ARTIFICIAL INTELLIGENCE FOR 5G ADVANCED WIRELESS NETWORKS

S. Selvakumar[1], Mary Selvan[2], Sumit Chaudhary[3], Gumpina Babu Rao[4], Sonia Maria D'Souza[5], Ashok Kumar[6]

[1]Department of Computer Science and Engineering, Aarupadi Veedu Institute of Technology, Vinayaka Mission Research Foundation, Salem, Tamil Nadu 636308, India. **selvakumar.avcs085@avit.ac.in**

[2]Department of Artificial Intelligence and Data Science, R M K College of Engineering and Technology, Thiruvallur, Tamil Nadu 601206, India. **maryselvanads@rmkcet.ac.in**

[3]School of Computer Science and Artificial Intelligence, Trans Stadia University, Kankaria, Ahmedabad, Gujarat 380022, India. **drchaudharysumit@gmail.com**

[4]Department of Computer Science, GITAM School of Science, Gandhi Institute of Technology and Management, Visakhapatnam, Andhra Pradesh 530045, India. **baburaogumpina74@gmail.com**

[5]Department of Artificial Intelligence and Machine Learning, New Horizon College of Engineering, Bengaluru, Karnataka 560103, India. **s1985md@gmail.com**

[6]Department of Computer Science, Banasthali Vidyapith, Rajasthan 304022, India. **kuashok@banasthali.in**

Abstract:- A new wireless radio technology paradigm is needed for next-generation wireless networks to accommodate extraordinarily high data rates and fundamentally new applications. The difficulty is in helping the radio to make intelligent, adaptive learning and decision-making decisions so that the many needs of next-generation wireless networks may be met. One of the most promising artificial intelligence methods, machine learning was developed to assist smart radio terminals. Future intelligent 5G mobile terminals are anticipated to employ sophisticated spectral efficiency learning and inference to autonomously access the most advantageous spectral bands, rely on energy efficiency learning and inference to control transmission power, and simultaneously adjust the transmission protocols using quality of service learning and inference. Therefore, we quickly go through the fundamental ideas of machine learning and suggest using them in the compelling 5G network applications, such as cognitive radios, massive MIMOs, femto/small cells, heterogeneous networks, smart grids, energy harvesting, device-to-device communications, and so on. In order to access hitherto untapped applications and services, our aim is to help readers improve the motivation, issue formulation, and technique of potent machine learning algorithms in the context of future networks.

Keywords:- Artificial Intelligence, 5G Networks, Machine Learning, Framework and Speed

1. INTRODUCTION

Currently in use are wireless communication networks of the fifth generation (5G), and networks of the sixth generation (B5G) are anticipated to be built during the next ten years. By using the massive volumes of data required for B5G, machine learning (ML) and other artificial intelligence (AI) technologies have the ability to effectively handle the unstructured and apparently intractable difficulties. This article investigates the use of AI and ML in the planning and management of B5G networks. We first provide a thorough overview of current developments and upcoming difficulties caused by integrating AI/ML technology into B5G wireless networks.

The path of overall telecommunications growth is presently being determined by fifth-generation telecommunication networks. In addition, fifth-generation communications networks' operational operations are orders of magnitude more complicated than those of present networks. To maintain the steady operation of communications networks, new technologies, such as artificial intelligence, are required. The scientific tasks for the fifth generation of communication networks that appear to call for the application of machine and deep learning seem to be recognised. Practical relevance The work's findings may be used to new research assignments for PhD students as well as to the teaching of networks and communications systems [1]-[5]. Through study and invention, wireless mobile communication technology has significantly developed over the years. It is now possible to link many wireless communication networks, applications, and technologies at once. 5G is the most recent technology. The next generation of wireless communication networks is known as 5G, or fifth generation mobile communication technology. Beyond the present 4G standard, 5G is the next phase in the evolution of mobile communications. There will be a new revolution in the mobile industry that will transform how cell phones are used in areas with extremely high bandwidth. The user has never experienced such high-value technology with so many cutting-edge features, and 5G technology will soon be the most potent and in great demand. It pushes us beyond only designing networks for mobile devices and into high-speed systems that link various device kinds [6]-[10] .

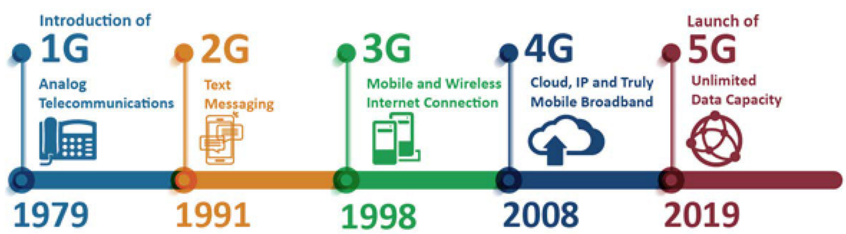

Figure.1. Evolution of Networks

2. ARTIFICIAL INTELLIGENCE

5G network developments will be extensive, multi-layered, very complex, dynamic, and diverse. Additionally, 5G networks need to analyse a lot of data produced by physical settings, maintain seamless connection, and ensure multiple QoS needs of various devices. AI techniques that have strong analytical capabilities, learning capabilities, optimization capabilities, and intelligent recognition capabilities can be applied in 5G networks to intelligently improve performance in areas such as knowledge discovery, complex learning, organisational structure, and complex decision-making. The goal of the computer science subfield known as artificial intelligence is to build "intelligent machines." a crucial element required to interpret the enormous volume of data generated these days and raise its worth to the company. Data preparation, data discovery, stream data visualisation, time-series data correctness, predictive and advanced analytics, as well as real-time geolocation and location data analysis will all benefit from AI (logistic data) [11]-[13].

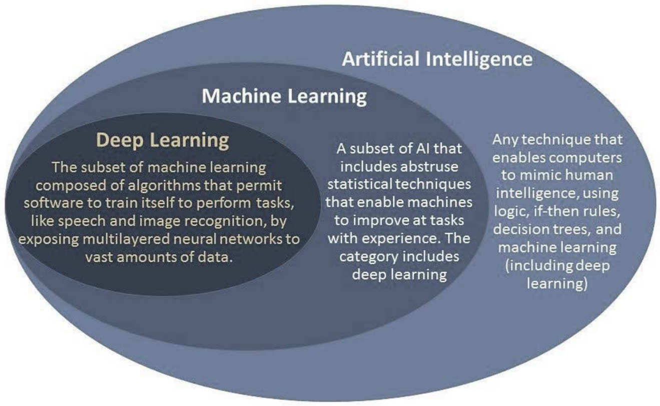

Figure.2. Artificial Intelligence

The use of optimization is also necessary for the next generation of wireless and mobile communication technologies in order to minimise or maximise some objective functions. It is necessary to approximate a number of nonlinear or non-polynomial problems in mobile and wireless communications. Artificial neural networks (ANN) are an AI method that have been proposed to model the objective function of the non-linear optimization problem.
Deep learning is a subset of machine learning (ML) that applies the machine learning process using the artificial neural network's hierarchical structure. Artificial neural networks, which are made of neural nodes connected in a network to resemble the human brain, are constructed. While traditional programmes construct data analysis in a linear manner, deep learning systems' hierarchical functionality enables machines to process data in a non-linear manner. When analysing data for use in decision-making, deep learning uses AI to simulate how the human brain works. Unstructured data may be used for deep AI learning.

Because of the expanding number of wireless users and newly developed wireless services, there is an increasing need for wireless communication networks on a global scale. In the future, it is anticipated that fifth generation (5G) and beyond fifth generation (B5G) wireless networks will be created. These networks will provide greater data speeds, better coverage, better cost efficiency, better resource usage, security, flexibility, and scalability . In the construction and optimization of 5G and B5G wireless networks, unstructured and apparently unsolvable challenges involving massive volumes of data must be addressed. Artificial intelligence (AI) technologies have the ability to do this effectively. Artificial intelligence (AI) is "the imitation of human cognitive processes by computers, particularly computer systems. The science of having computers execute jobs that need intellect on par with humans is how it is often characterised. Machine learning (ML), a modern (and perhaps the most prominent) application of AI, allows computers to learn from vast quantities of data and respond appropriately without being explicitly programmed, although AI is a larger idea of robots being able to carry out tasks intelligently. Deep learning is a specific sort of machine learning (ML) that examines artificial neural networks (ANNs) with several hidden layers to "simulate" the human brain. Deep learning is now one of the most popular ML techniques because to its effectiveness in a variety of industries, including computer vision, voice recognition, and bioinformatics.

By making real-time, robust decisions based on predictions of the networks and users' behaviour, AI technologies will not only reduce or even completely replace manual efforts for network development, configuration, and management, but they will also improve system performance, reliability, and adaptability of communication networks. It is anticipated that ML, a typical AI technology, would quickly take centre stage in B5G communication networks. Big data will be fully used to meet the problems of creating and running B5G networks. The following are potential advantages of ML integration in communication systems. First off, owing to the dynamic nature of wireless communication channels, particularly in B5G situations, channel and interference models are exceedingly complex in practise. By studying communication data and existing knowledge, machine learning algorithms may automatically extract information from unknown channels. Second, there is an urgent need for worldwide optimization of communication resources and fine adjustment of system parameters as the density of wireless access points keeps rising. However, these jobs are notoriously difficult to complete using current methods due to the vast quantity of resources, system parameters that must be adjusted, and their associated correlations. On the other hand, complex machine learning (ML) algorithms, such as deep learning and probabilistic learning techniques, may be able to describe the highly nonlinear relationships and predict (sub-)optimal system parameters. Finally, by identifying behavioural patterns and responding quickly and adaptably to diverse circumstances, such as predicting traffic and making plans ahead of time rather than just responding to unforeseen occurrences, ML will accomplish learning-based adaptive design of networks.

The 5G communication networks have incorporated massive MIMO technology. It is one of the most straightforward applications of AI. Massive MIMO may generate a lot of data despite its numerous benefits, including spectrum efficiency, energy economy, security, and durability. For instance, a gigantic MIMO system with 3256 antennas and 100 MHz bandwidth may generate data greater than 32 Gbyte in channel measurements. For vast MIMO systems, both detection and channel estimation are often laborious procedures that need a lot of computer resources. Massive MIMO's ability to handle large amounts of data prompts academics to consider ML techniques. The vast quantity of data produced by massive MIMO systems is represented by big random matrices and is subjected to single ring law analysis. Pilot contamination is one of the problems of huge MIMO systems, and it may have a big effect on how well they work. Pilot contamination may prevent systems from obtaining precise CSI data because it results from pilot interference between nearby cells.

3. 5G NETWORKS

Channels in beamspace become roughly sparse as the number of antennas rises; in other words, the majority of the MPC power comes from a few number of pathways that have congregated into clusters in the space, and the channel matrix only has a few nonzero components. The use the sparse Bayesian learning approach to derive the CSI of large MIMO systems based on the sparsity characteristic of channels in beamspace. The Bayesian learning approach may perform better in terms of pilot contamination than the traditional CSI estimators. For Bayesian compressive sensing, the sparse recovery issue is a crucial area of study. From a collection of noise-free data, it seeks to estimate a non-negative compressible vector. We describe a family of neural networks that, in general, are instruments for non-linear statistical data modelling and decision-making. They are frequently used to identify patterns in data or to model complex relationships between a system's input and output parameters. This family includes convolutional neural networks, deep neural networks, recurrent neural networks, and feed-forward neural networks. Reinforcement learning is concerned with the actions that intelligent agents must take to maximise a collective reward, such as to enhance a system property. Deep neural network-based reinforcement learning combines deep neural networks and has the advantage of being able to work with unstructured data. The use of combined analytical and machine learning modelling as well as machine learning assisted by expert knowledge are examples of hybrid solutions that are presented. Other specific approaches, including generative adversarial networks, unsupervised learning, and clustering, are presented in the final section.

In the follow-up 5G paper, use case and optimization issues that are being addressed with AI/ML are further discussed. These issues are divided into three main categories: I network planning; ii) network diagnostics/insights; and iii) network optimization and control. Attention is being paid to AI/ML assisted planning solutions in network planning. Parallel layers of connectivity are thought to be a trend towards disaggregated deployments, in which a base station is distributed over a set of separate physical network elements. This results in the growing number of services and network slices that need to be operated as B5G networks become more complex and multi-dimensional. Traditional network planning methods must be replaced with automated techniques that can use AI/ML to inform planning decisions as a result of the network's increasing complexity. In this regard, two solutions are discussed. First, the network element placement problem is introduced, with the goal of improving the identification of the ideal constellation of base stations, each located to provide the best network performance while taking into account a variety of factors, such as coverage, user equipment (UE) density and mobility patterns (estimations), necessary hardware and cabling, and overall cost. The dimensioning considerations for C-RAN clusters are the second issue that is taken into account in this regard. To address this issue, ML-based algorithms are used to provide the best baseband unit (BBU) function allocation (to the proper servers hosted by the central unit (CU)), resulting in the expected gains.

In Network Diagnostics, emphasis is placed on the tools that can independently examine the network condition and set off alerts as needed. The contributions are broken down into three categories: solutions for network characteristic predictions, exact user localisation techniques, and detection and forecasting of security incidents. Among the network characteristic forecasting techniques discussed are the use of AI/ML methods for high-resolution synthesising and effective forecasting of mobile traffic, QoE inference and QoS improvement through forecasting techniques, service level agreement (SLA) prediction in multi-tenant environments, and complex event recognition and forecasting. On the topic of high-precision user localization, we present 5G localization based on soft information and sequential autoencoding, as well as AI-assisted sensor fusion and line-of-sight (LoS)/non-line-of-sight (NLoS) discrimination. Finally, ML-based network traffic inspection and real-time detection of distributed denial-of-service (DDoS) assaults are briefly discussed in the section on anticipating security events following a quick introduction to contemporary attacks in mobile networks.

Because of the expanding number of wireless users and newly developed wireless services, there is an increasing need for wireless communication networks on a global scale. In the future, it is anticipated that fifth generation (5G) and beyond fifth generation (B5G) wireless networks will be created. These networks will provide greater data speeds, better coverage, better cost efficiency, better resource usage, security, flexibility, and scalability . In the design and optimization of 5G and B5G wireless networks, unstructured and seemingly unsolvable problems involving large amounts of data must be addressed. Artificial intelligence (AI) technologies have the potential to do this effectively. Artificial intelligence (AI) is "the simulation of human cognitive processes by machines, particularly computer systems". The science of making computers perform tasks that require intelligence on par with humans is how it is typically defined. Machine learning (ML), a current (and arguably the most popular) application of AI, allows machines to learn from vast amounts of data and act accordingly without being explicitly programmed, whereas AI is a broader concept of machines being able to carry out tasks intelligently. Deep learning is a specific sort of machine learning (ML) that examines artificial neural networks (ANNs) with several hidden layers to "simulate" the human brain. Deep learning is currently one of the most popular ML techniques due to its success in a variety of industries, including computer vision, speech recognition, and bioinformatics.

By making real-time, robust decisions based on predictions of the networks and users' behaviour, AI technologies will not only reduce or even completely replace manual efforts for network development, configuration, and management, but they will also improve system performance, reliability, and adaptability of communication networks. It is anticipated that ML, a typical AI technology, will quickly take centre stage in B5G communication networks. Big data will be fully utilised to meet the challenges of designing and running B5G networks. The following are potential advantages of ML integration in communication systems. First off, due to the dynamic nature of wireless communication channels, especially in B5G scenarios, channel and interference models are extremely complex in practise. The slicing in multi-tenant networks, radio resource provisioning and traffic steering, user association, demand-driven power allocation, joint MAC scheduling (across several gNBs), and propagation channel estimation and modelling are just a few of the applications of AI/ML in radio access that are discussed. Additionally, these solutions are divided into real-time, near-real-time, and non-real-time groups based on the application time-scale. The introduction of AI/ML algorithms for traffic management (using programmable switches), dynamic load balancing, effective per-flow scheduling, and ideal FH/BH functional splitting on transport and FH/BH networks. Other AI/ML applications for virtualization infrastructure include resource allocation for service function chaining, federated learning across MEC and NFV orchestrators, and dynamic resource allocation in NFV infrastructure. Applications for resource reservation (proactively in E2E slice) and resource allocation (jointly with slice-based demand prediction), slice isolation, and slice optimization are all discussed in the context of E2E slicing. Regarding network security, the use of AI/ML techniques in defending against attack incidents is discussed for two cases, namely moving target defence for network slice protection and self-protection against app-layer DDoS attacks. The dash prefetching optimization and Q-learning applications in federated scenarios are presented as the final two AI/ML applications in application function optimization.

4. CONCLUSION

The discussion of how AI and ML are applied to the 5G and B5G network architectures is covered in more detail in the 5G paper. This context includes the presentation of AI/ML-based solutions for autonomous slice management, control and orchestration, cross-layer optimisation framework, anomaly detection, management analytics, as well as aspects of AI/ML-as-a-service in network management and orchestration and ML enablement for the verticals' domain. The management of ML models and functions, specifically the training, monitoring, evaluation, configuration, and interface management of ML models, are covered after this. The paper also looks into standardisation efforts to enable AI/ML in networks, including the 3GPP definition of network data analytics function (NDAF), the ETSI ENI definition of categories of use cases where AI may help with network operation and management, the definition of an architecture to address challenges in network automation and optimization using AI, and finally the O-RAN definition of non-real-time and near-real-time RAN coexistence.

The paper also identifies the problems with privacy and trust in AI/ML-based networks, and it suggests possible solutions by introducing privacy-preserving mechanisms and the zero-trust management approach. The 5G paper concludes with a brief overview of AI/ML-based KPI validation and system troubleshooting. The 5G paper discusses the availability of reliable data sets as a crucial prerequisite to the efficiency of AI/ML algorithms. The most advanced cellular connectivity technology today is 5G. This incredibly fast generation offers smartphones, machines, and vehicles with flexible, unmatched control. It represents a fresh approach to enhancing lifestyle through quick access, low latency, and real-time communication. However, 5G networks pose a number of difficulties at high frequencies, including distortion and multi-path propagation, air-interface issues like crosstalk, reflection, fading, EVM, cell-interference, jamming, etc. This paper discussed these difficulties, their current remedies, and the necessary machine learning methods. Numerous novel technologies were introduced to improve the spectral efficiency of the channel. To lessen crosstalk problems in the physical layer, the advantages of CRKG techniques, the IPL model, the heuristic algorithm, PCA, and CASC schemes were discussed. We also discussed PHY-SI and its various capabilities for preventing unauthorised access and shielding the channel from eavesdroppers. The reader was also made aware of difficulties with eMBB, uRLLC, and mMTC use cases as well as 5G supporting technologies that make use of AI, machine learning, and deep learning tools. We have looked into how AI and ML can be applied in this article to effectively tackle the unstructured and ostensibly insurmountable issues in the upcoming B5G wireless communication networks. Including channel measurements, modelling, and estimation, physical-layer research, network management, and optimization, a thorough overview of recent developments in the integration of AI/ML and wireless networks has been provided. The difficulties and potential directions for further research have been discussed. The use of AI algorithms in B5G networks has been introduced. A summary of research being done by standard organisations and study groups on using AI and ML to B5G systems has also been given.

REFERENCES

[1] H. He, C.-K. Wen, S. Jin, and G. Y. Li, “Deep learning-based channel estimation for beamspace mmWave massive MIMO systems,” IEEE Wireless Commun. Lett., vol. 7, no. 5, pp. 852–855, Oct. 2018.

[2] H. Tang, J. Wang, and L. He, “Off-grid sparse Bayesian learning based channel estimation for mmWave massive MIMO uplink,” IEEE Wireless Commun. Lett., vol. 8, no. 1, pp. 45–48, Jan. 2019.

[3] Y. Li, Y. Zhang, X. Huang, H. Zhu, and J. Ma, “Large-scale remote sensing image retrieval by deep hashing neural networks,” IEEE Trans. Geosci. Remote Sens., vol. 56, no. 2, pp. 950–965, Feb. 2018.

[4] P. Sure, C. N. Babu, and C. M. Bhuma, “Applicability of big data analytics to massive MIMO systems,” in Proc. IEEE INDICON’16, Bangalore, India, Dec. 2016, pp. 1–6.

[5] X. Gao, L. Dai, and A. M. Sayeed, “Low RF-complexity technologies to enable millimeter-wave MIMO with large antenna array for 5G wireless communications,” IEEE Commun. Mag., vol. 56, no. 4, pp. 211–217, Apr. 2018.

[6] C. K. Wen, S. Jin, K. K. Wong, J. C. Chen, and P. Ting, “Channel estimation for massive MIMO using Gaussian-mixture Bayesian learning,” IEEE Trans. Wireless Commun., vol. 14, no. 3, pp. 1356–1368, Mar. 2015.

[7] B. K. Donohoo et al., “Context-Aware Energy Enhancements for Smart Mobile Devices,” IEEE Trans. Mobile Comput., vol. 13, no. 8, Aug. 2014, pp. 1720–32.

[8] C.-K. Wen et al., “Channel Estimation for Massive MIMO Using Gaussian-Mixture Bayesian Learning,” IEEE Trans. Wireless Commun., vol. 14, no. 3, Mar. 2015, pp. 1356–68.

[9] K. W. Choi and E. Hossain, “Estimation of Primary User Parameters in Cognitive Radio Systems via Hidden Markov Model,” IEEE Trans. Signal Process., vol. 61, no. 3, Feb. 2013, pp. 782–95.

[10] A. Assra, J. Yang, and B. Champagne, “An EM Approach for Cooperative Spectrum Sensing in Multi-Antenna CR Networks,” to appear in IEEE Trans. Veh. Technol.; DOI: 10.1109/TVT.2015.2408369, 2015.

[11] C.-K. Yu, K.-C. Chen, and S.-M. Cheng, “Cognitive Radio Network Tomography,” IEEE Trans. Veh. Technol., vol. 59, no. 4, May 2010, pp. 1980–97.

[12] M. Xia et al., “Optical and Wireless Hybrid Access Networks: Design and Optimization,” OSA/IEEE J. Opt. Commun. Netw., vol. 4, no. 10, Oct. 2012, pp. 749–59.

[13] R. C. Qiu et al., “Cognitive Radio Network for the Smart Grid: Experimental System Architecture, Control Algorithms, Security, and Microgrid Testbed,” IEEE Trans. Smart Grid, vol. 2, no. 4, Dec. 2011, pp. 724–40.