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REVIEW ARTICLE

Energy efficient routing with cluster approach in wireless networks – A literature review

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Abstract

This literature review examines the cluster-based approaches in wireless networks, focusing on their effectiveness in conserving energy, enhancing routing efficiency, and improving network credibility. Wireless networks are increasingly employed in various applications, from internet of things (IoT) systems to mobile ad hoc networks, where energy efficiency is critical due to the limited battery life of devices. Cluster-based techniques group nodes into clusters to optimize resource utilization, facilitating energy conservation by enabling localized communication and reducing redundant transmissions. The review explores various clustering algorithms, such as low-energy adaptive clustering hierarchy (LEACH) and hybrid energy-efficient distributed clustering (HEED), highlighting their impact on network longevity and scalability. Additionally, the study addresses the challenges of maintaining robust routing protocols within clustered networks, emphasizing the importance of reliable data transmission and node credibility to mitigate risks from malicious attacks. By synthesizing current research findings, this review provides insights into the future directions of cluster-based strategies in wireless networks, suggesting potential enhancements to ensure efficient energy management and reliable network performance.

Keywords: Wireless networks, Clustering approach, Efficient routing, Malicious attacks, energy efficient.

Introduction

Wireless networks have become integral to modern communication systems, powering a wide range of applications such as smart cities, environmental monitoring, healthcare systems, and industrial automation. Their decentralized nature and the flexibility they provide have driven advancements in various fields, especially in internet of things (IoT) ecosystems and wireless sensor networks (WSNs). Despite their advantages, wireless networks face critical challenges, including limited battery life, routing inefficiencies, and security vulnerabilities. Addressing these issues requires innovative strategies to ensure the network operates efficiently while conserving energy, maintaining reliable communication, and safeguarding the network's integrity, Zagrouba, R., & Kardi, A. (2021).

Clustering approaches have emerged as one of the most effective techniques to address these challenges. In a cluster-based architecture, nodes are grouped into clusters, with a designated cluster head responsible for coordinating communication within the cluster and forwarding data to other clusters or a central node. This hierarchical structure offers multiple benefits, including reduced energy consumption, scalability, and efficient data aggregation. By limiting long-range transmissions to cluster heads and minimizing direct communication between individual nodes and base stations, clustering conserves energy, which is critical in energy-constrained environments like sensor networks, Nakas, C., Kandris, D., & Visvardis, G. (2020), Samara, G., Alhammad, H., Aqel, M., Alsayyed, N., & Assal, H. (2020).

Energy conservation is a primary focus in wireless network research, as the longevity of the network often depends on the battery life of its nodes. Clustering reduces the energy expended during communication by localizing data exchanges within clusters and optimizing the selection of cluster heads based on their energy levels. Numerous algorithms, such as low-energy adaptive clustering hierarchy

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(LEACH), hybrid energy-efficient distributed clustering (HEED), and energy-efficient unequal clustering (EEUC), have been developed to balance energy consumption across nodes, prolonging the network's lifnetwork'sque, M. E., & Baroudi, U. (2020), Lodhi, A. K., Rukmini, M. S. S., & Abdulsattar, S. (2021).

Beyond energy efficiency, routing is another critical factor in cluster-based wireless networks. Routing protocols must be designed to handle dynamic network conditions, including the mobility of nodes and fluctuating energy levels. Clustering helps simplify routing by establishing a clear hierarchy, reducing the complexity of route discovery and maintenance. However, routing in clustered networks must still address issues like load balancing, minimizing packet loss, and reducing latency. Research has focused on developing robust routing protocols that adapt to network conditions, such as power-aware and multi-hop routing strategies, to enhance overall network performance, Dogra, R., Bhardwaj, N., Singh, R., & Verma, A. (2022), Wang, Z., Peng, L., Jiang, C., & Xie, F. (2020).

In addition to energy conservation and routing efficiency, the credibility and security of wireless networks are becoming increasingly important. Cluster-based networks are susceptible to various threats, including malicious attacks, node failures, and data breaches. Ensuring the integrity of data and the trustworthiness of cluster heads is crucial for the network's relnetwork's Trust-aware clustering approaches have been proposed, combining traditional clustering techniques with trust evaluation mechanisms to detect and mitigate malicious activities, ensuring that only credible nodes assume the role of cluster heads, Behera, T. M., Nayak, P., Lavanya, R., & Swain, S. K. (2022), Jiang, D., Xu, Z., Wang, W., & Shen, Y. (2021), Lahsen-Cherif, I., Zitoune, L., & Vèque, V. (2021).

This literature review aims to explore and analyze the existing research on cluster-based approaches in wireless networks. It will investigate how clustering algorithms contribute to energy conservation, improve routing efficiency, and enhance the credibility of the network. By examining key studies and their findings, this review will provide a comprehensive understanding of the current state of cluster-based strategies and offer insights into potential future developments in this area.

Background Study of Wireless Networks

Wireless networks have revolutionized communication systems by enabling data transmission without the need for physical connections. The flexibility and scalability of wireless networks have led to their widespread adoption across multiple domains, including healthcare, environmental monitoring, smart cities, industrial automation, and military applications. The underlying principle of wireless networks is their ability to connect nodes (such as sensors, devices, or routers) through wireless communication channels, enabling the transfer of information in real-time or near-real-time. However, the decentralized nature of wireless networks also presents significant challenges, especially concerning energy efficiency, routing, and network security, Zagrouba, R., & Kardi, A. (2021), Nakas, C., Kandris, D., & Visvardis, G. (2020).

Types of Wireless Networks

Wireless networks can be broadly categorized into different types based on their architecture and application domain:

Wireless sensor networks (WSNs)

WSNs consist of spatially distributed sensor nodes that monitor environmental conditions such as temperature, humidity, or pressure. These nodes communicate wirelessly to relay the collected data to a central base station. WSNs are typically used in remote or hazardous environments where human intervention is minimal, making energy efficiency crucial to their operation. WSNs are often resource-constrained in terms of power, processing, and communication capabilities, necessitating specialized techniques for energy conservation, data routing, and security.

Mobile ad hoc networks (MANETs)

MANETs are self-configuring networks of mobile devices connected by wireless links. These networks operate without any fixed infrastructure, with nodes dynamically forming and maintaining connections as they move. MANETs are particularly useful in disaster recovery, military operations, and emergency response systems. The dynamic topology of MANETs, where nodes frequently join and leave the network, poses challenges in terms of reliable communication, efficient routing, and energy consumption.

Internet of things (IoT) Networks

IoT networks connect a variety of smart devices, such as sensors, actuators, and consumer electronics, to share data over the internet. These devices often have limited processing power and rely on low-energy communication protocols like Zigbee, LoRa, or Bluetooth Low Energy (BLE). The scalability of IoT networks, combined with their diverse application environments (smart homes, smart cities, healthcare, etc.), makes energy conservation, data management, and security paramount concerns.

Wireless mesh networks (WMNs)

WMNs consist of routers that relay data to and from clients in a mesh topology. The decentralized structure of WMNs provides redundancy and fault tolerance, making them suitable for citywide wireless internet access and large-scale IoT applications. While WMNs offer robust connectivity, maintaining energy efficiency and optimizing routing in such networks requires careful consideration.

Background Study on Cluster-Based Approaches in Wireless Networks

Cluster-based approaches have emerged as a prominent solution to the challenges faced by wireless networks, particularly in the context of wireless sensor networks (WSNs), Mobile Ad Hoc Networks (MANETs), and the IoT. The fundamental idea behind clustering is to group nodes into clusters, each managed by a designated cluster head (CH) that coordinates communication within and between clusters. This hierarchical structure optimizes energy consumption, enhances routing efficiency, and improves network scalability and security Haque, M. E., & Baroudi, U. (2020); Lodhi, A. K., Rukmini, M. S. S., & Abdulsattar, S. (2021); Dogra, R., Bhardwaj, N., Singh, R., & Verma, A. (2022).

The Need for Clustering in Wireless Networks

As wireless networks grow in complexity and size, traditional flat architectures become less efficient due to increased energy consumption, routing overhead, and difficulties in managing large-scale communications. Clustering addresses these issues by reducing the number of transmissions required and localizing communication, which leads to several key advantages:

Energy conservation

In energy-constrained environments like WSNs, the battery life of nodes is a critical concern. By limiting long-range communication to cluster heads, clustering reduces the overall energy expenditure of the network. Non-cluster-head nodes communicate primarily with their local CHs, minimizing power-intensive transmissions over greater distances.

Improved routing efficiency

Clustering simplifies the routing process. Instead of all nodes transmitting data directly to a base station, only the cluster heads communicate this information, which reduces congestion and decreases the likelihood of collisions in the communication channel. This hierarchical routing structure enables more efficient data aggregation, resulting in reduced bandwidth consumption and latency.

Scalability

The cluster-based architecture facilitates scalability in wireless networks. As the network size increases, additional clusters can be formed without significantly affecting the existing structure. This adaptability is essential for environments where the number of nodes can fluctuate, such as in IoT applications where devices are continuously added or removed.

Enhanced network management

Clustering allows for better management of network resources and functionalities. The cluster head can be tasked with specific responsibilities, such as monitoring node status, managing communication protocols, and aggregating data. This division of labor streamlines network management and enhances operational efficiency.

Clustering Algorithms

Numerous clustering algorithms have been proposed in the literature, each designed to optimize various aspects of network performance, such as energy consumption, load balancing, and data aggregation. Some of the most notable clustering algorithms include Gururaj, H. L., Patil, M. S., Patil, S. S., & Neginhal, S. (2023), Kandris, D., Visvardis, G., Papatheodorou, T., & Kandris, S. (2023), Ismail, M., Jahanzaib, M., Batool, S., & Malik, S. (2023), Narayan, V., Daniel, A. K., & Chaturvedi, P. (2023), Biswas, K., Hoque, M. A., Mollah, A., & Mia, M. I. (2023):

LEACH (Low-energy adaptive clustering hierarchy)

LEACH is one of the pioneering clustering protocols designed specifically for WSNs. It uses a probabilistic approach to select cluster heads randomly, ensuring that energy consumption is evenly distributed among nodes. LEACH reduces energy usage by enabling data aggregation at the cluster head level, which minimizes the amount of data transmitted to the base station. The rotating nature of cluster head selection enhances the longevity of the network.

HEED (Hybrid energy-efficient distributed clustering)

HEED enhances LEACH by considering both node energy levels and communication costs when selecting cluster heads. By utilizing multiple rounds of clustering based on energy levels, HEED ensures a more balanced energy distribution across nodes. This approach effectively addresses the issue of premature node death, a common problem in WSNs.

EEUC (Energy-efficient unequal clustering)

EEUC addresses the limitations of equal clustering by proposing unequal cluster sizes, where nodes closer to the base station form smaller clusters. This design reduces the transmission distances for these nodes, thus conserving energy. The unequal clustering mechanism helps balance the energy consumption across the network more effectively.

C-LEACH (Clustered low-energy adaptive clustering hierarchy)

C-LEACH is a modification of LEACH that incorporates a centralized decision-making process to form clusters based on more comprehensive information about node locations and energy levels. This approach can enhance network performance by creating more optimal cluster structures.

Fuzzy-based clustering approaches

Some recent studies have incorporated fuzzy logic into clustering algorithms to improve the selection of cluster heads based on multiple criteria, including node energy, distance to other nodes, and reliability. These fuzzy-based approaches adaptively adjust clustering parameters, leading to better performance in dynamic environments.

Literature Survey

The authors suggested a collaborative energy-efficient routing protocol (CEEPR) for sustainable communication in 5G/6G wireless sensor networks (WSNs). Initially, this study gathered and collected the data at the sink node. The network's nodnetwork'sustered using the reinforcement learning technique (R.L.). Cluster head selection is employed for better data transmission using residual energy (RE) based cluster head selection algorithm. A collaborative energy-efficient routing protocol (CEERP) is proposed. We use a multi-objective improved seagull algorithm (MOISA) as an optimization technique to enhance the system's perfsystem's Finally, the presentation of the system is analyzed, Gururaj, H. L., Gururaj, B. S., Nayyar, A., & Sharma, V. (2023).

The authors aimed to clarify the most popular subdivision of this category of protocols i.e. the so-called hierarchical energy-efficient routing protocols. Specifically, LEACH, which is considered to be the pioneer protocol of this kind, is studied along with 18 of its descendant protocols. A theoretical comparison of these protocols in terms of various metrics is also performed. Additionally, the performance of LEACH is compared with that of 3 descendant protocols through simulation tests that are carried out. Finally, a discussion takes place and concluding remarks are drawn, Kandris, D., Nakas, C., Visvardis, G., & Dritsas, E. (2023).

The authors proposed a Shifted Energy Efficiency and Priority (SHEEP) routing protocol for UWSNs. The proposed protocol aims to enhance the efficiency of the state-of-the-art Energy Balanced Efficient and Reliable Routing (EBER2) protocol for UWSNs. SHEEP is built upon the depth and energy of the current forwarding node, the depth of the expected next forwarding node, and the average energy difference among the expected forwarders, Ismail, M., Alrajeh, N. A., & Shakshuki, E. (2023).

The Particle Swarm Optimization (PSO) method is utilized to form the cluster, and a Fuzzy based Energy Efficient Routing Protocol (E-FEERP) is proposed using average distance of SN from BS, node density, energy and communication quality to transmit data from cluster head to the BS in an optimal manner. The proposed protocol used parallel fitness function computing to quickly converge to the best possible solution with fewer iterations. The protocol used PSO-based clustering algorithm that recognize how birds act when they are in a flock. It is an optimization strategy that uses parallel fitness function computing to get to an optimal solution quickly and with a small number of iterations. Fuzzy is combined with PSO to increase coverage with reduced computational overhead. The proposed E-FEERP improves network performance in terms of packet delivery ratio, Residual Energy (RE), throughput, energy consumption, load balancing ratio, and network lifetime, Narayan, V., Daniel, A. K., & Chaturvedi, P. (2023).

The authors proposed an Energy Efficient Secure Multipath (EESM) routing protocol to securely construct efficient routes and transmit data packets between SNs and the base station (BS). EESM achieves energy efficiency through minimal task allocation among SNs whereas all computation-intensive tasks such as network information collection, routing table generation, and network maintenance, are performed by the BS. The proposed protocol incorporates lightweight security mechanisms, including a one-way hash chain, message authentication code, encryption, and clique-based coordinator selection and monitoring schemes to defend against numerous security attacks, Biswas, K., Djenouri, D., Mathew, J., & Ra, I. H. (2023).

The authors proposed a dynamic random multipath routing method (DRMRM) for LWSNs. The technique combines the node depth and residual energy models to select the optimal next-hop relay node without relying on the transmission routing table. At the same time, we designed a data loss retransmission mechanism and a data loop retreat mechanism to prevent data packets from reaching a dead end. The experimental results demonstrate that our routing method is superior to existing energy consumption balance and network lifespan protocols, Yang, H., Chen, M., Wang, Z., & Li, S. (2024).

An energy efficiency optimization routing decision system is proposed based on the establishment of a three-dimensional Voronoi polygon topology model. First, we define a node state-related attribute parameter that determines whether the source node and the forward node are linked. The data forwarding node is determined by comparing attribute differences. Then, a power control mechanism based on received signal strength is proposed to solve the energy consumption, which includes deterministic and random parts. Finally, the specific state of the network node is monitored by comparing the attribute decision matrix to ensure basic maintenance of network operation and improve network transmission reliability, Liu, D., Chen, G., & Wang, Y. (2023).

The key objective of this proposed scheme is to enhance the surviving period of WSN with the help of assistant cluster nodes. Energy optimization is achieved by developing an Improved-Optimized Energy-Efficient Routing Protocol (I-OEERP) which eliminates such residual nodes creation and enhances the network lifetime. The nature of the given scheme C-GSA is based on a hybrid of both Crow Search Algorithm (CSA) and Gravitational Search Algorithm (GSA). By utilizing the concepts of CSA cluster formation, residual node formation can be controlled. After that, GSA is used for routing, Kumar, S., & Agrawal, R. (2023).

The use of clustering and routing to extend the lifetime of a network, which is a significant issue in sensor networks, has been extensively researched. Routing entails numerous activities that significantly impact the network's lifnetwork's throughput. The clustering strategy with data aggregation on cluster heads impacts total network performance. The proposed method includes the k-medoid technique for clustering and a stochastic model of the CH selection for energy efficient green WSN. A predictive analysis of the slot scheduling model is also incorporated for further network energy conservation. Also, an improved ant colony optimization algorithm is used to find the optimal route. The proposed work is implemented in MATLAB and the results are taken in terms of packet delivery ratio (PDR), packet loss ratio (PLR), network lifetime, jitter, end-to-end delay, throughput, bit error rate (BER) and energy consumption for proposed and existing techniques, Banerjee, I., & Madhumathy, P. (2023).

The authors presented an intelligent, energy-efficient multi-objective routing protocol based on the RL algorithm with dynamic objective selection (DOS-RL). The primary goal of applying the proposed DOS-RL routing scheme is to optimize energy consumption in IoT networks, a paramount concern given the limited energy reserves of wireless IoT devices and the adaptability to network changes to facilitate a seamless adaption to sudden network changes, mitigating disruptions and optimizing the overall network performance. The algorithm considers correlated objectives with informative-shaped rewards to accelerate the learning process. Through the diverse simulations, we demonstrated improved energy efficiency and fast adaptation to unexpected network changes by enhancing the packet delivery ratio and reducing data delivery latency when compared to traditional routing protocols such as the Open Shortest Path First (OSPF) and the multi-objective Q-routing for Software-Defined Networks (SDN-Q), Godfrey, D., Qin, Y., Zhang, X., & Wang, H. (2023).

The authors proposed EEDC: An Energy Efficient Data Communication scheme by utilizing "Region-based"Hierarchical Clustering for Efficient Routing (RHCER)"—a multi-tie" clustering framework for energy-aware routing decisions. The sensors deployed for IoT application data collection acquire important data and select cluster heads based on a multi-criteria decision function. Further, to ensure efficient long-distance communication along with even load distribution across all network nodes, a subdivision technique was employed in each tier of the proposed framework. The proposed routing protocol aims to provide network load balancing and convert communicating over long distances into shortened multi-hop distance communications, hence enhancing network lifetime, Gupta, D., Chhillar, R. S., Verma, D. P., & Mankotia, M. (2023).

An efficient approach is essential to ensure reliable data transmission within these components. Suppose we adopt a holistic approach that encompasses hardware optimization, software strategies, and communication protocol choices. In that case, it is possible to maximize the lifespan of sensor nodes and ensure the reliable operation of these networks. However, it is important to strike a balance between energy efficiency and network performance to meet the specific needs of each application and that is the goal of our work. We decide to improve AODV protocol through combining it with energy-aware mechanisms and careful energy management strategies, we can significantly improve the energy efficiency of wireless sensor networks. AODV's on-demAODV'suting strategy aligns well with energy conservation in WSNs. The protocol minimizes routing overhead by creating routes only when necessary. However, AODV does not directly address energy efficiency in data transmission, such as data aggregation or duty cycling or other strategies; the proposed model shows that the improved 'eneciency' A'DV approa'h based on priority and load balancing minimizes extremely the energy consumption in WSN, Moulad, L., & Moussaid, L. (2024).

A novel cluster-based hierarchical routing protocol, named Pizzza, is introduced in this paper. Pizzza is creatively designed by forming minimum spanning trees among communicating nodes in each sector-shape cluster, where only eligible nodes from the first level of the architecture can undertake cluster head leading role. Employment of this innovative scheme has concluded in the prolongation of the network lifetime through the reduction in energy wastage resulting from the elimination of reverse data flow from BS, data transmission to the nearest neighbors, and balanced energy consumption in the network, Nasirian, S., De Lima, J., Naderi, H., & Tomic, S. (2023).

The authors proposed a routing protocol energy-saving called Bacterial foraging optimization routing protocol (BFORP). BFORP attempts to investigate the problem of the life of WSNs. It can decrease the routing of excessive messages that may result in severe energy waste by recycling the information that frequents the source node into the sink. In the proposed method, the preferable node in the sending routes may be chosen by prioritizing the lowest traffic load, the highest residual energy, and the shortest path to the sink. In comparison to the known protocols used in routing, the results of the simulation have proven the efficacy of the suggested protocol in lowering energy employment and reducing the delay of end-to-end, Abdulzahra, A. A., Khudor, B. A. Q., & Alshawi, I. S. (2023).

The authors attempted to overcome this limitation by proposing an energy efficient weight based clustering algorithm (EEWCA) scheme. In this approach, the weights of nodes are assessed using links between nodes in terms of node stability, node neighborhoods, energy consumptions, distance between nodes, node densities, and residual energies. The proposed CH selections framework is based on preventing dead CHs when their power falls below a range by choosing an alternative cluster node as CH. Adaptive particle swarm optimization (APSO) is formulated with Ad hoc On-demand distance vector (AODV) for detecting breakages in links by assessing node energies, densities, and reduced overheads, Tamizharasu, S., & Kalpana, P. (2023).

The authors proposed a Geographic Forwarding Energy Efficient Routing Protocol (GF-EERP), an enhanced version of the Geographic Energy Aware Routing (GEAR) protocol that helps to extend the network's lifespan and performance. The introduction of node categorization, a unique technique for choosing the region head, use of a multi-hop communication method and removal of dead nodes serve as the foundation of the GF-EERP. In this study, the proposed protocol's performance is also compared to other protocols already in use, like geographic adaptive fidelity (GAF), geographic energy aware routing (GEAR), greedy perimeter stateless routing (GPSR) and multihop-geographic energy aware routing (M-GEAR), using a variety of performance metrics including Network Delay, Data Delivery Ratio and Network Throughput, Bairagi, P. P., Dutta, M., & Babulal, K. S. (2024).

The authors presented a comprehensive review of AI-driven energy-efficient routing protocols tailored specifically for WSNs. It delves into the various methodologies of AI, including machine learning, evolutionary algorithms, deep learning, and reinforcement learning, and their integration into routing protocols to achieve optimal energy utilization. Machine learning-based approaches leverage historical data to predict traffic patterns and dynamically adjust routing decisions, thereby optimizing energy consumption. Evolutionary algorithms offer a nature-inspired optimization paradigm, evolving routing strategies over time to adapt to changing network conditions. Deep learning techniques enable the extraction of intricate features from sensor data, facilitating more informed routing decisions. Reinforcement learning empowers sensor nodes to autonomously learn and adapt their routing strategies based on feedback from the environment, Muniandi, B., Kumari, M., Dasgupta, S., Kumar, P., & Singh, M. (2024).

The authors implemented a novel routing protocol-based modified power line system to improve the network lifetime in 5G networks. The technique of data transfer with the optimum hop count is presented based on energy balancing, which completely minimizes the energy usage of data transmission. In some specific applications, the nodes must work at a similar time, and the effective working time of systems is determined by identifying the node with the highest energy levels in the network. The proposed M-POLC shows the highest energy level as compared to LEACH, EEUC, and CH LEACH for 200 nodes with 50 iterations. The Modified Power Line System (M-POLC) has more alive nodes compared to Energy-Efficient Uneven Clustering (EEUC) which has 70% alive nodes, Low-Energy Adaptive Clustering Hierarchy (LEACH) with 50% alive nodes, and Cluster Head Low Energy Adaptive Clustering Hierarchy (CH LEACH) with less than 20% alive nodes. Simulation outcomes suggest that the proposed strategy significantly reduces energy usage while also extending the lifetime of WSNs in 5G networks, Alqahtani, H., Deeba, F., Deebak, B. D., & Arul, R. (2023).

The authors studied and compares the energy efficiency and throughput of Low Energy Adaptive Clustering Hierarchy (LEACH) and Hybrid Energy Efficient Distributed (HEED); the most effective power-aware routing protocols by changing the packet size and node density. This study was performed through simulation by utilizing the MATLAB tool, Salih, M. A., & Sulaiman, D. R. (2023).

Priyadarshi, Rahul [30] Data capture and transmission to a distant server, frequently in an isolated place, are WSNs' main puWSNs'. These networks might be subterranean, underwater, terrestrial, or multimodal. They are utilized in industrial automation, traffic management, medical device monitoring, and other fields. Despite market growth, WSNs have several hurdles. Energy efficiency, storage and processing resource restrictions, bandwidth, error rates, scalability, and survival in hostile climates must be considered. This circumstance has made extending the longevity of these networks a major issue. Energy saving is a major difficulty in many vocations. Several bio-inspired algorithms have been developed to find the best route from member nodes to the sink node. These methods aim to reduce energy use and extend network life. This article investigates WSN routing and clustering, concentrating on optimization methods. We aim to give a comprehensive and insightful evaluation of WSN research, with an emphasis on AI integration. This study honors the development of clever methods to overcome WSNs' variousWSNs'acles. The above issues will affect sensor-based connection in our increasing global environment, and our research shows our commitment to understanding and resolving them, Priyadarshi, R. (2024).

Challenges in Cluster-Based Approaches

Despite the advantages of cluster-based approaches, several challenges remain:

Cluster head selection

The process of selecting an optimal cluster head is crucial for network performance. If a cluster head is chosen without considering its energy level or proximity to other nodes, it may deplete its resources quickly, leading to network partitioning or inefficient data routing.

Interference and data collision

As multiple clusters operate in proximity, interference between clusters can occur, particularly when multiple cluster heads transmit simultaneously. Effective channel allocation strategies are necessary to mitigate these issues.

Mobility of nodes

In mobile networks like MANETs, the mobility of nodes can disrupt established clusters. Adapting to dynamic topologies while maintaining efficient communication and minimizing energy consumption is a significant challenge.

Security concerns

Cluster heads can become prime targets for attacks, given their critical role in managing communication. Ensuring the integrity and reliability of data transmitted through cluster heads is essential for maintaining overall network security. Trust-based clustering approaches are being explored to mitigate the risks associated with malicious nodes.

Future Research Direction

Recent research has focused on enhancing the robustness and adaptability of cluster-based approaches. The integration of machine learning and artificial intelligence techniques is showing promise in optimizing clustering algorithms, enabling them to adapt to real-time network conditions. Furthermore, the emergence of hybrid approaches that combine clustering with other network topologies is being explored to address the diverse requirements of modern applications.

Additionally, as IoT continues to evolve, the demand for energy-efficient and secure communication in massive networks is likely to drive further innovations in clustering techniques. Researchers are investigating new methods for real-time monitoring, dynamic re-clustering, and enhanced data security to support the growing number of connected devices in various environments.

In summary, cluster-based approaches represent a vital strategy for addressing the challenges faced by wireless networks. By optimizing energy consumption, enhancing routing efficiency, and improving scalability, clustering has become an essential component of modern wireless communication systems. Continued research and development in this area are crucial for ensuring the effectiveness and reliability of wireless networks as they continue to expand and evolve. The following sections of this literature review will delve deeper into specific case studies and evaluations of clustering algorithms, exploring their impacts on energy conservation, routing performance, and network credibility.

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