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A Review of Deep Learning Based Energy Efficient Routing in MANET

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ABSTRACT - Mobile Adhoc Network (MANET) is an Infrastructure less network and it can change the network topology formation in different times. However, the topology changes, mobility of nodes, energy consumption and unreliable communication links significantly considered in analysis of routing effectiveness and efficiency. Conventional routing protocols are emerged for MANET Communication and Transmission but many problems are inherently unsolvable to manage adaptive routing and energy optimization. In recent years, deep learning techniques have shown massive prospective in addressing these boundaries by enabling intelligent, self-adaptive, and data-driven solutions. This paper proposed an analysis of deep learning based algorithms emerged for mobility of network and energy efficient routing in MANET, specifically neural networks, recurrent models such as LSTM and GRU, and deep reinforcement learning algorithms are considered.

Keywords: Wireless network, MANET, Mobility analysis, Deep learning Techniques,

1. INTRODUCTION

1.1 Wireless Networks

Wireless mobile networks is traditional network methodology that have been relied on good infrastructure based communication, Network considered to be base station to emerging communication for mobile devices with efficient way. . Typical examples of this kind of wireless networks are GSM, UMTS, WLL, WLAN, etc. Figure 1 shows Infrastructure Oriented wireless Network

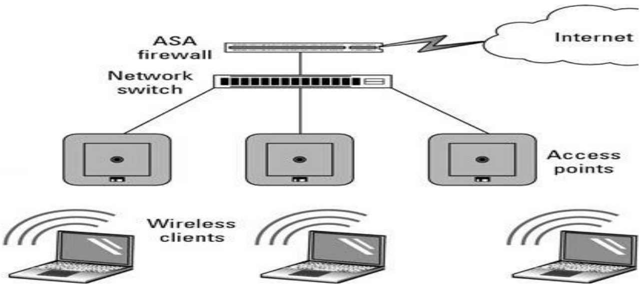

Figure 1. Wireless Network

1.2 MANET

.A MANET is a group of wireless nodes, but in the unavailability of fixed network infrastructure, it can dynamically build a network to share information. Cellular wireless network is also referred to as a mobile ad hoc network (MANET) in relation to the infrastructure-less method. This is a crucial component of communication technology since, in many situations; wireless connections must be quickly configured on the fly rather than relying on any stable network infrastructure for information flow between mobile units. Rather than being merely a supplement to the cellular system, wireless ad hoc networks themselves constitute an autonomous, broad field of study and application.

In MANET, Various routing proactive and Reactive protocols such as AODV, OLSR and hybrid protocols were implemented to improve the efficiency of networks to achieve less energy with highest Throughput. Due to highest node mobility leads to node instability and increased packet loss over the network. So not only those protocols should not relies on Optimized routing schemes and energy efficient routing mechanism. Even conventional protocols should not effectively analyse the network conditions to compromise node failures and Quality of Service (QoS) policy

Unlike Traditional approach, Deep learning Technique accurately analyse and find the complex pattern certainly. In recent years, the integration of Deep Learning (DL) into MANET frameworks has shown promising potential for overcoming those challenges [1]. We Compare and review various deep learning in MANETs and this paper aims to provide valuable perceptions into the network capabilities, limitations on routing and future directions of deep learning in MANETs. Main objective of this study is

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i) To Review various deep learning approaches LSTM or GRU to Maintain Mobility of Dynamic Infrastructure.

ii) To analyse Energy consumption constraints to manage Battery power

iii) To Examine and reduce Packet loss on link instability using deep Reinforcement Learning mechanism without compromising QoS

2. BACKGROUND STUDY

2.1 Characteristics and Architecture of MANET

A mobile ad hoc network is a collection of wireless nodes that can dynamically change the node connection and communication time by time. It is free to move and independently change their communication and it can act as router at the same time. The traffic types in ad hoc networks are quite different from those in an infrastructure wireless network.

2.1.1 Characteristics of MANET is listed below

i) **Dynamic Topologies** Nodes are freely move with different nodes and form topology at different times.

ii) **Energy Constrained** Energy conservation of some or any other node on the network may relies on batteries and consume more energy

iii) **Limited Bandwidth** Wireless links continue to have much lower capacity than infrastructure networks. The realized throughput of wireless communication - after accounting for the effects of multiple access and interference conditions, etc, is often much less than a radio's maximum transmission rate.

iv) **Security Issues** Infrastructure networks continue to have far greater capacity than wireless connectivity. When multiple access, interference, and other factors are taken into consideration, the actual throughput of wireless communication is frequently significantly lower than the maximum transmission rate of a radio.

2.1.2 MANET Architecture

In Manet all nodes are acting as Router and terminal to transmitting data rather than Infrastructure oriented communication. The choice of nodes that will ensure a communication session in an AdHoc network is done dynamically according to the connectivity of the network, hence the name "AdHoc".[2] In an AdHoc network, a node can communicate directly (point-to-point mode) with any node if its in the same transmission zone, while communication with a node outside its transmission zone is done via several intermediate nodes Figure 2 Illustrates MANET Architecture

Figure 2. MANET Architecture

2.2 Applications of MANET

i) Military battlefield: Ad-hoc networking more equipped to working on the military network communication. It can provide secure communication network technology to maintain an information network between the soldiers, vehicles, and military information head quarters. The basic Techniques especially designed for this field

ii) Commercial sector: Mainly useful in kind of emergency/rescue operations for disaster relief efforts, e.g. in fire, flood, or earthquake. To analyse and take precaution actions are made to use of this methodologies Information is relayed from one rescue team member to another over a small handheld.

iv) Personal Area Network (PAN): Short-range MANET can make it easier for different mobile devices (such a PDA, laptop, and cell phone) to communicate with one another. Wireless connections take the role of laborious wired cords.By using technologies like Wireless LAN (WLAN), GPRS, and UMTS, such an ad hoc network can also increase access to the Internet or other networks. In the context of pervasive computing in the future, the PAN is a potentially attractive application area for MANET.

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2.3 Conventional Routing Protocol

There are three ways to classify our protocols

i) Proactive Protocols

In table driven routing protocols, each node can be maintained the routing information and other nodes information relies on the network for on demand routing communication. There are some proactive protocols to handle those routing such as DSDV, GSR etc.

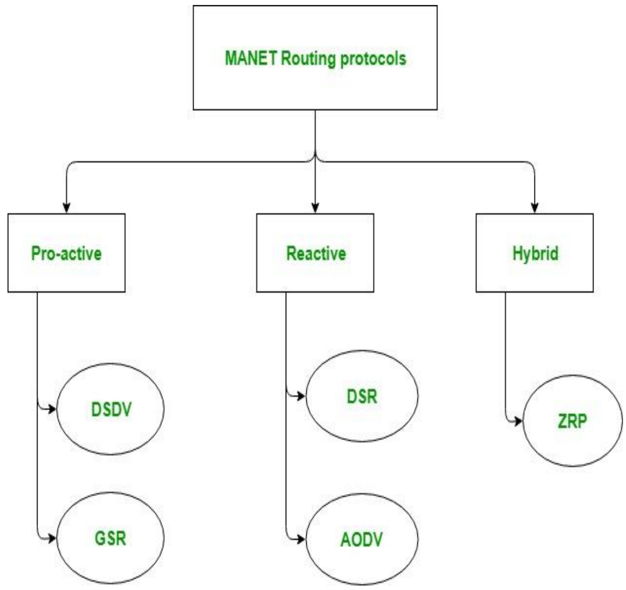

Figure 3. Classification of Routing Protocols

ii) Reactive Protocols

DSR, AODV Protocols are type of Reactive protocols to highly helps to On demand energy effective protocols.

iii) Hybrid Protocols

The hybrid routing protocol have the combination of both capability of proactive and reactive routing protocols to balance the delay and control overhead. It adapts large scale networks.

2.4 Issues in Conventional Approach

i) Dynamic topology and scalability: ad hoc networks do not allow the identical aggregation techniques that are available to standard Internet routing protocols, they are exposed to scalability problem

ii) Routing: changing nature of network topology is the issue of routing packets between any pair of nodes becomes a challenging task. When Multicast routing is another challenge due to the random movement of nodes within the network. Routes between nodes may potentially contain multiple hops, which is more difficult than the single hop communication.

iii) Power Consumption: Periodic updating of routing table consumes more energy made inefficiency of communication and packet loss.

2.5 Gaps In Existing Research

There is significant progress in applying DL to various communication systems, remain significant gaps in existing research. This paper focuses on review of existing work of different models with limited attention to large-scale real-world implementations of routing and energy optimization using conventional routing techniques and packet delay rate. Few studies have investigated the long-term stability and scalability of Network models when installed in live MANET. Furthermore, the incorporation of DL techniques for the most part for energetic optimization in network controls. DL techniques has the more prospective to continuously adapt to changes in network conditions, optimizing network performance without human intervention, Moreover, there is inadequate consideration specified to the interpretability of ML models where DL techniques such as CNNs and RNNs have established high accuracy in tasks like pattern analysis and prediction.[8] The lack of transparency poses problems for the widespread adoption of traditional model in critical MANET Topology.

2.6 Deep Learning Techniques for Communication Networks.

Deep learning is a subset of Machine learning, uses artificial neural networks (ANN) helps to analyse and predict complex pattern from large datasets using multi-layer perceptron. DL applications in optical communications include deep neural networks (DNNs) is engaging multiple layers to examine complex data relationships for generalize neural networks. For sequential data, recurrent neural networks (RNNs) are taken into consideration. They are especially helpful for traffic prediction in dynamic networks and optical signal processing. While processing spatial data, such as optical channel pictures or network topology visualisations, convolutional neural networks (CNNs) perform exceptionally well. Finally, deep reinforcement learning (DRL) integrates RL and DL to support intelligent decision-making in dynamic and complicated optical network environments. [9]

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3. DEEP LEARNING TECHNIQUES FOR ROUTE OPTIMIZATION AND ENERGY MANAGEMENT IN MANET

To enhance route stability and Mobility prediction, this paper review and presented Deep Neural Network, Recurrent Neural Network and Deep Reinforcement learning approach.

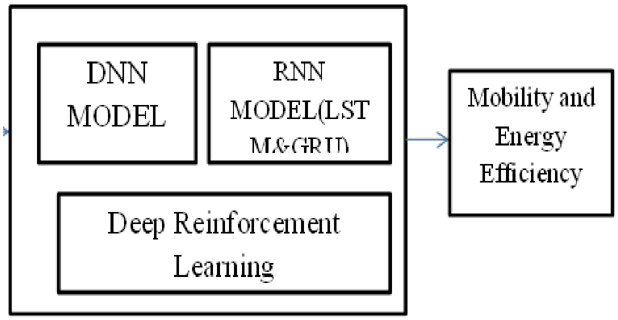

Figure 4. Deep learning based Routing Approach and Energy Efficient Architecture

Analysis of MANET, traditional models outperforms to mobility prediction and route adaptability for effective communication. DL based models DNN Helps to track pattern analysis of nodes over the network have to maintain the link stability and also to manage packet loss in very less manner.

3.1 Deep Neural Network Algorithm (DNN)

DNNs established across multiple FSO system configurations, including detectors, constellation shapers, and joint constellation-shaper-channel estimators rather than conservative heuristic-based methods, DNNs adaptively learn optimal signal mapping strategies, leading to greater performance in self-motivated network conditions. It is produced a low-complexity DNN-based detector for FSO systems, attaining performance equivalent to traditional detectors while considerably reducing computational resource requirements.

3.2 Recurrent Neural Networks (RNN)

Recurrent Neural Networks (RNNs) input of current layer is collected from the output of previous state.RNN's hidden layers have the capability to maintain the information. The output created in the previous state is used to update the hidden state. RNN has Long Short-Term Memory to predict previous state information, so it could permits to remember prior inputs. The outputs from the LSTM can be given as inputs to the current phase. RNNs encompass influences that create directed cycles. The LSTM's output becomes an input to the current phase, and its internal memory allows it to remember prior inputs. RNNs commonly used for Image captioning, time-series analysis, natural-language processing, handwriting identification, and machine translation.

RNNs, particularly Gated Recurrent Units (GRU) and Long Short-Term Memory (LSTM) networks, have established substantial enhancements in optical wireless communication, including FSO and VLC systems. Unlike feedforward neural networks, RNNs recollect the information about (memory) of past inputs, making them particularly suited for sequential data processing, such as time-series signal prediction and equalization.

3.2.1 Long Short-Term Memory Networks (LSTM)

Long-term dependencies can be learned and remembered using LSTMs, which are a form of Recurrent Neural Network (RNN). The default behavior is to remember historical evidence over long periods of time. LSTMs keep track of data throughout time. Because they remember past inputs, they are valuable in time-series prediction. Four interacting layers communicate in a unique way in LSTMs, which have a chain-like structure. LSTMs are also suits for node information, mobility of Networks in MANET.

3.2.2 Gated Recurrent Units (GRU)

GRU-based model was established for FSO channel estimation, utilizing RSS and weather information to predict future channel conditions. The model achieved an absolute percentage error below 6.9% in 90% of cases, it counter parts the predictable methods such as Back propagation Neural Networks (BPNN), SVM, and Random Forest in both accuracy and computational efficiency. In comparison to classic ML models, which frequently require extensive feature engineering and struggle with long-term dependencies, GRU significantly lowered the computing cost while reducing estimation mistakes to influence its capacity to preserve previous signal strength information.

GRUs can effectively identify the minor distinctions in mobility of nodes and predict the right node precisely at a certain timestamp. With high correlation coefficients, information on predicted node and the ground truth of the particular node has a strong linear relationship. This demonstrates unambiguously that GRUs may help forecast future node motions, which eventually enhances MANET routing performance.

3.3. Deep Reinforcement Learning Algorithms

Particularly deep RL methods, have revealed important prospective in optimizing resource allocation, adaptive decision-making, and network management in optical communication systems. These methods enthusiastically adjust to Moving environments; DRL is mainly applicable for different channel conditions, interference and mobility requirements.

In FSO systems, RL-based techniques have been employed for relay selection, power allocation, and transmission optimization .To balance rate and relay reliability a DQN-based approach develops relay selection in supportive decode-and-forward FSO systems rather than conventional greedy selection methods. Similarly, even combination of hybrid FSO/RF links, DQN improves link selection under adjustable weather conditions and also accomplishing faster convergence when reducing frequent switching with an ensemble consensus mechanism

3.3.1 Deep Reinforcement Learning in MANET

Traditional routing methods struggle to adapt to the dynamic alterations in network topology and the boundaries eradicated by constrained network resources. To address these problems, a Deep Learning-Based Reinforced Optimized Routing Algorithm (RDLORA) is proposed. Especially for MANET, It is intended to offer intelligent and adaptable routing options. This is achieved by integrating an intrusion detection system, merging parameter settings, and choosing the Cluster Head (CH) using a Reinforcement deep learning technique. Sleep scheduling is involved manage node energy through sleep-wake cycles on different traffic patterns and network lifetime. DRL Agents involves to maintain duty cycles to handle energy saving and communication latency.

4. COMPARATIVE ANALYSIS

4.1 Conventional Approach VS Deep learning Approach in MANET

DL-based protocols establish higher flexibility, energy efficiency, and scalability by leveraging real-time learning and predictive modelling, building more efficient in dynamic and mobile network environments.
Many Traditional approach were established for maintain the stability of network, packet forwarding mechanism and reliability
Management protocols. But After implementation of Deep learning techniques on the internet that scores a lot.
Table 1 compares traditional MANET routing protocols with deep learning-based approaches Traditional approach [15]. It also explains what are the schemes implemented, how the security it has and also some limitations of those protocols.
Finally these papers analyze and produce performance results in Table 2.

Protocols	Approach	Routing Scheme	Analysis	Limitation
DSR	Traditional Routing	Reactive Routing scheme for dynamic topology	Scalability issue for Large size	Susceptibility to network partitioning issues, affecting overall reliability.
OLSR	Traditional Routing	Proactive Routing and manage overall topology information using periodic link-state updates.	Higher overhead in terms of control message transmission	Lacks adaptability to sudden topology changes
AODV	Traditional Routing	Reactive Routing and generate on demand routing	suffer from route detection potential in large networks with frequent topology changes	vulnerable to security threats like black hole attacks
ZRP	Traditional Routing	Combination of Reactive and Proactive approach	Sensitive to parameter settings, impacting performance.	less in configure and optimize
DNN	DL-Based Routing	Trust Aware Routing	learns from real-time data and adapts	Needs to label the data
RNN (LSTM & GRU)	DL-Based Routing	Mobility Prediction	Predicts movement and adjusts routes accordingly.	Less accuracy for long term data

Table 1: Traditional vs. DL-Based Routing Protocols

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4.2 Performance Analysis on Various Deep learning Techniques in MANET

4.3

Model Type	Prediction Accuracy (%)	Link Lifetime (s)	PDR (%)	Delay (ms)	Energy Efficiency (J/bit)	QoS (%)
LSTM [16]	85	12.5	92	115	1.9	89
GRU [17]	83	11.8	90	120	2.1	87
ANN[18]	82	11.0	89	125	2.2	84
CNN-[19]	80	10.0	85	140	2.6	82
CNN-LSTM[20]	87	12.8	92	115	1.8	90
RNN [21]	80	11.0	89	125	2.2	86
DNN [22]	78	9.5	90	130	2.8	83

Table 2: Performance Comparison of Deep Learning Models in MANETs

5. RESULTS AND DISCUSSION

5.1 Prediction Accuracy

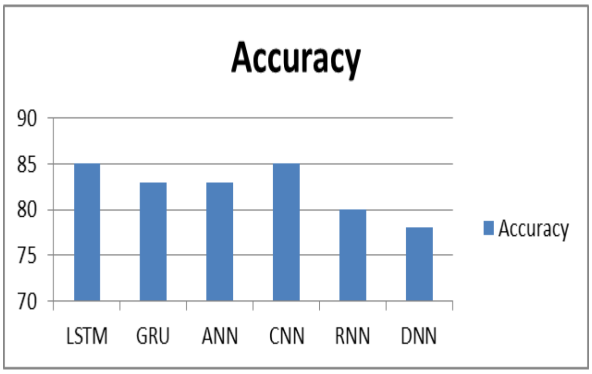

Figure 5. Accuracy

5.2 Network Life Time

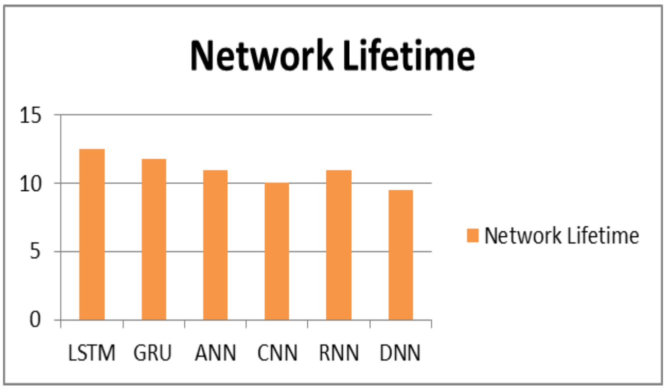

Figure 6. Network Lifetime

5.3 Energy Efficiency

Joules per bit (J/bit) represents the amount of energy required to transmit, process, or compute one bit of data.

Energy per bit=Total Energy (Joules)\

Number of bits

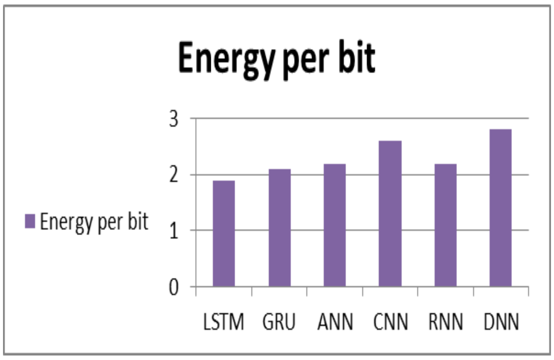

Figure 7. Energy Efficiency

Figure 5, 6, 7 Demonstrate the comparison analysis chart for performance accuracy, Network Lifetime and Energy evaluation between deep learning based algorithms. It shown LSTM and CNN producing highest performance accuracy but CNN Very less performance in other parameters Energy management and Network life than LSTM, DNN helps to manage energy level for network mobility, GRU also produces good in QoS Management.

6. CONCLUSION

for improving MANET Mobility adaptive routing and energy management, mainly through Deep learning based algorithms DNN, LSTM, GRU and Deep Reinforcement learning analysed with conventional algorithm and other DL based algorithm. Because they are Dynamic changing, mobility of nodes moving around and communicating in different ways in MANET, deep learning models look like a good way to solve these problems. Neural networks and different deep learning methods, such as ANN, CNN, RNN and Dual Reinforcement Learning, are very important for making MANETs smarter and better at learning on their own. By looking for trends and adapting to changes in the network, these methods help routing protocols choose the best routes, even when traditional algorithms fail. One important part of the study is to test these LSTM, GRU and DNN algorithms that use deep learning in a range of situations, such as those with different routing protocols, network scenarios, mobility models, and traffic volumes.

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