



Deep Learning Based Energy Efficiency in Wireless Sensor Network

A. Manikandan*

**Assistant Professor, ECE Department, SSM Institute of Engineering and Technology, Dindigul, India*

*Corresponding Email: *manikandan.aapec@ssmiet.ac.in*

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Abstract: *Wireless Sensor Network (WSN) comprise of huge amount of sensor nodes. These nodes sense the data from their surroundings and pass this information to the sink node using cluster head. Due to the emergence of new technology, it is widely used in distinct applications such as habitat monitoring, health science, border surveillance etc. There are several issues in WSN such as Quality of Service (QoS), localization, routing and data aggregation. Sensor nodes have limited energy, so there is a need to enhance the energy efficiency across the network. This paper focuses on two mechanisms of energy efficiency: energy consumption and energy harvesting. Energy consumption can be minimized by using different Machine Learning (ML) approaches. The other mechanism is energy harvesting. It provides the further two sources: ambient source and external source. Ambient source consists of renewable resources such as radio frequency, solar, thermal and flow-based energy harvesting. Radio frequency converts the radio waves into electric signal, solar mechanism converts solar rays to electric signals, thermal mechanism converts heat energy to electric energy and flow technique convert the rotatory movement to electric signal. External source includes mechanical and human based energy harvesting. Further, the proposed statistical analysis of eight years (2014-2021) illustrated the fact that different ML techniques applied in energy efficient parameter reduces the consumption of energy across the network. These two mechanisms enhance energy efficiency parameter and network lifetime by using ML. Author vision is discussed as an open issue in the last.*

Keywords: *Energy-Efficiency, Machine Learning, Quality of Service, Wireless Sensor Networks.*

1. INTRODUCTION

Wireless Sensor Network (WSN) is applicable in road side communication, border surveillance, habitat, health, industrial and environmental monitoring due to the advancement



of technology. Sensor nodes can be placed in terrestrial, underwater, underground and multimedia WSN. Due to dynamic behaviour of the WSN the location of the sensor nodes is changed continuously. There is a requirement of Quality of Service (QoS) assurance in real world scenario. It is responsible to improve the performance and security of the network in terms of throughput, delay, jitter, bandwidth, energy efficiency, reliability and availability (E. Mbowe and S. Oreku, 2014). Energy efficiency parameter is very crucial due to the size of sensor node. It is difficult to replace the batteries of nodes in the entire network. So, there is a requirement to increase the energy-efficiency parameter for optimal working of WSN. Energy efficiency can be improved by two approaches as: reducing the consumption of energy and introduce new energy harvesting mechanisms. Machine Learning (ML) is a technique that learns from itself through its past experiences. It is implemented at the base station and enhance the QoS in WSN.

Wireless Sensor Network

WSN is a collection of tiny devices known as sensor nodes which are deployed in the sensing region of the geographical area. The other name of sensor nodes are motes. These devices have limited bandwidth, energy, computational and storage capacity (Praveen Kumar, Amgoth and Annavarapu, 2019). These devices sense the data from their respective sensing region and forward this information to the cluster head through hop-to-hop delivery shown in Fig. 1. The cluster head transmit the data to the base station for processing and useful data is extracted from the gathered data which is free from error and noise. This useful information is further transferred to the user by using internet gateway.

Quality of Service

QoS is a crucial issue of WSN which can be evaluated in terms of different metric. These metrics are correlated with each other. Sometimes one metric reduces the performance of another metric. Due to this reason, it is complex to achieve the optimal QoS entire the network. It can be categorized based upon performance attributes and privacy and security attributes shown in Fig. 2.

Performance Level

The attributes which are calculated based on performance of the network is known as performance attributes of QoS. It can be evaluated in terms of throughput, latency, reliability energy-efficiency etc. All the parameters of performance level are given as:

Throughput: It indicates the total work done (data transmitted from source to target) per unit time and measured in bits/sec.

Delay: It represents the delay of data when communicating from one end to another end across the network. It can be estimated in terms of sec.

Reliability: It is system capability to perform specific task with given conditions.

Availability: It gives assurance only authorized users can access the resources.

Energy Efficiency: It indicates to perform same task with minimum energy.

Packet Error: The count of corrupted packets during transmission.



Packet Loss: The total number of packets lost during transmission.

Privacy and Security Level

These attributes are non-measurable and examine based on privacy and security. Confidentiality, safety, integrity and security are considered as an its attribute. The parameters of privacy and security level is discussed as:

Security: It indicates intruders are not able to access network resources

Confidentiality: Only authorised users can access the sensitive information.

Integrity: The consistency of data is not altered.

Safety: It is a harmless state of the network.

Machine Learning

Supervised Learning

ML is applied in several research areas such as cognitive science, artificial intelligence, signal and information, statistics and so-on. ML is divided into three parts: supervised, unsupervised and reinforcement learning (Alsheikh *et al*). It is a technique which generates rules automatically from the past activities or examples stored, processed and validated in a learning database. It deals with the labeled data. Expected outcome is already known in supervised learning. Human intervention plays a vital role during training phase and responsible to build a concise model based on labeled input. It is used to solve the problems of regression and classification. The few examples of supervised learning are as:

Decision Tree: The test or conditions are represented in the hierarchal manner. It consists of root, internal and terminal nodes. It is an intelligent approach and produces high accuracy. It produces remarkable outcomes in real world scenario.

Support Vector Machine (SVM): This approach is used to solve the problem of two group classification. It gives good results even data is unstructured form. It uses the concept of kernel trick.

KNN: It is an easy approach to solve the problem of regression and classification. It assumes that the similar objects are close to each other and follow the concept of proximity and closeness.

Regression: It is a statistical approach to model the relationship between dependent variables and independent variables. Target is acts as a dependent variable and predictor is an independent variable. It can be of different types such a linear, logistic and support vector regression.

Unsupervised Learning

It is an approach which main goal is to determine the hidden models or patterns from the datasets. It deals with unlabeled data and there is no human intervention is required in this approach for training phase. It is used to solve the problems of clustering and association. The examples of unsupervised learning are:



K-means: It is used to solve the problem of clustering. In this approach centroid is placed within a cluster and repeats the process till there is no pending points. It is used in WSN to improve the QoS in terms of network lifetime and energy efficiency.

PCA: It is a statistical approach which is used for dimensionality reduction. With the help of orthogonal transformation, it converts the correlated features to linear uncorrelated features
Reinforcement Learning

It is an approach which uses the intelligent agents to observe the outcomes of the previous tasks. It interacts with the environment and take actions to enhance the cumulative rewards. Rewards can be positive or negative in this approach. There is no supervision is required. The sequentially decision making is performed in reinforcement learning Q-Learning is an example of reinforcement learning. It is a model free reinforcement learning and uses the action values.

Energy Harvesting

Energy harvesting technique is categorized into two parts: Ambient and External Sources.

Ambient Sources

It consists of several renewable energy harvesting mechanisms such as Thermal, Solar, Radio-frequency (RF) and Flow (Hydro and Wind) based energy harvesting mechanism.

Radio Frequency: In this scenario, radio waves are converted into direct current (DC) signals by various techniques such as multistage or single stage. This mechanism consists of two models: In first model, sensor use two radio, one for communication and other for RF energy harvesting. In second model only one radio is used for both purposes.

Solar: Solar energy is clean and affordable which resolves the problem of limited energy in WSN. Solar rays are converted into DC signals. There are several mechanisms to implement solar based energy harvesting depends upon the type of solar panels and battery. Solar energy can be adapted for data transmission and sleep and wake up duty cycles.

Thermal: In this mechanism, heat energy is converted into electrical energy by using Thermal Electric Generator. It has long life and reliable but due to low efficiency it is not used widely.

Flow: It converts rotational movement into electric energy by using turbines and rotors. It follows the rule of electromagnetic induction. This mechanism is implemented on wind energy and hydropower energy.

External Sources

External sources comprise of two energy harvesting mechanisms: mechanical and human based energy harvesting.



Mechanical: Energy can be harvested from pressure, vibrations and stress-strain but it requires Mechanical to Electrical Energy Generator. It uses MEEG for electrostatic, electromagnetic and piezoelectric mechanism.

Human: Energy can be harvested from human in many ways to save power such as locomotion, blood flow and body heat. It can be categorized based on the activity of the human

Statistical Analysis

The statistical analysis of ML technique in Energy efficiency parameter of QoS is shown as in Fig. 3(a). According to the analysis, reinforcement learning techniques are maximum applied to enhance the energy efficiency metric across the network. It reduces the energy consumption at network level. It is considered as first choice of researchers with a count of 13. SVM and k-means shows their significance at the second position. Decision Tree gains third rank. Naïve bayes comes at last position. Fig. 3(b) depicts the significance of supervised learning. It shows that supervised learning is maximum used between the period of 2014-2021. It represents as 63.24% gain as compared to other machine learning techniques. Reinforcement learning is also a buzzword in current scenario and shows its significance as 19.12%. The unsupervised learning comes at last position as 17.65%.

Open Challenges

Energy efficiency plays a vital role in QoS of WSN. There are various open issues when addressing the energy-efficiency parameter such as efficient prediction approach, energy efficient reliable systems, protocol adaptation, generic harvester and miniaturization.

Protocol Adaption: There is a requirement of energy-efficient routing protocols which provides the maximum information based on existing harvested energy. The selection of optimal routing protocol is very complex. It depends upon the various factors such as network's topology, fault tolerance, section of cluster head and redundancy management.

Efficient Prediction Approach: The currently present prediction techniques are simple and can cause prediction errors. These errors are responsible to degrade the performance of the network. In future, there is requirement of new energy efficient prediction approaches which are free from errors.

Energy Efficient Reliable Systems: Energy-efficient reliable system is an open issue in WSN. But new energy harvesting systems uses the ultra-energy efficient sensor nodes. Due to this, it consumes less energy and provide the reliable network lifetime. Reliability of the network can be improved in future by using hybrid machine learning approaches.

Generic Harvester: It is an open issue to harvest the energy from the multiple sources. It needs advanced power management approaches. This issue can be resolved by generic harvester.



Miniaturization: Due to the bulky harvested systems, cost is increased and it is not economical. This bulky harvested system will be replaced by nano- scale harvested systems in future.

2. CONCLUSION AND FUTURE WORK

Wireless Sensor Network (WSN) consist of small devices known as motes or sensor nodes. These motes are resource constraint in nature such as low bandwidth, memory and energy. It is placed in the geographical area to monitor the environmental conditions. WSN is used in diverse fields due to the rapid growth of new technologies. It can be applied in border surveillance, health, environment and industrial monitoring. Energy is a crucial issue in the network because of its tiny size. Here, energy efficiency parameter of QoS is mainly focused in this paper. It can be improved by two approaches: energy consumption and energy harvesting. Energy is consumed at the two levels namely node level and network level. Machine Learning (ML) techniques are used to reduce the consumption of energy entire the network. Energy harvesting is performed by using renewable sources. It is subcategorized into two sources such as ambient and external sources. Thermal, solar, radio frequency and flow (wind and hydro) energy harvesting are considered in ambient sources. Mechanical and human energy harvesting comes in the category of external sources. The main aim of this paper is to enhance the QoS in terms of lifetime of WSN powered by environmental energy. Statistical analysis shows the significance of reinforcement learning used in energy efficiency parameter. It reduces the energy consumption across the network. These two mechanisms enhance energy efficiency parameter and network lifetime by using ML. In future ensemble modeling can be applied to reduce the consumption of energy in the entire network. The new mechanisms of energy harvesting will be incorporated to enhance lifetime of WSN.

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