Deep Learning Driven Network Control

Abstract- Deep learning has been applied in applications to solve multiple issues and had enabled automation in vast variety of domains. The main reason of this extensive application of deep learning is the huge data availability, innovation in deep learning techniques and improvements in the computation techniques. Deep learning is now applied in the complex issues related to network operation and management. There are a few of surveys available that explain deep learning implementation in network control, however in this paper we target at some of the specific areas related to network control and how deep learning techniques can help in improving the network control and management. The main targeted areas are the network traffic, network optimization, network scheduling and routing, and mobile edge computing. Due to advancements in mobile networks, the network operation and management has become one of the key problem area.

Keywords—Deep Learning, Network Optimization, Network Security, Mobile Edge Computing, Network Traffic

I. INTRODUCTION

Deep learning has enabled systems to analyze the data in form of information and then deduce knowledge based on that to make decisions. It is different from the simple learning and knowledge extraction techniques as it utilize the knowledge to learn over time. The main objective of deep learning is identification and exploration of patterns in the collected data, which in turn help in extracting the unknown knowledge [1]. Deep learning is a drastic shift from traditional automation model, where the programs are coded to perform specific tasks. Deep learning has made the automation techniques much more flexible and resilient when applied in real world scenarios. They can be applied in the range of applications from complex to mundane. Application of deep learning in healthcare has achieved great results in the areas like medical imaging and computed based diagnosis. For mundane application, deep learning is applied in search engines for suggestion of queries, spelling correction, ranking of the searched pages and web indexes [2].

Clearly as the world is moving towards more and more automation, be it either home automation or automatic vehicles, deep learning is being applied in all aspects of our lives in making analysis and decisions. In addition to advancements in deep learning techniques, another major factor of such huge implementation of deep learning is the data availability. There is huge amount of data available over the network now a days and is expected to increase exponentially with latest networks for example Internet of Things (IoT) [3].

Latest advances in data computation have enabled the storage and processing requirements that can be used for verifying deep learning techniques on huge data sets. For an example cloud computing provide abundance of computing and storage resources. Graphic processing units (GPU) enable advanced training and the interfaces for huge amount of data [3]. Deep learning models can be used for the interface of low scale devices too for instance smartphones. However, with all these advancements, management of network is still problematic and network issues are widespread most often due to human error. Faults in network cost a lot of financial liability and tend to defame the network provider too. That is why now there is a need of strong automatic networks that are self-configuring, self-optimizing and self-protecting [4].

Even though there is a strong need of cognitive controlled network management, there are many challenges when applying deep learning in network operations. First, the every network structure is unique and there is not any uniform standardization across networks. A good example of this is the enterprise network, which vary from organization to organization. Hence, any deep learning patterns that work in one network cannot be feasible when applied on a different network. Secondly, the continuous evolving nature of network makes it difficult to have fixed set of rules and patterns for network management. Manual management and upgrade of network is not feasible due to continuous growth in network data and applications connected to it [5].

This survey is focused on automation of network control by using deep learning. The main areas that are focused in this paper are network traffic, network optimization, network scheduling and routing, and mobile edge computing. In network traffic control, we provide highlight of deep learning techniques when applied to control network traffic. In network optimization, we discuss an approach that is self-learning to optimize performance [6]. In the context of mobile edge computing, we discuss application of deep learning in mobile edge caching in order to enhance quality of experience.

The survey is structured as follows. Section II explains the background about the topic, targeting what deep learning is, how it works and the research already conducted for the application of deep learning in network control. Section III explains the implementation of deep learning in targeted areas of network control and management. Section IV discusses and analyzes the solutions and then the paper is concluded in section V.

www.ijcsi.org

II. BACKGROUND

Innovations in networking technology for example network programmability using SDN (Software Defined Networking) allows application of deep learning in networks. The challenges include, the decision regarding the categorization of data that shall be collected, the type of controlling activities for traditional networking devices. The cognitive nature of deep learning can be used for automating the network management and control and is one of the interesting research are that requires the understanding of deep learning techniques and the issues when these techniques are applied in networking [9].

Deep learning is a sub-branch of machine learning that enables the algorithms for making predictions and enable decision making without the need of being programmed explicitly [7]. A few of examples are the k-nearest neighbor classifier and Q-learning. The algorithms used in deep learning extract knowledge in a hierarchal manner by non-liner processing of raw data in multiple layers [8].

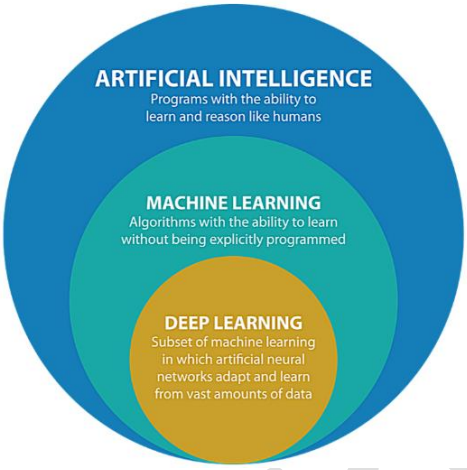

Fig. 1. Relationship between AI, ML and DL

Neural network is the most known deep learning model. Other examples of deep learning models include Gaussian processes [10], neural processes [11] and deep random forests [12].

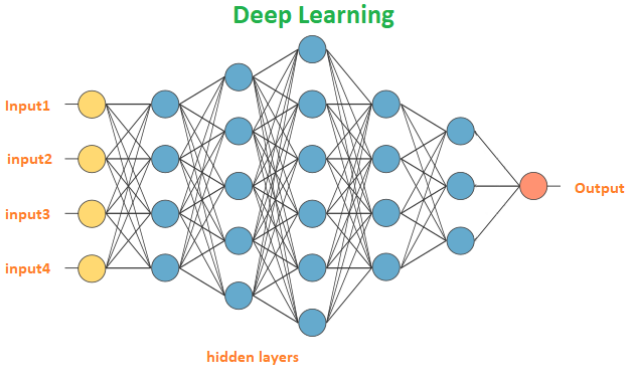

Fig. 2. Deep Learning Neural Network

Neural networks perform complex operations through basic operation units termed as neurons. The example of such complex operations may include images mapping, computation of future stock process, making decision of next chess move etc. These operations are performed based on the weighted combination using nonlinear functions based on the model structure. Neural networks are similar to the brain perceptive process where based on the situation specific neurons are activated to influence the human action or output [8].

Some research is already done in the domain of deep learning implementation for network management and operation. A learning framework based on spark was proposed by Alsheikh et al. for highlighting the advantages and issues to utilize big data in the domain of mobile analytics. Another research was done by Wang and Jones to highlight deep learning techniques for intrusion detection. To improve the QoE performance, a 5G network optimization framework was presented by Zheng et al.. Similar a research was conducted by Fadlullah et al., to understand deep learning areas in network traffic control. Ahad et al. explained the innovative techniques and guidelines that can be applied on the neural networks in wireless setup [8].

III. DEEP LEARNING IN NETWORK CONTROL AREAS

A. Deep Learning in Network Traffic

Now days due to huge network traffic, huge amount of data is generated and transmitted over the network and that is utilized in training the deep learning algorithms. Technology giants like Google, Facebook and Amazon are already investing in GPU accelerated deep learning initiatives. A few examples of such platforms to enhance real time packet processing are as follows:

1. TensorFlow: Prepared by Google, it is an open source platform allowing using CPU and GPU in scalable form
2. Torch: Provides efficient GPU support
3. Caffe: Convolutional Architecture for Fast Feature Embedding is applied in large-scale applications like network control [9]

Deep learning is also implemented in wireless networks over decades. Bayesian inference and Gaussian Process Regression are applied in WSNs. Neural networks and decision trees are used in WSNs, which are formed on small low cost sensor node used for collection of data from multiple sources like thermal, chemical or other data. K-nearest neighbor being a lightweight learning algorithm was also applied in WSN for query processing. In addition to supervised learning models, a few of unsupervised learning models can also be applied in WSN, mostly for node clustering, and to resolve challenges related to data aggregation. K-means clustering is one such example. Q learning is applied to resolve the issues of network traffic and routing [9].

Deep learning in network traffic classification is also a significant research area. It can be done by first identifying the local traffic at SDN edge switches. Network classification is then applied by the help of network controller. Network controller refine the quality of service policies on the information of network received. As the data flow through network traffic with the respective classification, the issue of protocol classification had resolved by deep neural networks [10].

Network flow prediction is also as important as network classification. Many deep learning algorithms are applied in this area too. Network traffic flow is actually the data packets sequenced together that are sharing the same context from source to destination. For the management of network resources the information regarding the burst size and the inter burst gaps is used. When talking about SDNS, the information of traffic flow is used for programming routers, scheduling network traffic etc. Auto-regressive moving average process is a deep learning process that can be used to estimate the packet size by performing packet sampling over the routers. Another deep learning method to predict network traffic is to gather the original frequency of the flow length by applying sparse packet sampling [9].

Social networks have now become the major area of research as now 5G network has emerged with better deep learning implementation. Understanding the user's behavior towards application and utilization is very important for network operators. Advertisement sites, online marketing and e-commerce sites use this information of users to improve the efficiency and recommending users the items of their interest. The patterns that are observed are time spent on an application, repeated visits, frequency of search of a particular item or application etc. These patterns are used to understand the search behavior of users. In one of research, a probabilistic model is presented to understand a user purchase history and the search history. The purpose of this work was to predict the user decisions in specific contexts and then presenting user appropriate recommendations. Deep learning methods are superior to standard machine learning models because of their ability to understand nonlinear relationship among the inputs [10].

B. Deep Learning in Network Optimization

With increase in the users of wireless network, the coverage and size are exponentially day-by-day. This huge numbers of users causing issues in accessing the network bandwidth and more network traffic cause the limited number of users may access to the information over the network. Simultaneously heterogeneous and multi-layered network structure, empower various network and manipulation of new transmission methods and increase the complexity of network model. Many researchers face problem when present and give solution for the optimization of the network performance such as the scale of the problem due to enlarge size of the network. Thus, proposing an efficient algorithm is now major task to resolve the network optimization problems. The Machine learning and deep learning algorithms maybe help to overcome those issues.

There are some existing algorithms too, which mainly covers the complexity problem. By using those algorithms, we over the complexity but not able to optimize the network and not able to utilize the fill network resources. Therefore, more efficient and flexible algorithms need to develop in this area. One more problem with the existing algorithms is that the huge computing power need which cause reducing in network speed and reduce the efficiency of network. To highlight all aspects and hidden connections between input and output we need to add deep learning in this complex network [10].

To get the better understanding and grasp all domain we give input to the deep learning algorithm to extract the information from the multiple processing layers. Deep belief net (DBN) is one of deep learning methods, which is projected by G. Hinton [11].

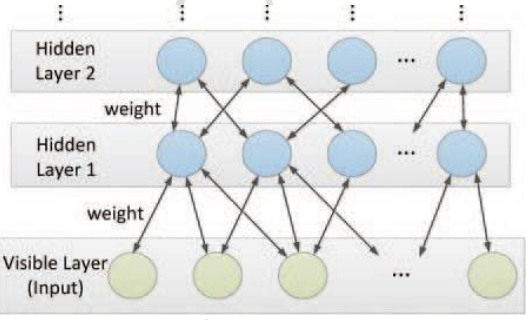

Fig. 3. DBN structure.

DBN can be formed through many hidden layers also known as 'stochastic hidden cause' and an input data visible layer. Data is communicating by different layers and different nodes, the data weight maybe vary from each node. DBN is trained to observe data in visible layer in result of data changes in hidden layers. By deep learning, we observe the behavior of data and predict some sample optimization rule, which may help full in further work. By the deep learning now the DBN able to learn itself in unsupervised conditions, in other words, now the model does not need more sample training data to learn further as shown in Fig, 3 and the featured output is collected on the result layer. However, whenever we need to fine-tune our algorithm and enhance the efficiency we again use the supervised classification learning method by adding some more layers to the solution. We need to apply back propagation (BP) fine-tuning to enhance the algorithm efficiency as shown in Fig 4. [12]

www.ijsr.com

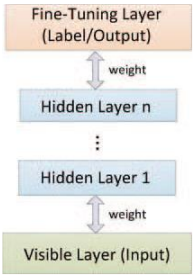

Fig. 4. DBN with BP fine-tuning

BP fine-tuning algorithm helps in regulating the the data of units and weights to compete every sample of the input to its matching label. On the bases of sample training, BP fine-tuning and DBN process work by learning the data within the weight of networks and the hidden layers. Later the data sample in the visible/ input layer can be changed to get the required output based on classification [12].

C. Deep Learning in Network Scheduling & Routing

Scheduling plays an essential role in the wireless infrastructures that is utilized by multiple users. This is because the quality of service (QoS) when there are many users involved is majorly relying on allocation of the radio resources. The scheduling issue is demonstrated as a Markov decision procedure. A deep reinforcement-learning agent can be employed to identify the user and the number of uninterrupted RBs per user shall be scheduled on every stage of RB assignment. This agent is also used for enhancing the energy at RSU. RSU is responsible for making a few of the decisions related to scheduling. This is useful for improving the lifetime of batteries and help in reduction of the latency involved in message transfer. Better scheduling lead to overall better quality of service in deep learning and enables RSU to perform optimum scheduling. RSUs no longer need to resolve the complex time consuming and optimization equations [5].

With the use of Deep Learning now, the resources are more efficiently used and all components are working together to product a single reliable output. The routing is not more need to supervise once the training is complete with the sample data. However, more variety of data needs to enhance the algorithms [6].

D. Deep Learning in Mobile Edge Computing

Exponential growth in mobile users has increased the mobile data usage and data consumption increases the cellular network traffic. The application services that provide mobile services like tracking, music, gaming, and video streaming are increased by large numbers of users. With this growth the network traffic, also increase with the significant numbers of mobile data users. Some researches estimates that this growth in cellular network the usage would exceed half a zettabyte by 2021. Now it become more complicated to handle all the requests and maintain the quality of experience (QoE). An efficient solution was provided to overcome this issue i.e., caching at the mobile edge to localize the network traffic. By using this technology, all the requests from macro base stations (MBSs), small base stations (SBSs) or even user equipment(s) (UEs) are handled locally. This successfully diminishes the reoccurrence of traffic over the network and significantly expands the quality of experience for mobile data users [8].

Fog computing and edge computing helps in stabling the nodes over the network edge, permits capability of storage and enhance the computing power. These technologies make possible to optimize the networks, analysis of big data and empower the deep learning in edge network. Deep learning in network enable to analyze the network patterns and give the idea to create the awareness of context as well as the intelligent ways to cache mobile edge. Context awareness is responsible to make every cache server aware about the environment in which it is functioning. However, the intelligence in caching allows the servers in improving decision making regarding selection of contents that shall be cached. [12].

To enhance the usage of redundant data over the network we need to decide to locate the caching device and synchronization every reused information on those caching devices. Thus, we need to introduce the smart network rather than to use the traditional network which every time request the main server to fulfill the request. The closest sync node is use to get the latest information and request is serve accordingly. The limitations in the capacity backhaul links possibly can be congested because of recurring transmissions and that lead to bad quality of experience to end users. In order to avoid this issue, contents shall be cached at the BS. BS are also better option because they are low cost units. With the introduction of 5G network and device-to-device communication resolve the problems of storage, make the communication faster and the assurance of data delivery. MBSs, SBSs, and UE can all be used to cache the contents [4].

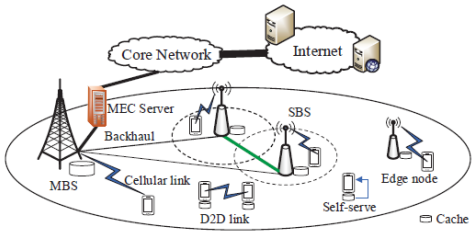

Fig 5. Mobile Edge Caching - Architecture

Implementation of intelligence and the context awareness in caching over mobile edge is complex since it enables the edge nodes to learn based on stored data. Edge notes become capable of making decisions based on cached data like forecasts etc. With enabling of Reinforcement Learning RL agent, the nodes are able to observe the network trends, based on the observation take action if needed rather than to ping the server, active the network topology and nodal mobility to overload the network. This will increase the QoE and offload the network [8].

www.ijsr.net

IV. DISCUSSION AND ANALYSIS

Deep learning has been utilized for network control and management operations for example controlling and managing network traffic, optimizing the performance of network traffic, scheduling and routing, and mobile edge computing. The increased advancements in the network traffic highlights the need of time to implement such solutions in networking that are self-operating based on the situation and avoid the need of specific coding.

TABLE I. IMPACT OF DEEP LEARNING ON NETWORK CONTROL

Network Domain	**Benefits/ Advancements**
Deep Learning in Network Traffic Control	- Optimizes network traffic - Allow effective management of network traffic - Better network prediction lead to better network management - Increased overall performance - Better decision making and recommendations for social network users
Deep Learning in Network Optimization	- Better utilization of resources - Minimum network monitoring - Increased performance - Reduced complexity due to multi-layer architecture - Flexible and scalable network
Deep Learning in Network Scheduling and Routing	- Energy optimization - Minimize latency - Quality of Service - Rapid decision making - Fast processing of complex and endless problems
Deep Learning in Mobile Edge Computing	- Enhanced performance - Better computing power - Quick responses - Context awareness - Allow forecasting and prediction - Improved Quality of Experience

V. CONCLUSION

Fast growing internet and mobile communication has led to complex, heterogeneous and dynamic networks. Better switching capabilities has made core networks larger. Routers that are having effective radio links are used in wireless networks and hence the network system becomes complex. This complexity has overall led to many challenges related to operation, management and maintenance of network traffic. Smart devices additional have added on the data over the network because of extensive mobile users, social media sites etc. The current network guidelines and policies cannot cope with this continuous changing structure and data on the network along with the enormous growth in networks and data. Incorporation of intelligence is network control is the utmost need today to improve and guarantee Quality of Service in networks. Deep learning algorithms when applied in network operation and management have handled many network related issues. Deep learning has made the network operations self-configuring, self-optimizing and self-operating.

REFERENCES

[1] Zhang, C., Patras, P. and Haddadi, H., 2019. Deep learning in mobile and wireless networking: A survey. *IEEE Communications surveys & tutorials*, *21*(3), pp.2224-2287.

[2] Meng, Z., Wang, M., Bai, J., Xu, M., Mao, H. and Hu, H., 2020, July. Interpreting deep learning-based networking systems. In *Proceedings of the Annual conference of the ACM Special Interest Group on Data Communication on the applications, technologies, architectures, and protocols for computer communication* (pp. 154-171).

[3] Cheng, Y., Yin, B. and Zhang, S., 2021. Deep Learning for Wireless Networking: The Next Frontier. *IEEE Wireless Communications*.

Yu, J., Hao, X., Xie, H., & Yu, Y. (2020, August). Fair

[4] Zappone, A., Di Renzo, M. and Debbah, M., 2019. Wireless networks design in the era of deep learning: Model-based, AI-based, or both?. *IEEE Transactions on Communications*, *67*(10), pp.7331-7376

[5] Sarao, P., 2019. Machine learning and deep learning techniques on wireless networks. *International Journal of Engineering Research and Technology*, *12*(3), pp.311-320.

[6] Mohammed, A.R., Mohammed, S.A. and Shirmohammadi, S., 2019, July. Machine learning and deep learning based traffic classification and prediction in software defined networking. In *2019 IEEE International Symposium on Measurements & Networking (M&N)* (pp. 1-6). IEEE.

[7] Wani, M.A., Bhat, F.A., Afzal, S. and Khan, A.I., 2020. *Advances in deep learning*. Springer.

[8] Ahmad, J., Farman, H. and Jan, Z., 2019. Deep learning methods and applications. In *Deep Learning: Convergence to Big Data Analytics* (pp. 31-42). Springer, Singapore.

[9] Luong, N.C., Hoang, D.T., Gong, S., Niyato, D., Wang, P., Liang, Y.C. and Kim, D.I., 2019. Applications of deep reinforcement learning in communications and networking: A survey. IEEE Communications Surveys & Tutorials, 21(4)

[10] Zhang, C., Patras, P. and Haddadi, H., 2019. Deep learning in mobile and wireless networking: A survey. *IEEE Communications surveys & tutorials*, *21*(3), pp.2224-2287.

[11] Sun, R.Y., 2020. Optimization for deep learning: An overview. *Journal of the Operations Research Society of China*, *8*(2), pp.249-294.

[12] Wang, F., Wang, F., Liu, J., Shea, R. and Sun, L., 2020, July. Intelligent video caching at network edge: A multi-agent deep reinforcement learning approach. In IEEE INFOCOM 2020-IEEE Conference on Computer Communications (pp. 2499-2508). IEEE.

Working