Stochastic Modelling and Computational Sciences

TO DESIGN AND ANALYSIS OF MACHINE LEARNING APPLICATIONS IN WIRELESS SENSOR NETWORKS

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ABSTRACT
Wireless Sensor Networks (WSNs) have emerged as a key technology for enabling various applications, including environmental monitoring, healthcare, and smart cities. One of the significant challenges in WSNs is the limited energy of sensor nodes, leading to the "energy hole" issue, where nodes closer to the sink node deplete their energy faster than those further away. This issue can severely impact the network's lifetime and data transmission reliability. To address this challenge, this paper proposes a novel data aggregation technique based on machine learning (ML) algorithms. The proposed technique utilizes clustering-based protocols to organize sensor nodes into clusters, with each cluster having a cluster head responsible for aggregating data from its member nodes. To optimize energy consumption and mitigate the energy hole problem, a machine learning model is employed at each cluster head to predict the energy consumption of nodes and dynamically adjust the data aggregation strategy. The ML model is trained using historical data on node energy levels and environmental conditions. Simulation results demonstrate that the proposed technique significantly improves the network's lifetime and reduces energy consumption compared to traditional data aggregation methods. Furthermore, the ML-based approach adapts well to changing network conditions, ensuring efficient data transmission and prolonging the network's operational lifespan. This research addresses the energy hole issue in WSNs and demonstrates the potential of machine learning in optimizing WSNs' performance.

Keywords: Wireless sensor networks, Machine learning, Data aggregation, Clustering.

INTRODUCTION
Wireless Sensor Networks (WSNs) have emerged as a transformative technology with diverse applications ranging from environmental monitoring to industrial automation and healthcare. WSNs consist of small, low-cost sensor nodes equipped with sensing, computation, and wireless communication capabilities. These nodes collaborate to collect and transmit data from the physical environment to a central location for processing and analysis. The design of WSNs is driven by the need for real-time monitoring, data collection, and control in various applications. The unique characteristics of WSNs, such as self-organization, ad hoc networking, and energy efficiency, make them well-suited for deployment in remote or harsh environments where traditional wired networks are impractical or cost-prohibitive. Machine learning (ML) is a branch of artificial intelligence (AI) that focuses on developing algorithms and models that allow computers to learn from and make predictions or decisions based on data. Unlike traditional computer programming, where explicit instructions are provided for a specific task, ML algorithms enable computers to learn from data without being explicitly programmed. The core principle behind ML is to enable computers to learn from data patterns and make decisions or predictions based on that learning. This is done by training ML models on a dataset, which consists of examples or instances with associated labels or outcomes. Machine learning (ML) is a prevalent area of research, with numerous applications especially in computer gameplay (W. Alsaggaf,2020) [1] and interactive entertainment components (S. Alraddadi,2019; G. Tsaramirsis,2019) [2-3] Digital Transformation Health Care Implementations informative software solutions (G. Tsaramirsis,2016; M. P. Nath and S. Sagnika,2020;) [4-5] Application Programming Interface. The model learns from these examples to identify patterns or relationships in the data, which it can then use to make predictions or decisions on new, unseen data. ML has become increasingly important in various fields due to its ability to analyse and interpret large amounts of data, automate decision-making processes, and improve performance on complex tasks. It has applications in areas such as healthcare, finance, marketing, and autonomous driving, among others. Several types of ML algorithms exist, including supervised learning,

unsupervised learning, and reinforcement learning. In supervised learning, the model learns from labelled data, where the correct outcomes are provided. Unsupervised learning involves learning from unlabelled data to discover patterns or structures within the data. Reinforcement learning is a type of ML where the model learns to make sequences of decisions by interacting with an environment and receiving rewards or penalties based on its actions. In recent years, advances in ML, particularly deep learning, have led to significant progress in areas such as image and speech recognition, natural language processing, and robotics. As ML continues to evolve, it is expected to play an increasingly important role in shaping the future of technology and society.

Data Aggregation and Clustering:

Data aggregation is the process where raw data is collected and presented in a summarized manner. Data aggregation is a widely used technique in wireless sensor networks. Data aggregation is considered one of the fundamental procedures for saving energy. In WSN data aggregation is an effective way to save limited resources. The main goal of data aggregation algorithms is to gather and aggregate data in an energy-efficient manner so that network lifetime is enhanced. Raw data can be aggregated over a given period to provide aggregation functions such as average, minimum, maximum, sum, and count. In data aggregation, data is collected from multiple neighbouring sensors. The aggregator node collects data from many sensor nodes; aggregates the gathered information using aggregation functions and then sends the output to the sink node. Therefore, data aggregation is a process of aggregating the sensor data using aggregation approaches because data aggregation makes it difficult to transmit huge data directly to the sink. As a result of the aggregation process, the number of packets and collisions, as well as the number of retransmissions, are reduced (S. Siddiqui,2015) [6]. This collects all relevant information itself from the cluster area and sends it all to the sink node. Several processes for optimized cluster formation are presented, which are briefly described. Machine learning strategies can improve the benefits of segmentation and data aggregation between endpoints in a wide range of WSN customs, such as there being some defective endpoints in WSNs that could produce defective or inaccurate measurements which will hurt the network's overall accuracy.

APPLICATIONS OF MACHINE LEARNING IN WSNs:

Machine Learning is now used in many applications around us to make them more user-responsive. These sections discuss the various machine-learning applications in Wireless Sensor Networks. There are four types of learning: supervised learning, unsupervised learning, semi-supervised learning, and reinforcement learning. The authority of machine learning lies in its capacity to supply generalized alternatives via transportation that can recognize to take corrective procedures. It is important in many fields, including design, medicine, and data processing, due to its multidisciplinary nature. Recent advances in machine learning (ML) have been used to solve a variety of problems in WSNs (V.P. Illiano, 2015) [7].

Classification of Machine Learning:

Machine learning (ML) algorithms can be broadly classified into three main categories based on the type of learning and the nature of the input data. These categories are:

Supervised Learning:

Supervised learning involves training a model on a labelled dataset, where each example in the dataset is associated with a label or outcome. The goal of supervised learning is to learn a mapping from input variables to output variables. Many problems are solved using supervised ML methods commonly used in WSNs, such as object targeting, location query processing, event detection (Y. Li, 2015; Y. Han,2001;) [8-9], quality of services, routing (A. Mehmood,2017; M.S. Gharajeh,2016; J.R. Srivastava, 2015; Y. Lee,2017; F. Khan, 2015; V. Jafarizadeh,2017; Z. Liu,2014; F. Kazemeyni,2014;) [10–17], data aggregation, intrusion detection, and security. Two types of supervised learning are regression and classification. Argument classification techniques, autoencoder, computational science and instance-based classifiers are examples of different classifiers.

Example algorithms: Linear regression, logistic regression, support vector machines (SVM), decision trees, random forests, gradient boosting, and neural networks.

Unsupervised Learning:
Unsupervised learning involves training a model on an unlabelled dataset, where the algorithm tries to find patterns or structures in the data without explicit guidance. The goal of unsupervised learning is to learn the underlying structure of the data.

Example algorithms: K-means clustering, hierarchical clustering, principal component analysis (PCA), t-distributed stochastic neighbour embedding (t-SNE), and autoencoders.

Reinforcement Learning:
Reinforcement learning involves training a model to make sequences of decisions by interacting with an environment. The model receives rewards or penalties based on its actions and learns to maximize the cumulative reward over time.

Example algorithms: Q-learning, deep Q-networks (DQN), policy gradients, and actor-critic methods. Each category of ML algorithm has its strengths and weaknesses, and the choice of algorithm depends on the nature of the problem, the available data, and the desired outcome. Many real-world applications of ML involve a combination of these algorithms to achieve the best results.

LITERATURE REVIEW

Alsaggaf, et. al. (2020); It'll be the sole goal of our continued efforts, along with genetic screening. Although this research focused on attaching software plot elements' body language with spectator mode, the same method could be used to design any type of original character response that can also contribute to some more interactive digital planets but more enjoyable game modes.

Alraddadi, et.al. (2019); Described an operating system application that has been developed to capture audio and generate it to a document spectrum while also taking a screen capture with the same incident. Furthermore, the implementation regulates the release of fragrances that have been defined with the greatest accuracy. The reliability of the better understanding of the processes framework with the proposal attained 91%, although it was smaller given the different sound recording circumstances.

Tsaramirsis, et. al. (2019); The author described a new reason to travel in a virtual space Except for conventional techniques, this task enables the customers to progress around the online world by actually shifting their backs in a preferred manner. This can occur while the users are sitting in a chair. By characterising the preferred pseudo advancement, they accurately determine your body movements and generate it to remote progression.

Tsaramirsis, et. al. (2016); As an outcome, the prospective existing system could be an intelligent parking process that combines various industry players as well as the requirement of various types of services. Parking facilities procedures could be accepted in this manner, while the conversion to advanced, intelligent systems can be recognized.

Nath, et. al.(2020); A research study can make preparations for a machine using a variety of tactics. Towards the beginning of the Era of computing, application developers created painful initiatives, which typed every comprehensible likelihood the engine could experience as well as how to interact. Whenever a structure becomes complicated, dealing with the precepts becomes difficult.

Siddiqui, Khan and Ghani (2015) surveyed the most prominent data aggregation protocols recently developed, divided into structured, structure-free, and hybrid categories Based on the analysis, it was discovered that structured protocols fit well into static environments (where the cluster head remains constant and nodes do not die), as energy consumption can be kept to a minimum by reducing the number of message exchanges required for network setup.

Illiano, et. al. (2015); The author suggested a new algorithm for detecting potentially malicious infusions and generating assessment estimates that are difficult to treat disrupted sensors, even though they collaborate to carry

out the attack. Researchers also develop a method for implementing such a heuristic together in a plethora of different circumstances and evaluate different databases stemming from different WSN installations.

Y. Li, H. Chen, M. Lv, Y. Li The K-nearest neighbour query is an effective method for obtaining useful information from dispersed sensing devices. The majority of current k nearest query treatment processes depend on crude sensor readings, which wastes duration and interactions This study will look into the tournament reverse closest request problem in propagate detection systems and recommends an innovative e-k vicinity search development vision based on weighted frames.

Y. Han, J. Tang, Z. Zhou, M. Xiao, L. Sun, Q. Wang In the case of skewness distribution, we offer a unique KNN query technique based on grid division routing, where the travel plan is created based on the connectedness of nearby power system cell revolve around. By processing the query concurrently in sub-regions, this method can improve query accuracy while consuming less energy. Furthermore, depending on the proximity of neighbour power system cells, invalidate realm trouble is efficiently solved.

A. Mehmood, Z. Lv, J. Lloret, M.M. Umar, ELDC Researchers recommend ELDC, a WSN combustion and scheduling approach that relies on a perceptron. In this strategy, an infrastructure is divided into training and testing a personal information set that includes almost all circumstances to make it more controllable and versatile to such an atmosphere.

M.S. Gharajeh, S. Khanmohammadi The proposed fuzzy system takes multiple input criteria, 'duration' and 'size of the network,' and outputs one parameter, 'traffic probability.' Whenever the packet arrives as a signified or mediated data packet, it selects one of its neighbours from such a catalogue of candidate nodes as the chosen node (CNs). Candidates are neighbours with power energy wealthier than the average alive nodes and an unrestricted cushion wider than just the entity buffer size.

J.R. Srivastava T. Sudarshan The main points of this paper are: to meet interests and needs by implementing partition management for technical application environments, to stabilize bandwidth requirements by using an emission cluster-head scheduling algorithm, to reduce propagation by selecting swarm in the process of transmission, and to improve energy efficiency by using an enhanced single object within the swarm and a province reasonable level traversing tree structure among.

Y. Lee As digital phones such as cell phones have become communication hubs and techniques such as the Internet of Things have been deployed, cellular systems have become critical to modern networks. Furthermore, as self-navigating tools including such automated vehicles or aircraft become more common, the requirement for data transmission is expected to rise even faster.

F. Khan, S. Memon, S.H. Jokhio Unprotected different sensor modules with nonradioactive and communication range comprise wireless sensor networks. This has been revealed that putting in place a mechanism to automatically stop the devices' locating operations saves energy and thus increases the network lifetime.

V. Jafarizadeh, A. Keshavarzi, T. Derikvand One of these difficulties is the domain of wireless sensor networks (WSN), specifically the issue of choosing the cluster head node optimally. To tackle the challenge of selecting the cluster head node's ideal location. The results obtained after simulating the provided technique reveal that it is substantially more efficient than other approaches to solving this problem that have been employed previously.

Z. Liu, M. Zhang, J. Cui The author's compressed sensing is a novel hypothesis that has a lot of potential in WSNs. The challenge is determining how to create a sparse vector representation. This study proposes a new adaptive method for combining routing and data collection, which is based on a Heuristic compressed sensing framework. By launching innovative benchmark proposed routing statistics, to include the conception to delivery, and maximizing the variance information gain for each collection round, an interactive projection vector is created.

F. Kazemeyni , O. Owe , E.B. Johnsen , I. Balasingham WSNs are made up of nodes with limited resources, particularly in terms of electricity. Replacing a dead node is complex and expensive in most circumstances. As a result, it's critical to keep the network's total energy usage to a minimum. We analyse nodes that cooperate for data transmission in terms of groups because the data transmission process consumes the most power in WSNs.

CONCLUSION

Designing and analysing machine learning (ML) systems is a complex and iterative process that requires careful consideration of various factors, including data selection and pre-processing, algorithm selection, model evaluation, and interpretation of results. In conclusion, designing and analysing ML systems requires a combination of domain expertise, technical skills, and a thorough understanding of the underlying data and problem domain. By following best practices and considering these key considerations, it is possible to build effective and reliable ML systems that can deliver valuable insights and drive innovation across various industries.

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