International Journal of Advanced Multidisciplinary Research and Innovation

E-ISSN: XXXX-XXXX editor@ijamri.com

Volume 1, Issue 1, March-April 2025

Optimizing Energy-Efficient Machine Learning Algorithms for IoT Sensor Networks: A Performance Analysis

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Abstract

Machine learning (ML) has become an effective approach to enhance wireless sensor networks (WSNs) in the realm of Internet of Things (IoT). This paper reviews the effect of ML algorithms in this regard, focusing on energy-efficient routing protocols and data transmission optimization in IoT sensor networks. A secondary qualitative research methodology was adopted using existing literature in the area of how ML can enhance WSN. ML greatly increases network life and service efficiency towards realisation of industrial automation objective. But computational complexity and data quality are obstacles. Energy efficient ML models for scale and sustainability of IoT applications can be a future research area.

Keywords: Machine learning (ML), Internet of Things (IoT), Wireless Sensor Networks (WSNs), Deep Neural Networks (DNN), Deep Learning-based Grouping Model Approach (DL-GMA), Quality of Service (QoS), RNN-LSTM, Engroove Leach (EL).

1. Introduction

The technology of machine learning has demonstrated significant benefits in different fields and robust performance in various applications involving natural processing of language, systems for recommendations, image recognition and speech recognition. In recent times the relevance of this technology within the wireless sensor networks (WSNs) created significant attraction which is a significant element in the Internet of Things [1]. Wireless sensor networks (WSNs) are a significant technology that allows sensors to collect different data related to sensing in the area of monitoring. It accomplishes intelligent processing of data and decisions. The technologies

International Journal of Advanced Multidisciplinary Research and Innovation
E-ISSN: XXXX-XXXX editor@ijamri.com
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related to machine learning significantly favored in acknowledging the limitation in conventional green routing in WSNs.

2. Literature Review

The study of Ding *et al.* (2021) [2] presented a thorough outline of routing algorithms in WSNs. The study defined the conventional approaches and machine learning techniques in the design of green routing in WSNs. This study conducted a thorough analysis and comparison and depending on the results it suggested a mathematical hypothesis model of a routing algorithm based on machine learning for enhancing the lifespan of WSNs.

In accordance with the research of Bagwari *et al* (2023) , enhanced energy optimization models have the potential to significantly enhance the industrial wireless sensor networks [3]. This leverages machine learning for streamlining the implementation of data provided by sensors within the operations of industries. The study also says that the models develop a connected, more accurate and efficient process of data management. Industrial wireless sensor networks can be structured with increased accuracy and less consumption of energy by this model. This will result in decreased cost related to installing, operating and maintaining sensory networks of the industries.

The research of Ahmed *et al.* (2022) utilized architectures of deep learning and provided a distinctive strategy for resource allocation for WSNs_IoT with energy efficiency and optimization of data [3]. This study shows that energy efficiency of the network has been significantly enhanced by whale optimization based on Deep Neural Networks (DNN). It leveraged a heuristic based multi objective firefly algorithm to optimize data. Application of this proposed method has been conducted for streamlined allocation of energy and choosing relay. The study indicated that the best allocation of resources can be accomplished through decreasing overall transmit of power and an optimal selection of relay can be completed by fulfilling the standards of Quality of Service (QoS). Results of the study shows that an energy efficient protocol can be achieved through these processes.

Surenther *et al.* (2023) in their study introduced and demonstrated Deep Learning-based Grouping Model Approach (DL-GMA) as a significant methodology for increasing energy efficiency in the Wireless Sensor Networks. The research shows that DL-GMA streamlines the consumption of energy, decreases congestion, increases quality of service and network

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E-ISSN: XXXX-XXXX editor@ijamri.com
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extendability and stability by utilising the techniques of advanced grouping and clustering [4]. It also shows that leveraging RNN-LSTM in DL-GMA develops intelligent cluster formation, selection of head in the cluster and maintenance of collection which results in an efficient transmission of data.

3. Methodology

The study adopted a secondary qualitative method of research which involves secondary collection of data from various different reliable and valid sources. The study is about determining the contribution of machine learning algorithms in streamlining IoT sensor networks. The aim of this research is to analyse the performance improvements of these networks after the integration of machine learning algorithms. The process of secondary qualitative analysis involves collection and evaluation of data or information from priorly conducted or existing research to determine similarities and patterns. In simple words it is a reutilisation of qualitative or qualitative data gathered by other researchers. This process targets to leverage existing data to its extreme potential. The collection of data involved various academic sources such as journals, articles, reports and other literature. All the data collected through reliable and credible sources involving Google Scholar and ScienceDirect. All the journals and articles are selected by considering their relevance and reliability. Significant ethical concerns involving consent of the authors, acquiring permission, maintenance of transparency and appropriate providence of credit to the original researcher all have been considered in the induction of this study [5].

4. Findings and Analysis

Ding *et al* (2021) significantly discussed green routing algorithms in WSNs. The outcomes of his study demonstrated that setting a particular node-based routing algorithm can significantly decrease the burden on the general nodes [6]. It also shows that routing algorithms based on machine learning significantly accomplishes energy efficiency by decreasing unrequired data, streamlining pathways and protocols. The study represents that hybrid machine learning based Engroove Leach (EL) streamlines the protocols of routing to balance cost and consumption of energy. The research denotes that the application of these machine learning algorithms for IoT sensory networks have been conducted in various sectors involving intelligent healthcare, underwater sensing, industrial applications, intelligent systems for transportation and smart home.

International Journal of Advanced Multidisciplinary Research and Innovation

E-ISSN: XXXX-XXXX editor@ijamri.com

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However, the research suggests that the algorithms of machine learning still need excessive computation and energy for accurate learning of parameters in the level of training learning.

Bagwari *et al.* (2023) demonstrated in his research that algorithms of machine learning allowed industrial wireless sensor networks to perfectly analyze and monitor data for determining potential issues and creation of new and better processes to enhance efficiency in the production [4]. The research also shows that the algorithms can identify abnormalities in collected data by industrial wireless sensor networks and can estimate the time maintenance is required. It also says that the algorithms have the ability to detect potential disruptions in the operational environment and notifies the operators to respond with appropriate measures which significantly increases safety and prevents accidents. As per the study industrial wireless sensor networks have the ability to automate operations and activities which significantly decreases cost related to labour and enhances accuracy. The algorithms of machine learning can also identify issues in products prior to their shipment which also reduces return related cost and improves satisfaction of the customers.

The research of Saravana Kumar *et al.* (2022) shows that a hybrid framework with the amalgamation of reinforcement learning and machine learning perfectly accomplishes the target of connecting the nodes [3]. Additionally the activities of nodes can also be determined accurately by incorporating the methods of reinforcement learning so that the streamlined collection of nodes can be structured and the connectivity between them also can be enhanced. The outcomes of this research represented a drastic improvement in the transmission of data with the analysis of different metrics involving goodput, PDR, throughput and Delay. It also shows that the lifespan of the network is also enhanced by 50% compared to other conventional methods.

5. Discussion

The studies by Ding *et al.* (2021), Bagwari *et al.* (2023), and Saravana Kumar *et al.* (2022) illustrates the increasing utilization of ML algorithms to maximize energy efficiency and improve performance in IoT sensor networks [2]. Ding *et al.* (2021), which focuses on how green routing algorithms based on machine learning can preserve energy by enabling the process of data flowing more efficiently, routing protocols that improve their efficiency, and preventing duplicate transmissions from occurring. However, it also notes that the high computational requirements during the training are still a challenge in resource-limited IoT scenarios.

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Bagwari *et al.* (2023) illustrate the effectiveness of machine learning algorithms for industrial wireless sensor networks machinery as they help in identifying anomalies, production efficiency and predicting maintenance [1]. These features help reduce costs, improve product quality, and improve workplace safety. Yet data quality, in its reach and variety, and continuous monitoring to avoid false alarms are problems that are here to stay.

Saravana Kumar *et al.* (2022) in his work shows that specifically IoT networks suffer connectivity issues and a solution is provided by use of integrating reinforcement learning with traditional machine learning methods [5]. They discovered shrinks for data transmission, network life and overall reliability. Taken together, these studies illustrate the promise of machine learning for IoT networks while identifying areas for further work in their resource efficiency and computational requirements.

6. Conclusion and recommendations

Machine learning algorithms have significant application on optimizing routing protocols, data transmission & energy efficiency in IoT sensor networks. However, high computational costs and data quality issues continue to pose challenges. To maximize the potential for the practical use of ML models across sustainable energy and computing, future research must focus on optimizing the design of ML in terms of energy consumption as well as computational complexity, enabling effective deployment in industrial, healthcare, and smart infrastructure networks.

7. References

1. Ding, Q., Zhu, R., Liu, H. and Ma, M., 2021. An overview of machine learning-based energy-efficient routing algorithms in wireless sensor networks. *Electronics*, *10*(13), p.1539. https://www.mdpi.com/2079-9292/10/13/1539

2. Bagwari, A., Logeshwaran, J., Usha, K., Raju, K., Alsharif, M.H., Uthansakul, P. and Uthansakul, M., 2023. An enhanced energy optimization model for industrial wireless sensor networks using machine learning. *IEEE Access*, *11*, pp.96343-96362. https://ieeexplore.ieee.org/abstract/document/10239155/

3. Ahmed, Q.W., Garg, S., Rai, A., Ramachandran, M., Jhanjhi, N.Z., Masud, M. and Baz, M., 2022. Ai-based resource allocation techniques in wireless sensor internet of things networks

in energy efficiency with data optimization. *Electronics*, *11*(13), p.2071. https://www.mdpi.com/2079-9292/11/13/2071

4. Surenther, I., Sridhar, K.P. and Roberts, M.K., 2023. Maximizing energy efficiency in wireless sensor networks for data transmission: A Deep Learning-Based Grouping Model approach. *Alexandria Engineering Journal*, *83*, pp.53-65. https://www.sciencedirect.com/science/article/pii/S1110016823009018

5. Bagwari, A., Logeshwaran, J., Usha, K., Raju, K., Alsharif, M.H., Uthansakul, P. and Uthansakul, M., 2023. An enhanced energy optimization model for industrial wireless sensor networks using machine learning. *IEEE Access*, *11*, pp.96343-96362. https://ieeexplore.ieee.org/abstract/document/10239155/

6. Saravana Kumar, N.M., Suryaprabha, E. and Hariprasath, K., 2022. Machine learning based hybrid model for energy efficient secured transmission in wireless sensor networks. *Journal of Ambient Intelligence and Humanized Computing*, pp.1-16. https://link.springer.com/article/10.1007/s12652-021-02946-y