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To overcome the optimization issues in clustering by introducing innovative, energy-efficient cluster-based routing protocols based on intelligent computing techniques

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Abstract

This abstract provides a novel strategy for tackling optimization problems in clustering techniques through the development of creative and resource-saving cluster-based routing protocols using advanced computing techniques. In many fields, such as wireless sensor networks, data mining, and picture segmentation, clustering is a crucial approach. However, the efficiency of traditional clustering techniques is frequently hampered by optimization issues. This study promotes the use of intelligent computing methods into the creation of cluster-based routing protocols as a means of overcoming these difficulties. The proposed protocols attempt to improve the overall performance of clustering processes by using the power of artificial intelligence, machine learning, and other cutting-edge computational techniques.

The development of energy-efficient techniques for cluster-based routing protocols is a major area of research. In contexts with limited resources, such as wireless sensor networks, where energy-efficient communication directly affects the network's operational lifetime, energy consumption is a major concern. By carefully controlling data transmission, reception, and node activation inside clusters, the protocols seek to maximize energy efficiency. The protocols are also made to change dynamically with the state of the network. Traditional clustering techniques sometimes rely on static settings, which might not be able to adequately handle changing conditions. The proposed protocols can assess real-time data, forecast changes, and modify cluster formations and routing schemes accordingly thanks to the integration of intelligent computing.

The two expected advantages of this research are as follows: First, the novel protocols promise to resolve common optimization issues with conventional clustering approaches. Second, it is anticipated that putting a focus on energy efficiency will greatly increase the lifespan of networks with limited resources. This study adds to the growing body of information relating to intelligent computing, energy-efficient networking, and clustering. This abstract summarizes a project that aims to revolutionize clustering approaches by using intelligent computing techniques. The suggested cluster-based routing protocols aim to improve the performance and endurance of various types of networks by addressing optimization difficulties and prioritizing energy efficiency.

Keywords: Optimization, clustering, energy-efficient, cluster-based routing protocols, intelligent computing techniques

Introduction

The introduction creates the framework for the study by providing background information, summarizing the problem statement, and stressing the research objectives. The study's significance and the reader's interest are both established. Putting related network nodes or data points together for quick processing and communication is a major method used in the disciplines of networking and data analysis. But optimization issues frequently reduce the efficiency of traditional clustering methods, leading to less-than-ideal outcomes. Additionally, in environments with constrained resources, such as wireless sensor networks, energy efficiency is essential for increasing operating

lifetimes. This work proposes novel cluster-based routing protocols as a novel approach to these issues. Predictive modeling, artificial intelligence, and machine learning are all examples of intelligent computing that support these protocols. The goal of this integration is to remove obstacles to optimization and raise the general efficiency of clustering processes. The main focus of this work is the development of energy-efficient strategies within these processes.

The focus on energy efficiency stems from the knowledge that conventional routing methods usually overlook this crucial aspect, which causes node energy to run out too quickly. By dynamically managing data transmission, reception, and node activation, the protocols seek to

minimize energy waste. The protocols are also designed to adapt in real time to the shifting network dynamics. Instead of the static configurations of typical systems, these protocols may analyze data patterns, anticipate changes, and modify cluster topologies and routing algorithms accordingly.

Wireless sensor networks

Wireless Sensor Networks (WSNs) are a specialized category of networks consisting of numerous small, autonomous devices known as sensor nodes. These nodes are equipped with sensors to collect and transmit data from their surrounding environment, such as temperature, humidity, light, sound, or specific events like motion detection.

Key characteristics of wireless sensor networks

Decentralized Nodes: Sensor nodes operate autonomously and collaboratively without a central controlling entity. Each node typically performs sensing, processing, and communication functions.

Limited Resources: Sensor nodes are resource-constrained in terms of processing power, memory, energy supply (often relying on batteries), and communication bandwidth. Energy efficiency is a critical concern due to the difficulty of replacing or recharging batteries in many deployment scenarios.

Ad Hoc Networking: Sensor nodes communicate directly with each other or through multi-hop communication to reach a sink node or base station, which acts as a gateway to the external network.

Self-Organization: Nodes in a WSN often organize themselves into clusters to facilitate efficient data collection, aggregation, and transmission. This clustering structure helps conserve energy and manage network scalability.

Data Aggregation: Since WSNs generate a substantial amount of data, in-network processing and aggregation are employed to reduce the volume of data transmitted, thus saving energy and bandwidth.

Diverse Applications: WSNs are used for various applications, such as environmental monitoring (e.g., forest fire detection, air quality), industrial automation (e.g., equipment monitoring, quality control), healthcare (e.g., patient monitoring), smart agriculture (e.g., precision irrigation), and smart cities (e.g., traffic monitoring, waste management).

Hardware Architecture of Wireless Sensor Node

As depicted in Figure 1. [5], [6], the architecture of a sensor node typically consists of a single unit that houses the sensing, processing, communication, and power supply modules.

Additionally, depending on the requirements of the application, location-finding systems (such a GPS receiver) and mobility modules may also be included. Serial interface is favored over parallel interface due to the low size requirements of wireless sensor nodes and the fact that parallel interfaces take up more space when transferring many bits at once (rapid data transfer). The following section provides a quick explanation of the sensor node's components.

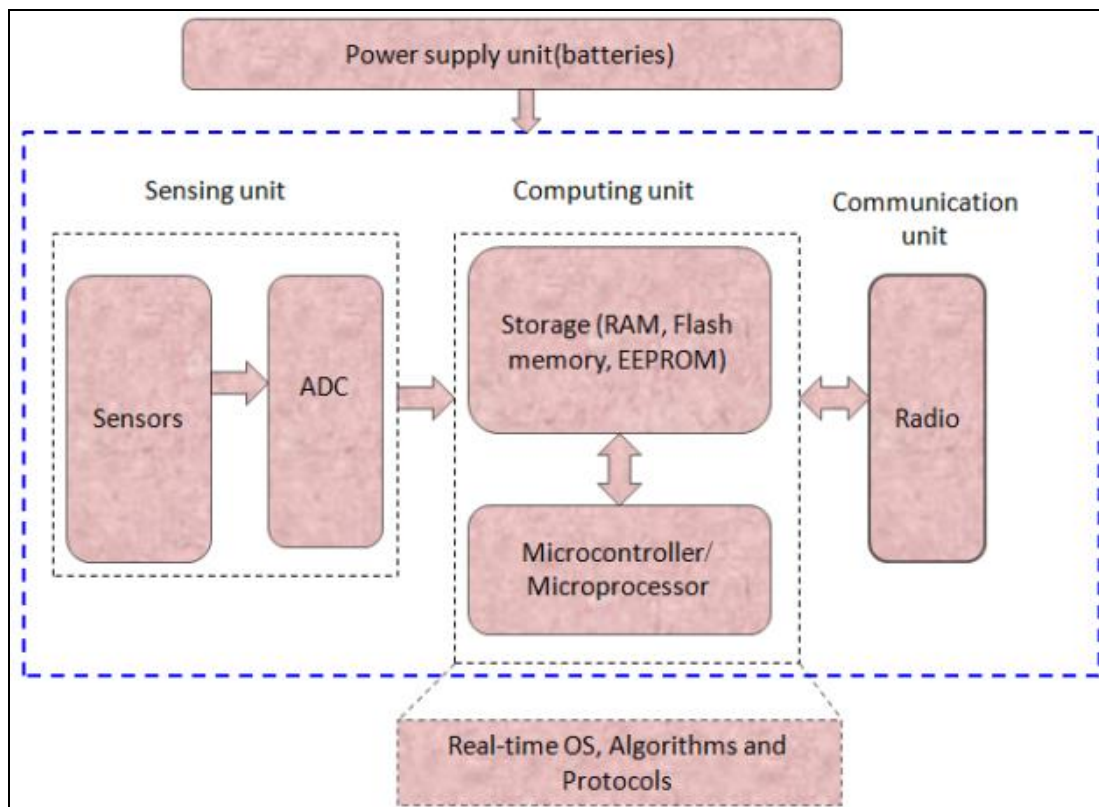


Fig 1: System architecture of wireless sensor node.

Processing unit

The processing module is in charge of handling data from sensors. It is also in charge of carrying out application programs and communication protocols. Sensor data, program instructions, and packets are all kept in memory or storage subunits. The effectiveness, cost, and flexibility of the node are directly impacted by the choice of processor subsystem from among the many off-the-shelf processors,

including microcontroller, Field Programmable Gate Array (FPGA), Digital Signal Processors (DSPs), and Application Specific Integrated Circuits (ASIC) [7]. Since the majority of the transceiver's components are shut off, the radio cannot immediately transmit or receive in the sleep state. The transceiver must therefore have recovery time to initialize and configure the radio before beginning its regular duty, which may take startup energy to complete.

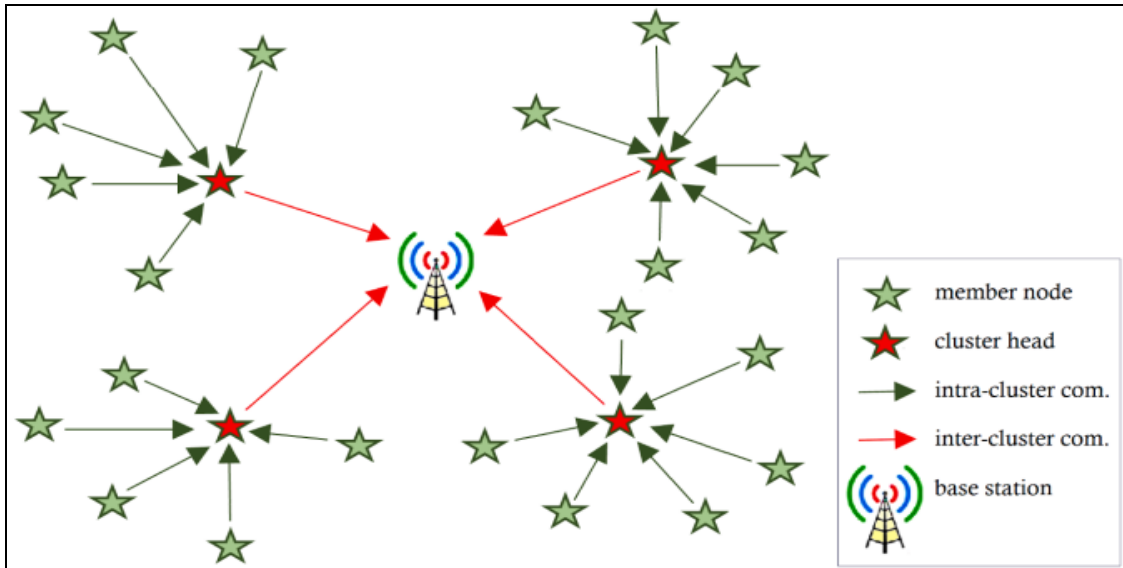


Fig 2: Single-hop single-BS clustered WSN topology

There are several operational states (various power consumption modes) for the radio, including transmit, receive, idle, and sleep [12, 13]. Significant portions of the reception electronics are kept operational in idle mode, while hardware operations can be turned off. As a result, the radio uses energy as it operates in an idle state while waiting for a signal.

networks, in contrast to the Internet, are not intended for all-purpose applications [26]. While other applications, like wildlife control, require routine monitoring, time-critical applications, like fire breakout surveillance, are particularly sensitive to delays. While some applications require a high data rate, others only need a moderate data rate. Figure 3 depicts the network topology of wireless sensor networks [27]. The following describes the five protocol layers.

Communication Protocols Architecture: Wireless sensor

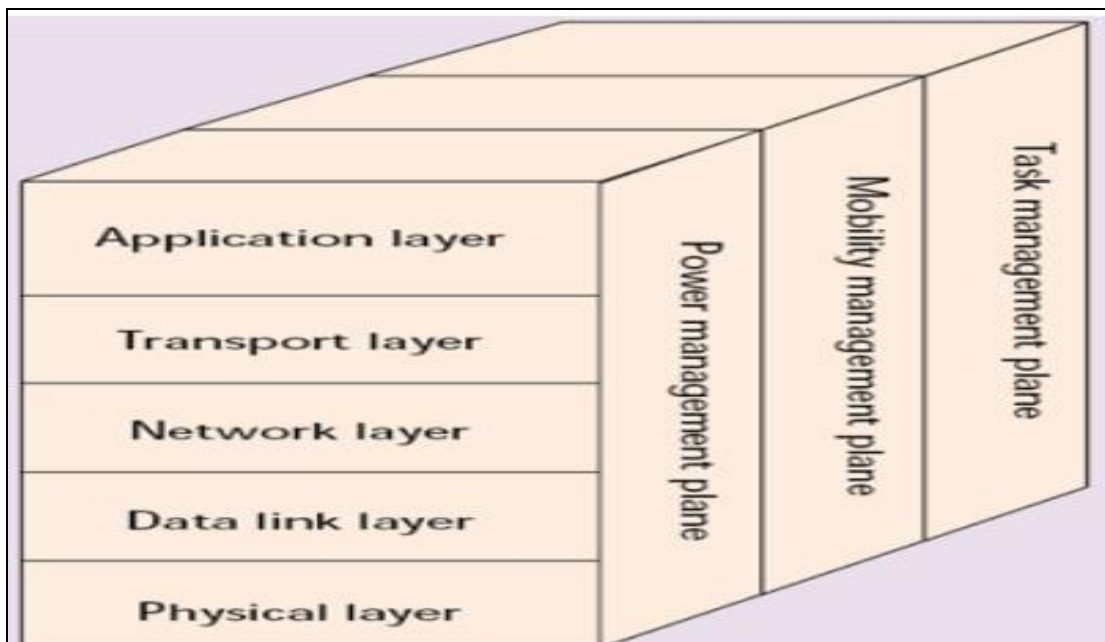


Fig 3: Network architecture of WSNs

Physical layer: The physical layer transforms data link layer bit streams into signals that may be transmitted via a communication media. Therefore, the physical layer is in charge of carrying out operations such as carrier frequency selection, modulation, creation of Radio Frequency (RF) signals, and amplification.

Data link layer (DLL): Medium Access Control (MAC) and Logical Link Control (LLC) layers are the two sublayers of the data link layer (DLL). There is a potential of interference in wireless communication, especially in contention-based protocols when a large number of wireless terminals are vying for access to a single transmission medium (channel).

Network layer: Using single-hop or multi-hop transmission mechanisms, network layer is responsible for packet routing between source and destination nodes.

Transport layer: Congestion control and reliable packet transmission are handled by the transport layer protocols. In contrast to TCP/IP networks, wireless sensor networks may not always require 100% dependability because sensors can read redundant data, with the exception of sensor control command and query transmission in the downstream channel (sink to sensor). As a result, wireless sensor networks are not a suitable fit for the TCP and UDP transport layer protocols, which are thought to have a solid reputation on the Internet [28].

Application layer: Since wireless sensor networks are designed to support a wide range of applications, it is difficult to create application layer protocols that can fully satisfy user needs. The characteristics, constraints, common demands, and issues of WSN applications must be fully and in-depth understood in order to create application layer protocols. In most cases, application layer protocols are employed to hide from the user the hardware and software characteristics of lower levels.

Applications of wireless sensor networks

The use of wireless sensor networks is quite broad because smart sensors may be placed everywhere to control the physical phenomena in our daily activities and because there is a growing need for information domination in both military and civilian society. When biological, nuclear, and chemical threats are detected on the battlefield, sensor networks provide the commander of an army with the information they need to be in control of the situation militarily [29–33]. Inspecting war zones and tracking targets are further possible uses for wireless sensor networks in military surveillance. The monitoring and management of elderly persons while they are at home is one great application of sensor networks in community care services. People now live modern, opulent lives thanks to the spread of technology, but the ecology has become out of balance as a result of the vast amounts of chemicals that are constantly released into the atmosphere.

Applications of WSNs in businesses include pipeline oil or gas leak detection, process control, and machine fault detection [41, 42]. Wireless sensors can be used in building automation to control a room's temperature, ventilation, and

humidity in order to save energy [43]. Wireless sensor networks make it simple to assess the mechanical load on any structures or bridges built in an earthquake-prone area.

Limitations and WSN Design Challenges

Wireless Sensor Networks (WSNs) face several limitations and design challenges due to their unique characteristics and operational constraints. These challenges impact the efficiency, reliability, and overall performance of WSNs. Here are some key limitations and design challenges:

- **Limited Energy Resources:** Sensor nodes are typically powered by batteries with limited capacity. Energy-efficient design is crucial to prolong the network's operational lifetime. This challenge drives the need for energy-efficient communication, data processing, and sleep scheduling strategies.
- **Data Communication and Reliability:** Wireless communication in WSNs can be affected by interference, signal attenuation, and environmental obstacles. Maintaining reliable data transmission in the presence of these challenges is critical, especially in applications requiring real-time data delivery.
- **Network Scalability:** As the number of sensor nodes increases, managing network scalability becomes complex. Scalability issues impact routing efficiency, data aggregation, and overall network management.
- **Dynamic Network Topology:** Nodes can join or leave the network, and connections between nodes may change due to mobility or environmental factors. Designing routing and communication protocols that adapt to dynamic network topologies is a challenge.
- **Localization:** Determining the physical location of sensor nodes accurately is challenging. Localization is essential for various applications like tracking and monitoring in both indoor and outdoor environments.
- **Data Aggregation:** Aggregating data at intermediate nodes to reduce data transmission helps conserve energy and bandwidth. However, achieving accurate aggregation while minimizing errors is a complex task.
- **Security and Privacy:** WSNs are vulnerable to security threats due to their open and distributed nature. Ensuring data confidentiality, integrity, and authenticity, along with protecting against node compromises and unauthorized access, presents significant challenges.
- **Quality of Service (QoS):** Some applications demand specific QoS requirements, such as low latency or high data throughput. Achieving these requirements while considering energy constraints can be challenging.
- **Fault Tolerance:** Node failures due to hardware issues, energy depletion, or external factors can disrupt network operations. Developing fault-tolerant mechanisms to ensure the network's reliability is essential.
- **Resource Constraints:** Limited processing power and memory on sensor nodes can hinder the implementation of complex algorithms and protocols.
- **Heterogeneity:** Sensor nodes may have different capabilities, such as varying energy levels, processing power, and sensing ranges. Designing protocols that accommodate such heterogeneity is a challenge.
- **Interoperability:** Ensuring compatibility and

interoperability between different sensor node types and network protocols is essential for integrating WSNs into larger systems.

Statement of the problem

Despite deploying WSNs for many ubiquitous and pervasive applications, maintaining sensor functionality over an extended time horizon is difficult due to power supply constraints. Low power radio designs and energy-saving protocol architectures are the first and most researched demands for power-constrained WSNs because the main source of energy consumption in wireless sensor nodes is connected to dissipation for communications in the radio hardware.

System models

Proposed protocol design

In wireless sensor networks, the arrangement of nodes into clusters has a significant impact on how well-functioning nodes are. For optimal node distribution in the clusters, the average distance between nodes and the corresponding cluster heads is minimized. If the placement of nodes into clusters is optimized, it can effectively regulate imbalanced load distribution in addition to decreasing communication costs within the cluster.

Consider a network that has N nodes. The solution is to cluster N nodes into c clusters while minimizing the estimated distance of nodes from cluster centers. The cluster centers on the reception of the geographic location of nodes in the WSN field are computed by the base station. The fuzzy (soft) clustering method has been used to partition the network into clusters since many scientific and technical problems are fuzzy in nature.

$$fobj = \sum_{j=1}^c \left(\sum_{i=1}^N u_{ij}^m d_{ij}^2 \right)$$

Where m is the fuzziness index and dij represents the Euclidean distance of node i from cluster centroid j. The centroid of clusters is located using the fuzzy c-means clustering algorithm. Let Uf be a variable made up of vectors representing the degree to which each node belongs to the specified cluster.

$$u_{ij} = \frac{1}{\sum_{\ell=1}^c \left(\frac{d_{ij}}{d_{i\ell}} \right)^{2/m-1}}$$

As indicated in the following equation, the centroid of each cluster is calculated by averaging all data points (the positions of nodes in the WSN field) and weighting those data points according to how much they belong to the cluster.

$$c_j = \frac{\sum_{i=1}^N u_{ij}^m pos(node\ i)}{\sum_{i=1}^N u_{ij}^m}$$

The FCM algorithm terminates when either a predetermined maximum number of iterations is achieved or the difference between the contents of Uf in subsequent iterations is smaller than a threshold value.

The cluster leader configuration is then applied to eligible set nodes that are also extremely near the cluster centroid. Finally, the base station broadcasts configuration information back to nodes, including the matching cluster leader for each regular node and the TDMA transmission schedule information. The cluster members relay the information to their cluster chiefs as soon as they receive the message.

Experimental Results and Discussion

The simulation tool OMNeT++ is used to implement the protocol. N (N100) sensor nodes are dispersed throughout the 100m x 100m WSN area at random. Initial energy = 2J, base station location = (175, 50) m, control packet size = 25 bytes, data packet size = 500 bytes, Eelc = 50nJ/bit, energy loss for data aggregation (Eda) = 5nJ/bit/signal, efs = 10pJ/bit/m2, emp = 0.0013pJ/bit/m4, and TDMA frames per round = 6 are the parameters used in the simulation. The simulation looks at the number of active nodes in each round, the variation in their energy consumption, and the total energy consumed by nodes.

Table 1: Shows the duration until the specified proportion of nodes dies for the LEACH, LEACH-C, CHEF, and FCM protocols.

Metric	LEACH	LEACH-C	CHEF	FCM
FND	110	177	189	640
20% of nodes die	287	575	453	652
40% of nodes die	399	581	569	657
HND	440	584	599	662
60% of nodes die	501	589	655	667
80% of nodes die	592	628	684	672
LND	777	809	819	707

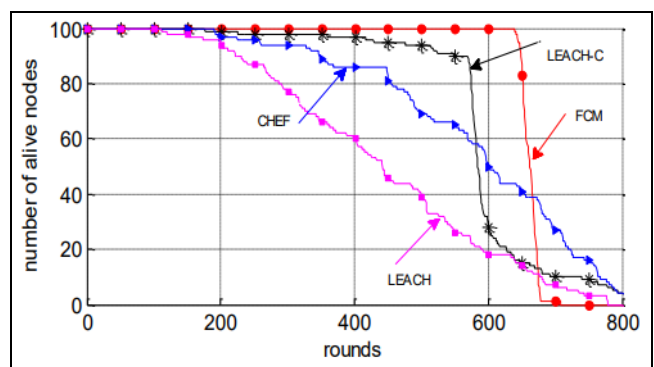


Fig 6.1: Functional nodes per simulation rounds.

In WSNs, the balance of energy dissipation among nodes is necessary to prevent nodes from dying too soon. The network's load balance has been assessed using the variation of nodes' residual energy during each round. The simulation outcome shown in According to Figure 6.2, the FCM-based approach outperforms LEACH, LEACH-C, and CHEF protocols with regard to network load balancing. The overall energy In the simulation, node consumption each round is also looked at. Figure 6.3 shows 20 cycles are chosen at random to compare each node's overall energy consumption protocol.

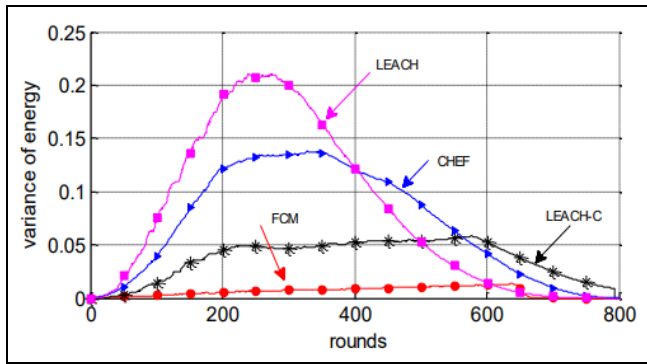


Fig 6.2: The variance of residual energy among nodes.

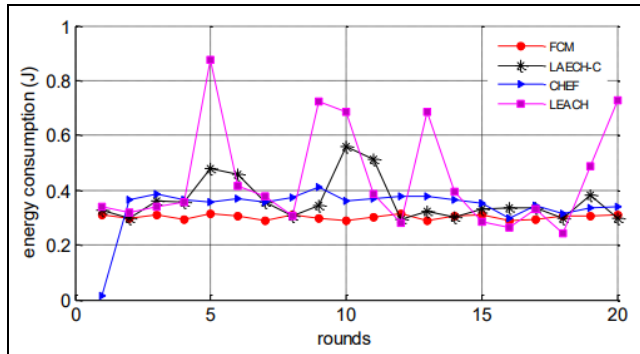


Fig 6.3: Total energy consumption of nodes versus time

The design and development of protocols for wireless sensor networks are complicated by the energy constraints that exist in sensor nodes. Energy-efficient routing protocol is described using the fuzzy c-means clustering algorithm in light of the fact that energy efficiency is one of the earliest and most researched concerns in wireless sensor networks. The clustering of nodes is optimized by the suggested protocol. The FCM-based routing protocol has undergone testing for node longevity, load balancing, and overall node energy usage.

Conclusion

In conclusion, addressing optimization challenges in clustering through the introduction of innovative and energy-efficient cluster-based routing protocols that leverage intelligent computing techniques holds great promise. Clustering remains a crucial technique in various domains, including wireless sensor networks, data mining, and machine learning. However, traditional approaches often grapple with optimization problems that hinder their performance and scalability. By incorporating intelligent computing techniques such as machine learning, artificial intelligence, and optimization algorithms, researchers and practitioners can devise novel solutions that optimize clustering processes. These techniques can facilitate efficient cluster formation, data aggregation, and communication among clusters while minimizing energy consumption, latency, and other performance bottlenecks. The synergy between clustering and intelligent computing empowers systems to adapt dynamically to changing conditions, harnessing insights from data patterns to enhance routing decisions, load balancing, and resource allocation. Moreover, the utilization of energy-efficient routing protocols can significantly extend the lifespan of

battery-powered devices in resource-constrained environments, fostering sustainable and resilient network operations. Nevertheless, the realization of these benefits demands thorough research, experimentation, and validation. It is essential to consider real-world scenarios, evaluate protocol performance through simulations and practical deployments, and iteratively refine the proposed techniques based on empirical findings.

References

1. Ghayvat H, Mukhopadhyay S, Gui X, Suryadevara N. WSN- and IoT-based smart homes and their extension to smart buildings. *Sensors*. 2015;15:10350–10379. [Google Scholar] [CrossRef] [PubMed]
2. Zhou M, Zhao M, Liu A, Ma M, Wang T, Huang C. Fast and efficient data forwarding scheme for tracking mobile targets in sensor networks. *Symmetry*. 2017;9:269. [Google Scholar] [CrossRef]
3. Heinzelman WB, Chandrakasan AP, Balakrishnan H. An application-specific protocol architecture for wireless microsensor networks. *IEEE Trans. Wirel. Commun.* 2002;1:660–670. [Google Scholar] [CrossRef][Green Version]
4. Essam M, Shaaban E. Enhancing S-LEACH security for wireless sensor networks. *Int. J. Appl. Comput.* 2011;4:101–107. [Google Scholar]
5. Manzoor B, Javaid N, Rehman O, Akbar M, Nadeem Q, Iqbal A, Ishfaq M. Q-LEACH: A new routing protocol for WSNs. *Procedia Comput. Sci.* 2013;19:926–931. [Google Scholar] [CrossRef]
6. Wang A, Yang D, Sun D. A clustering algorithm based on energy information and cluster heads expectation for wireless sensor networks. *Comput. Electr. Eng.* 2012;38:662–671. [Google Scholar] [CrossRef]
7. Abdulsalam HM, Ali BA. W-LEACH based dynamic adaptive data aggregation algorithm for wireless sensor networks. *Int. J. Distrib. Sens. Netw.* 2013;9:1–11. [Google Scholar] [CrossRef]
8. Sasikala ASD, Sangameswaran N. Improving the energy efficiency of LEACH protocol using VCH in wireless sensor network. *Int. J. Eng. Dev. Res.* 2015;3:918–924. [Google Scholar]
9. Batra PK, Kant K. LEACH-MAC: A new cluster head selection algorithm for wireless sensor networks. *Wirel. Netw.* 2016;22:49–60. [Google Scholar] [CrossRef]
10. Liu Y, Xu K, Luo Z, Chen L. A reliable clustering algorithm based on LEACH protocol in wireless mobile sensor networks. In *Proceedings of the International Conference on Mechanical and Electrical Technology*, Singapore, 10–12 September 2010; pp. 692–696. [Google Scholar]
11. Katiyar V, Chand N, Gautam GC, Kumar A. Improvement in LEACH protocol for large-scale wireless sensor networks. In *Proceedings of the International Conference on Emerging Trends in Electrical and Computer Technology*, Nagercoil, India, 23–24 March 2011; pp. 1070–1075. [Google Scholar]
12. Kim DS, Cha HS, Yoo S. Improve far-zone LEACH protocol for energy conserving. In *Proceedings of the International Conference on Wireless Communications, Networking and Mobile Computing*, Shanghai, China, 21–23 September 2012; pp. 1–4. [Google Scholar]

13. Lee JY, Jung KD, Moon SJ, Jeong HY. Improvement on LEACH protocol of a wide-area wireless sensor network. *Multimedia Tools Appl.* 2017;76:19843–19860. [Google Scholar] [CrossRef]
14. Marappan P, Rodrigues P. An energy efficient routing protocol for correlated data using CL-LEACH in WSN. *Wirel. Netw.* 2016;22:1415–1423. [Google Scholar] [CrossRef]
15. Cho S, Han L, Joo B, Han S. P-LEACH: An efficient cluster-based technique to track mobile sinks in wireless sensor networks. *Int. J. Distrib. Sens. Netw.* 2014;2014:803656. [Google Scholar] [CrossRef]
16. Klaoudatou E, Konstantinou E, Kambourakis G, Gritzalis S. A survey on cluster-based group key agreement protocols for WSNs. *IEEE Commun. Surv. Tutor.* 2011;13:429–442. [Google Scholar] [CrossRef]
17. MIT uAMPS LEACH ns Extensions. Available online: <http://www2.ece.rochester.edu/projects/wcng/code.html> (accessed on 1 December 2018).
18. Khediri SEL, Nasri N, Wei A, Kachouri A. A new approach for clustering in wireless sensors networks based on LEACH. *Procedia Comput. Sci.* 2014;32:1180–1185. [Google Scholar] [CrossRef]
19. Devika G, Karegowda A. A programmatic study of LEACH and its descendant routing protocols in WSN. *Int. J. Comput. Intell. Inform.* 2015;4:300–307. [Google Scholar]
20. Singh SK, Kumar P, Singh JP. A survey on successors of LEACH protocol. *IEEE Access* 2017;5:4298–4328. [Google Scholar] [CrossRef]
21. Liu JL, Ravishankar CV. LEACH-GA: Genetic algorithm-based energy-efficient adaptive clustering protocol for wireless sensor networks. *Int. J. Mach. Learn. Comput.* 2011;1:79–85. [Google Scholar] [CrossRef]
22. Kang SH, Nguyen T. Distance based thresholds for cluster head selection in wireless sensor networks. *IEEE Commun. Lett.* 2012;16:1396–1399. [Google Scholar] [CrossRef]
23. Ram SS, Manjunath D, Iyer SK, Yogeshwaran D. On the path coverage properties of random sensor networks. *IEEE Trans. Mobile Comput.* 2007;6:494–506. [Google Scholar] [CrossRef]
24. Liu B, Towsley D. A study on the coverage of large-scale networks. In *Proceedings of the IEEE International Conference on Mobile Ad-hoc and Sensor Systems*, Fort Lauderdale, FL, USA, 25–27 October 2004; pp. 475–483. [Google Scholar]
25. Zhang H, Hou J. On deriving the upper bound of α -lifetime for large sensor networks. In *Proceedings of the 5th ACM International Symposium on Mobile Ad-Hoc Networking and Computing*, Tokyo, Japan, 24–26 May 2004; pp. 121–132. [Google Scholar]
26. Lagarias JC, Reeds JA, Wright MH, Wright PE. Convergence Properties of the Nelder–Mead Simplex Method in Low Dimensions. *SIAM J. Optim.* 1998;9:112–147. [Google Scholar] [CrossRef]
27. Gao F, Han L. Implementing the Nelder–Mead simplex algorithm with adaptive parameters. *Comput. Optim. Appl.* 2012;51:259–277. [Google Scholar] [CrossRef]
28. Santhosh G, Prasad KV. Improved Fault Tolerance Energy Efficient Cluster Based Routing Through Second-Cluster Head. *Int J Intell. Syst. Appl Eng.* 2017;11(9s):407-413.
29. Gbadebo RA, Sanni ML, Akinyemi BO, Ajayi TO, Aderounmu GA. An Enhanced Cluster-Based Routing Model for Energy-Efficient Wireless Sensor Networks. *Indones J Electr Eng Inform.* 2017;11(2):586-609.
30. Sharma S, Hussain SZ. A Secure and Energy Efficient Cluster Based Routing Using Energy and Trust Aware-Multi Objective African Vultures Optimization for MANET.
31. Mishra R, Yadav RK. Energy Efficient Cluster-Based Routing Protocol for WSN Using Nature Inspired Algorithm. *Wirel Pers Commun.* 2017;130(4):2407-2440.
32. Shyja VI, Ranganathan G, Bindhu V. Link quality and energy efficient optimal simplified cluster based routing scheme to enhance lifetime for wireless body area networks. *Nano Commun Networks.* 2017;100465.
33. Darabkh KA, Amareen AAB, Al-Akhras M, Kassab WAK. An innovative cluster-based power-aware protocol for Internet of Things sensors utilizing mobile sink and particle swarm optimization. *Neural Comput Appl.* 2017:1-44.
34. Chithaluru P, Al-Turjman F, Stephan T, Kumar M, Kumar S. An Optimized Bio-inspired Localization Routing Technique for Sustainable IIoT Networks & Green Cities. *Sustainable Cities Society.* 2017;97:104722.
35. Maheshwar K, Veenadhari S, Almelu S. Performance analysis of energy efficient optimization algorithms for cluster based routing protocol for heterogeneous WSN. In: *Applications of Artificial Intelligence and Machine Learning: Select Proceedings of ICAAAIML 2015*. Singapore: Springer Nature Singapore; 2018. p. 631-643.
36. Mishra R, Yadav RK. Energy efficient cluster-based routing protocol for wireless sensor network using nature inspired mechanism. 2018.
37. Gayatri V, Kumaran MS. Energy Efficient Cluster based Multipath Routing Protocol in MANET using Genetic Particle Swarm Optimization Algorithm. *Int J Intell Syst Appl Eng.* 2018;10(4):231-239.

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