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MACHINE LEARNING TECHNIQUES FOR ROUTING, LOCALIZATION AND QOS FOR FUTURE WIRELESS SENSOR NETWORKS

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Abstract: WSNs plays a crucial role in adopting new generation techniques and their use in creating future-ready technologies. The key difficulties with Wireless Sensor Networks (WSNs) are energy-efficient routing, localization strategies and QoS, as these tiny sensor nodes rely solely on battery power to operate in hazardous situations. So there is a need to research and develop efficient, resilient communication techniques and localization mechanisms to address the issues of WSNs and keep the network operating for an extended period. As a result, low complexity machine learning models manage several difficult tasks such as routing, data aggregation, localization, and motion tracking to define system behavior. Machine learning approaches are thought to be useful for developing energy-efficient routing and localization strategies. Furthermore, machine learning techniques inspire various practical ways to optimize resource utilization and hence increase the lifespan of the sensor network. In this article, an effort has been made to present a broad overview of several machine learning approaches that may be utilized to address various challenges in WSNs, with specific emphasis on routing problems and localization strategies and QoS.

Keywords: Machine Learning, Routing, Localization, QoS, WSN**.**

I. INTRODUCTION

WSN is a network of several sensing devices that are often located in remote places to monitor environmental factors like temperature, humidity, wetness, and so on. Sensing devices consist of sensors such as chemical, acoustic, motion, image, weather, pressure, temperature, optical sensors, and so on. WSN is utilized in a variety of applications, including healthcare, military, industrial, smart cities, IoT, transportation, and agriculture. Because of the changing network structure, resource-constrained behavior of sensor nodes, and varied traffic flows, it is difficult to meet QoS requirements in various applications[1]. Despite its wide range of applications, WSN suffers a number of common obstacles, such as energy scared sources, memory, speed, and bandwidth, which causes the WSN performance to deteriorate and shorten the life span of the network. WSN developers must focus on a variety of problems such as data aggregation, fault detection, routing, localization, clustering, motion tracking, and so on. Among all the tasks, routing and localization are the most critical since they consume the majority of the energy[6].

Machine Learning is one of today's most innovative and significant technologies. Machine Learning is a subset of AI that is robust enough to tackle a variety of issues in the medical, engineering, and networking fields, such as classifications, grouping, regression, and optimization. ML empowers computer systems to learn on their own, without the need for human intervention, and to respond appropriately. It generates a model by automatically, swiftly, and precisely interpreting complicated data; ML can learn from generalized structures and propose a clarification to increase the performance. Using Machine Learning strategies in WSNs not only increases system efficiency but also minimizes hard chores such as reprogramming, manually accessing large data, and extracting meaningful information from the data[2]. As a result, machine learning techniques are particularly beneficial for retrieving enormous volumes of data and extracting relevant information.

II. USE OF MACHINE LEARNING TECHNIQUES IN WSN

Machine Learning techniques plays an important role in addressing the various challenges in Wireless Sensor Networks.

A. Energy conservation

As sensor nodes struggle with limited battery power, machine learning can help predict optimal energy consumption.

B. Routing

Machine Learning plays an essential role in enhancing the performance of the network by dynamically routing data packets in the correct route.

C. Localization

As WSNs modify their topologies dynamically, the primary use of WSNs is monitoring dynamic surroundings that differ fast over time. This shift in behavior is attributed to either external influences or system design limitations. Machine Learning is essential for avoiding unnecessary WSN designs.

D. Identification of Malicious Node

Machine Learning techniques are beneficial in spotting malicious nodes, allowing many security threats to be avoided in advance.

E. Machine Learning in QoS

ML techniques are used to achieve QoS in WSN achieved using Machine learning techniques like data fusion, K-means SVM, ANN, BP-NN Bayesian are employed.

F. Collaboration with Other Technologies

Because of the increased need for WSN applications, WSNs must be integrated with IoT, Artificial Intelligence, Cloud computing, machine to machine (M2M) connections, and other technologies. As a result, intelligent decision-making systems based on Machine Learning approaches must be created.

III. MACHINE LEARNING-BASED ROUTING IN WSN

This section explores several machine learning techniques for routing WSNs. The primary difficulties in WSN include collecting sensed information, extracting relevant information from the obtained data, processing the data, sending the data to the BS. As a result, one of the essential design goals of WSNs is energy conservation, and routing protocols are the most well-known methods for energy conservation. Using machine learning techniques in routing allows you to analyze a large quantity of data in less time and with more accuracy[7], benefits of ML-Based Routing:

- ML minimizes routing complexity and meets QoS criteria by utilizing basic computational algorithms and classifiers.
- Because of environmental changes, ML does not require reprogramming.
- In routing, ML also aids in the selection of the appropriate number of cluster heads**.**
- ML also minimizes packet overhead and latency.

A. Artificial Neural Network based routing

The ANN model is inspired by the neurons of the human brain. ANN is concerned with the processing of vast amounts of data in order to provide reliable results. ANN was utilized for training routing algorithms utilizing different factors such as sensor node distance, CHs, residual energy, wider nodes, and base station[3]. Backpropagation neural networks are particularly beneficial for selecting certain dependable CHs in WSNs that remain energy consumption and avoid data loss. ANN employs two types of learning processes. The first supports the principle of self-learning, whereas the second corresponds to the notion of corrective learning. The most common ANN model is the Self-Organizing Map (SOM), a self-learning model that does not require human involvement throughout the learning process. It should have minimal knowledge of the physical properties of the input data and use a neural network to construct effective topologies in WSNs. These Efficient topologies facilitate routing and efficiently minimize energy consumption in WSNs.

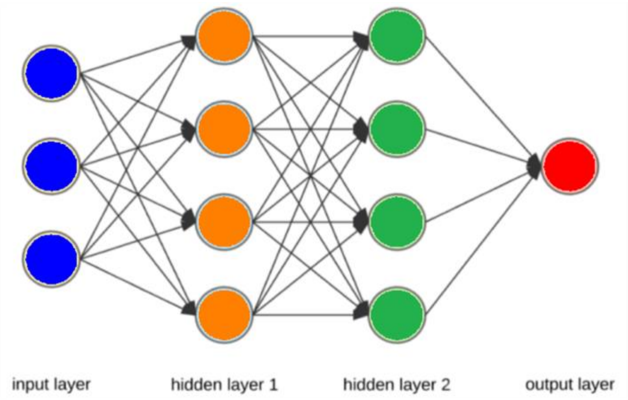

Figure 3.1 Artificial Neural Networks

B. Reinforcement Learning Based Routing

Q-learning, a reinforcement learning method, solves multicast routing difficulties in wireless sensor networks by allocating dependable resources. In Reinforcement learning, the sensor node energy and latency are utilized as measurements to build the learning reward function, which effectively enhances routing protocol performance. Q-Probabilistic Routing (Q-PR) uses reinforcement learning and a Bayesian decision model to determine optimal pathways by learning from prior routing[8]. CHs in WSNs that remain energy consumption and avoid data loss.

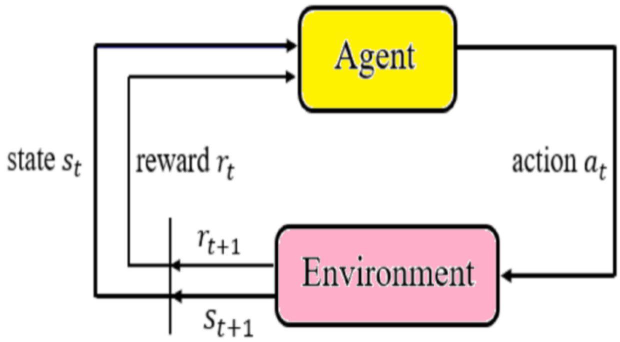

Figure 3.2 Reinforcement Learning

C. Genetic Algorithm based routing

The Genetic Algorithm is a bio-inspired algorithm that works on the idea of natural selection, in which the fittest individuals are chosen to create offspring for the following generation. GA employs the following biological operators to produce new offspring[6].

- Selection operator
- Crossover operator
- Mutation operator

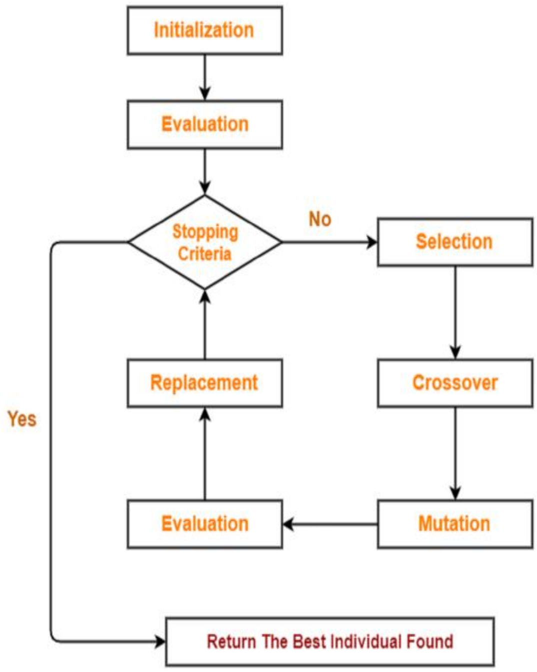

Figure 3.3 Genetic Algorithm Operators

The Genetic Algorithm (GA) is utilized to solve WSN routing difficulties. GA is used to cluster non-uniformly dispersed nodes and pick cluster heads (CHs) among the clusters. When a cluster's geographic position changes or a cluster head fails, the technique may be used to reorganize the clusters and cluster heads[6]. The Genetic Algorithm is also used to increase energy efficiency by optimizing the operating environment. The fitness function of a GA-based approach is determined based on two key characteristics, distance and energy, and is used to extend the life of a wireless sensor network**.**

D. Fuzzy Logic-based routing

Instead of true or false, fuzzy logic computing is intended to forecast the degree of truth. Fuzzy Logic has four components for predicting system output. Fuzzifiers, Fuzzy Rules, Fuzzy Inference Systems, and De-fuzzifications are examples of these[7]. In the WSN, The routing of a dynamic base station is more complicated than that of a static base station. Compared to a static base station, the fuzzy controller improves the energy consumption necessary for node movement, CH selection, and load balancing. As a consequence, the network's lifetime is increased. The fuzzy C means clustering is used to divide nodes into clusters and to pick CH.

IV. MACHINE LEARNING TECHNIQUES FOR LOCALIZATION IN WSN

As the most significant component of sensor networks, station localization is critical in assessing the quality and usefulness of the data acquired by the sensors. Localized sensors are also required for effective network administration. ML techniques may be used to appropriately organize the anchor nodes. In sensing devices, ML algorithms are used to construct groups, and each grouping may be produced individually if the sensor node organizes quickly[8].

A. Bayesian Node Localization

In WSN, Bayesian learning employs a few anchor nodes for localization. For getting closer to the posterior likelihood, this approach predicts samples from likelihoods. This technique is well-suited for localizing huge networks, such as those made up of thousands of sensor nodes. The basic concept of utilizing the Bayesian method to localize is interesting since it can deal with insufficient data sets by evaluating previous information and probability[5].

B. Localization based on Artificial Neural Network

ANN is important in sensor node localization; multi-layer perceptron (MLP), recurrent neural networks (RNN), and radial basis function (RBF) result in low localization error at the expense of high resource requirements; on the other hand, MLP results in low computational and storage resource consumption. The capability of these neural network-based localization algorithms to offer a position in the form of continuous-valued vectors is their fundamental benefit. It is a non-probabilistic technique, as opposed to statistical or Bayesian alternatives[8]. This reduces the precision of an unknown node's predicted placement and, as a result, the cost of localization mistakes.

C. Localization using Self Organization Map

Self-Organizing Map (SOM) is utilized for situating WSNs with thousands of nodes. The SOM method is run at each node, consisting of a 3x3 input layer coupled to two neurons in the output layer. The spatial parameters of eight anchor nodes next to the unknown node are used to generate the input layer in specific. Following appropriate training, the output layer is used to depict the spatial information of the unknown node in a 2D space. The key disadvantage of this technique is that nodes must be positioned uniformly over the monitored zone[9].

D. Localization using K-Nearest Neighbour

This is one of the basic approaches for calculating distribution functions from data. When a node is introduced into the space, this approach searches for the closest components. This distance indicates that the new element and its neighbours share the same attributes and belong to the same class. This is one of the most often used strategies for categorizing information[6].

V. QOS IN WSN USING MACHINE LEARNING

WSN technology is employed in various fields, including transportation, military, industry, IoMT, agriculture, the IoT,. The fast development of smart sensors is the cause of this growing utilization. Because of the dynamic network state, varied traffic flows, and resource-constrained behaviour of sensor nodes, it is difficult to meet the Quality of Service (QoS) requirements in various applications[8]**.**

ML is a technology that improves learning, analysis, observation, or previous data and forecasts the result or behaviour based on the acquired data without any modification after the first training phase. It generates models by studying very complicated datasets automatically and with great precision. It also offers a scientific foundation for WSN QoS. It is used in various QoS parameters, including security, reliability, energy efficiency and so on.

A. Security

Security in wireless networks is a significant and necessary component of QoS. It is described as the process of designing an activity to safeguard data from unauthorized users, optimize network usability, and ensure the integrity of data transferred across the network. It is a non-functional QoS parameter that cannot be measured.

The IDS is responsible for supervising, analyzing, and recognizing conflicting events that violate the system's safety policy as an illegal activity by a malevolent or permitted entity. When illegal conduct is detected, IDS monitors network activity and sends an alarm. Machine learning-based IDS is used to detect and avert security assaults in wireless sensor networks[10]. Machine learning is used to continually learn by analyzing information and data to uncover patterns in encrypted communication to detect viruses. Because of their continuous learning and data analysis, machine learning-based IDS techniques are well suited for infrastructure-free and scalable wireless sensor networks. SVM technique handles other security parameters.

B. Throughput

Throughput is a quantifiable QoS statistic used to calculate network performance. It is defined as the total quantity of data successfully transported from sender to receiver in a certain time. By lowering latency, throughput may be optimized. If the throughput count is low, only a certain number of packets are successfully transmitted in the allotted period. When throughput is poor, throughput affects the network speed, and packets do not arrive at their destination at the same consistent pace as the rest of the network. Machine learning approaches Reinforcement learning, genetic algorithms, ANN, and KNN can all help to increase network throughput.

C. Energy Efficiency

Because sensors have limited energy to execute their jobs during their lifespan, energy efficiency is important in QoS. In WSN, energy harvesting is an essential and difficult task. Machine Learning methods, such as ANN and reinforcement learning, play a key role in increasing efficiency by reducing energy usage[8].

D. Reliability

QoS reliability is crucial in the subject of networking. It is defined as the system's ability to do its needed duty under specified conditions for a certain amount of time. Data fusion is a machine learning approach that makes data more trustworthy, informative, and helpful to the user. It translates raw, inconsistent data into informed, consistent, and usable information. K-means, SVM, BP-NN, SMPSO, ANN, NBC ML and Bayesian techniques are employed for data fusion.

VI. CONCLUSION

Wireless Sensor Networks are cutting-edge networks that are utilized for installations in extreme environments. Sensor nodes gather information from their surroundings and pass it to the sink node for further processing. Developing routing protocols, localization, improving life duration, and ensuring Quality of Service (QoS) are the most difficult tasks in WSN. Machine Learning approaches to aid in improving WSNs' ability to adapt to environmental dynamics. This article provides an analysis of how different machine learning approaches are utilized in WSNs to address common WSN issues and extend network lifetime while using less energy. Furthermore, the emphasis has been placed on machine learning approaches solely employed in WSNRouting, localization, and QoS.

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