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Performance Optimization of Wireless Sensor Network Using Machine Learning Approach: An Overview

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Abstract: *Wireless sensor networks (WSNs) are made up of spatially dispersed autonomous sensors that work together to cooperatively transmit their data to a central point via the network while monitoring the physical or environmental conditions. Because of the constrained energy resources, fluctuating network topology, and requirement for dependable data transfer, WSNs require efficient routing. In WSNs, machine learning (ML) approaches have shown promise as ways to improve routing protocols.*
The study looks at different machine learning (ML) methods, including as deep learning, reinforcement learning, supervised learning, and unsupervised learning, to address the issues of energy efficiency, scalability, and adaptability in WSNs.

Key Words: *WSN, Machine Learning, Deep Learning.*

1. INTRODUCTION :

In recent times, wireless sensor networks, or WSNs, have attracted a lot of attention because of its numerous uses in the military, smart cities, healthcare, and environmental monitoring, among other fields. These networks are made up of many tiny, data-collecting, battery-operated sensor nodes. Nevertheless, WSNs have a number of difficulties, such as finite energy supplies, fluctuating network topologies, and the requirement for dependable data transmission. When traditional routing protocols are unable to satisfy these requirements, machine learning (ML) techniques are investigated as a possible remedy [1].

2. Integration of Machine Learning with WSN :

WSN performance and efficiency can be improved with the use of machine learning. WSNs are able to predict network conditions, optimise energy consumption, enhance data accuracy, and make intelligent routing decisions by utilising machine learning techniques. There are various essential processes involved in integrating ML into WSNs Fig.1 shows ML in WSN applications.

The use of machine learning techniques in disaster management applications greatly improves the performance of wireless sensor networks. WSNs can increase data accuracy, predictive power, and resource efficiency by utilising machine learning (ML), which will ultimately result in more effective disaster response, monitoring, and mitigation. A strong framework for tackling the intricate problems brought on by natural and man-made disasters is provided by the integration of multiple machine learning (ML) techniques, from supervised and unsupervised learning to deep learning and hybrid approaches [2].

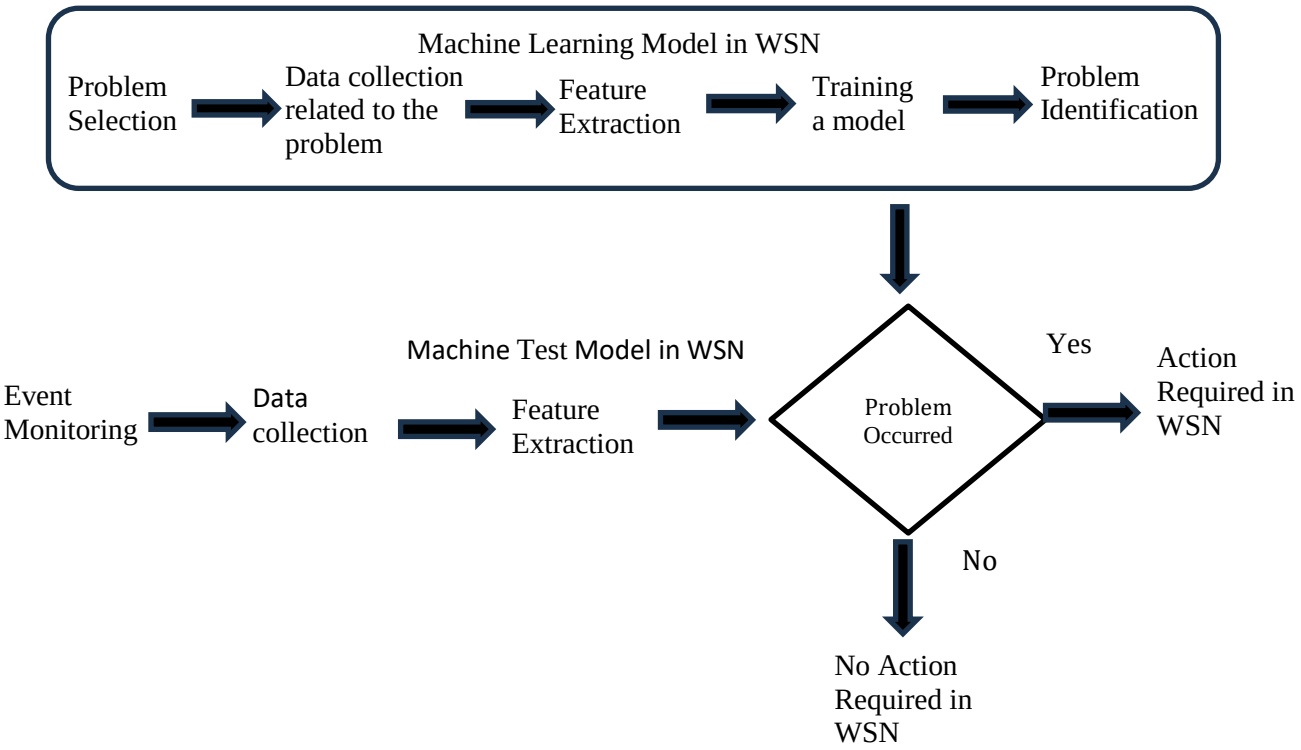

Fig.1. ML in WSN Applications

Sensor nodes collect unprocessed data, which is subsequently pre-processed to eliminate noise and extraneous information. Extracting pertinent characteristics from the data so that ML models can use them is known as feature extraction. To understand patterns and generate predictions, machine learning models are trained on past data. Trained models are used to optimise resource utilisation, adjust to network changes, and make routing decisions in real time.

3. Machine Learning Techniques and Algorithms in WSN:
Numerous machine learning techniques have been used to tackle various WSN features, such as energy management, routing, and anomaly detection. Some of the well-known ML methods applied in WSNs are as follows:

Support Vector Machines (SVM): Used for categorization tasks including network traffic pattern prediction and defective node identification. Routing protocol decision-making techniques use decision trees.
Random Forests: Increase accuracy and dependability by mixing several decision trees.

K-Means Clustering is an unsupervised learning technique that is used to group sensor nodes according to their operational or spatial properties in order to maximise communication.
Reduces the dimensionality of data for effective processing and routing through Principal Component Analysis (PCA).
Q-Learning is an RL method that facilitates node learning through Reinforcement Learning (RL) [3-4].

4. Deep Learning:
Convolutional neural networks, or CNNs, are utilised in the processing of sensor data to extract spatial information for the purpose of classifying and detecting anomalies.
RNNs, or recurrent neural networks: useful for time-series prediction, including predicting network traffic and spotting trends over an extended period of time. [5-7].

5. Hybrid Strategies:
Combining neural networks and fuzzy logic, neuro-fuzzy systems are able to manage imprecision and uncertainty in sensor input when making routing decisions. By modelling natural selection and evolution processes, genetic algorithms (GAs) are used to optimise routing pathways.

Utilising ML in WSN Applications The routing
Routing that Uses Less Energy: Machine learning models forecast energy usage and choose routes that use the least amount of energy, extending the life of the network. Reliable communication is ensured by adaptive routing, which uses machine learning techniques to help nodes adjust to changes in traffic patterns and network topology.
Fault Management: To preserve network performance and integrity, machine learning techniques are used to detect and isolate malfunctioning nodes.
Load balancing: In order to avoid congestion and node fatigue, machine learning techniques randomly distribute traffic around the network [8].

6. Conclusion:

The integration of machine learning into WSNs offers a promising pathway to address the inherent challenges of these networks. By utilizing various ML algorithms and methods, WSNs can achieve significant improvements in routing efficiency, energy management, and overall network performance. As research in this area continues to evolve, the synergy between ML and WSNs is expected to unlock new potentials and drive the development of intelligent, self-optimizing sensor networks.

By leveraging ML models, the proposed routing protocols can predict optimal paths, adapt to dynamic network conditions, and prolong the network's lifetime. Key ML approaches such as Q-learning, neural networks, and clustering algorithms are discussed for their role in improving route discovery, load balancing, and fault tolerance.

The integration of machine learning techniques into WSN routing protocols demonstrates significant improvements in performance metrics, including reduced energy consumption, increased data delivery rates, and enhanced network stability.

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