IARDO, ISRPM, IACSIT, ICSES, SPG, SDIWC, IJSPR, and EAI Community. He can be contacted at email: kannadhasan.ece@gmail.com.