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The Role of IoT and WSN in Smart Cities: A Review of Recent Developments and Future Prospects

Rachit Manchanda

Assistant professor, Chandigarh University, Department of Electronics and Communication, Chandigarh, India

Abstract: - Wireless Sensor Networks (WSN) has a limited amount of resources. By reducing the quantity of data transmitted, clustering and data aggregations are utilized to lower network energy usage. Swarm intelligence, reinforcement learning, and neural networks are examples of machine learning methods that decrease data transmission and make advantage of the network's distributive properties. It presents a comparison of the performance of various algorithms in order to assist designers in developing acceptable machine learning-based clustering and data aggregation solutions. This work includes a review of multiple machine learning-based clustering and data aggregation approaches utilized in WSN, as well as a proposal for enhanced similarity-based clustering and data aggregation using Independent Component Analysis (ICA).

Keywords: - Internet of things; Wireless Sensor Networks; Clustering; Machine learning; Data aggregation

1. Introduction

A wireless sensor network (WSN) is a collection of nodes that are grouped in a logical network. Every sensor node has computing power, as well as several types of memory, a radio frequency transceiver, and a power supply. The nodes communicate wirelessly and self-organize after being distributed haphazardly. The system might have up to 10,000 nodes. WSNs have a great capability for developing effective applications with their qualities and requirements because of this range [1]. Developing good algorithms for various contexts is a difficult undertaking. Reliability, clustering, security, aggregation, localization, event scheduling, fault detection, and energy-aware routing should all be addressed by WSN designers. Machine learning is a field of artificial intelligence (AI) that allows computers to learn and improve on their own without having to be explicitly programmed. Machine learning is concerned with the development of computer systems that can access data and learn on their own [10]. It plays a vital part in a variety of WSN applications for the following reasons:-

• Because WSN is deployed in complex contexts, it is challenging to construct an adequate mathematical model to characterize system behavior
• Due to the large volume of data, network designers may be unable to establish correlations among them in exploratory applications
• WSN integration with new technologies such as the Internet of Things (IoT) and Cyber-Physical Systems (Cyber-Physical Systems) has been developed, requiring a larger number of smart decision makers

In recent years, the use of sophisticated machine learning techniques in WSN has risen. The subject of machine learning is thought to be one of themes and patterns. Machine learning techniques are quite adaptable and may be used in a variety of WSN applications. ML algorithms are frequently divided into three categories: supervised, unsupervised, and reinforcement. The supervised learning technique comes with a labeled training dataset [13]. A system model is developed utilizing the data set to represent the relationship between input and output. Labeled data is not given with the algorithm in the case of unsupervised learning. It divides the samples into categories based on commonalities found between the input samples (clusters).The agent learns in a reinforcement learning method by communicating with its environment [14].There is a need for a study of the application of machine learning algorithms especially for clustering and data aggregation because there aren't many articles explicitly covering machine learning methods for clustering and data aggregation in WSN.

2. Role of IoT in WSN

Several research articles and studies have backed up significant categorization views and surveys of WSN and IoT-based energy-saving devices. Some of these great literary works are discussed in this part, which presents their primary topics and other categories designated by them:

The research [11] described the design and implementation of a solar energy-powered precision agricultural (PA) network with the WSN using IoT architecture to meet the need for developing highly effective approaches to manage a smart agriculture system. This system provides farmers with vital information on saltwater intrusions, soil moisture, water level, wet conditions, temperature, and the overall state of the land in a user-friendly and easy-to-access manner via real-time data transfers via IoT.

The Authors of [12] conducted research on IoT data collection and decision-making ideas. The Chaotic Whale Optimization Process was recommended in the research [13] as a way to improve energy use in WSN-IoT environmental activities. Energy efficiency outcomes were attained in comparison to other standard procedures. The findings showed that the proposed technique delivers greater energy efficiency in the WSN-IoT integrated system.

From the perspective of a WSN, a survey was conducted in [14] on delays, energies, jitters, throughput, and packet-delivery ratios (PDR), and the performance of routing protocols were tested using latencies, bandwidth, jitter, and delay. In the IoT, an algorithm was created to optimize AODV routing. For protocol optimization, two tables, namely the table of routing and the table of internet access, were consolidated into one. The major goal of this research was to look at simulation studies of the IoT AODV routing protocol and use the NS2 simulator to improve AODV and IoT AODV performance.

WSN-assisted IoT also has a number of constraints, making it impossible to employ classic routing protocols directly. For WSN-assisted IoT devices, energy is a critical restriction. More power is used to communicate among sensor nodes than is used for sensing and computing. As a result, to extend the network's life, appropriate energy management strategies are required. The author proposed an energy-conscious multi-user & Multi-Hop Hierarchical Routing Protocol (EAMMH-RP) in paper [15], which covers Communication with Multi-Hop, a novel sequence of algorithms for cluster adaptation and rotating, and a novel energy consumption reduction mechanism for long-range communications.

The sensors can track the atmosphere and send back data for a longer period of time. [16] Suggested a protocol that includes a robust routing mechanism for IoT sensor networks. Initially, a meeting place was constructed in the network field's centre. Clustering and multipath methods were used because they reduce energy consumption and increase dependability. The presented protocol was simulated in the Castalia simulator in order to achieve efficiency under various scenarios, including packet transmission, average energy use, end-to-end latency, and network lifetime.

In [17], the routing algorithms and models were examined in terms of succession characteristics such as minimizing latency, lowering energy consumption, and improving the data delivery ratio. The energy consciousness, latency, throughput, data transmission, and packet loss aware IoT and WSN algorithms were classified into two classes for classification. The paper [18] improved on the traditional routing protocol by introducing a revolutionary protocol with features such as a new data transfer mechanism and a more effective technique of CH selection. As a result, the WSN gap in the real world and the actual heterogeneous setting were linked. The conclusion of simulation demonstrated the discrepancy between present Hy-IoT and anticipated protocol using performance measures.

3. Challenges of WSN in IoT

Different heterogeneous artifacts exhibited and communicating in various situations add to the IoT's complexity and make security mechanism implementation even more difficult. Existing WSN security research focuses on solving subjective problems, rather than considering the influence of IoT concepts and characteristics, which are discussed in this document.

A. Real time management

It's a challenging problem for resource-constrained sensor networks. In such instance, smart data-driven middleware architecture and an efficient service gateway design in the IoT system are required to reduce the quantity of data to be communicated by continually evaluating user data and communicating real-time information only when readings exceed a threshold [19].

B. Security and Privacy

Safety, trust, and privacy are also essential considerations in real-world applications. The path to various levels of safety is both arduous and easy. These security solutions are appropriate for M_2M deployments in which the device and the server already have a trust relationship [20].

Sensor nodes with this "IP to the field" paradigm have extra tasks in addition to their typical sensor functions. As a result of this increased responsibility, the sensor nodes will face new responsibilities or problems. Security, service quality (QoS), and network configuration are three potential responsibilities that will be explored. The following issues are dealt with.

C. Quality of Service

All heterogeneous IoT devices must contribute to the quality of service provided to sensor nodes in terms of intelligence. This heterogeneous device allows for task distribution amongst nodes with resources available. Due to changeable network setups and connection properties, the current QoS techniques available on the Internet still require enhancement [21].

D. Configuration

Sensor nodes must manage a variety of responsibilities in addition to QoS management and security, such as networking for new nodes joining the network [22], ensuring self-healing by recognizing and eliminating faulty nodes, and addressing management for the construction of scalable networks, among others. However, self-configuring the most recent Internet node is not a standard feature. If this network configuration is to perform well, the user must install the relevant software and take proper precautions to prevent device failures.

E. Availability

The presence of hacked nodes can provide access to WSNs [23]. An additional expense would be levied to integrate an encryption algorithm for WSN security. However, researchers have devised significant ways, with some modifying and reusing code and others relying on supplemental communications to achieve their objectives. Aside from that, strategies for accessing the data have been developed. As a result, maintaining WSN operating services need availability. It also aids in the upkeep of the entire network till it is terminated.

F. Data Integrity

When a hostile node enters the network and injects incorrect data, or when a vacillating wireless channel corrupts the original data, WSN can be infiltrated [24]. For example, if a mobile node transmits fake data to packets received by the BS, the data integrity will be compromised. However, data loss or data tampering might be triggered by a defective network. As a result, data integrity must be maintained throughout the data packet transmission process.

G. Confidentiality

IoT security is complicated by a number of issues, the most important of which is confidence. The data is kept private by using encryption techniques such as the Blowfish; AES block cypher, and Triple DES [25], which use common and shared secret key encryption algorithms. However, as a security mechanism, encryption is insufficient to protect the privacy of data and information. The attacker can do a traffic analysis for the encrypted data in order to successfully disseminate sensitive information.

4. Data Aggregation

WSNs, as previously said, are critical IoT building blocks that have proliferated in a variety of real-time applications. WSN nodes are typically tiny, battery-powered devices. As a result, network lifespan is a significant issue for WSN data aggregation. Several issues, such as increased energy use, i.e. energy ineffectiveness, and longer lifetime, were discovered throughout the data gathering process [26].

To maintain acceptable service efficiency in the dissemination of sensed data, data aggregation algorithms are commonly utilized. The goal of the data collection is to efficiently incarcerate and disseminate data packets in order to reduce energy consumption, traffic congestion, network life, data consistency, and so on [27].

5. Conclusion

Advances in computer technology have aided the evolution of WSNs, which can sense the required parameters at any moment. In recent years, IoT-based WSN systems have gotten a lot of interest. Despite this, these systems have limited bandwidth, power, and resources when transmitting point-to-point. Data collection is an illustrious way for resolving this issue. How critical information may be handled in a more energy-efficient manner is a significant topic in sensor networks. As a result, several data aggregation methods were utilized to reduce power consumption, as discussed in this work. The existing works outlining the function of IoT in WSN are examined in this study, followed by a presentation of the various data aggregation methodologies provided in earlier works. The strategies for data aggregation are focused on network energy conservation, lifespan enhancement, higher QoS, and high-level security.

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