Ajay Damor, 2025, 13:5
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science, Engineering and Technology
An Open Access Journal

Novel Approach to Implementation of Channel Estimation in 6g Spectrum by Using Noma and Artificial Intelligence Hybrid Technique

Ajay Damor, Dr Nidhi Tiwari (Associate Professor)
And Prof Madhavi S Bhanwar (Assistant professor)
Department of Electronics and Communication Engineering, SAGE University, Indore

Abstract- The emergence of sixth-generation (6G) wireless networks demands highly efficient spectrum utilization and robust communication strategies to support ultra-reliable, low-latency, and high-capacity services. One of the critical challenges in 6G is accurate channel estimation, especially in dense user environments where spectrum resources are limited. This paper proposes a novel hybrid approach for channel estimation that integrates Non-Orthogonal Multiple Access (NOMA) with Artificial Intelligence (AI)-driven algorithms. The NOMA framework enables simultaneous multi-user transmission within the same spectrum band, thereby enhancing spectral efficiency, while the AI-based module leverages deep learning and reinforcement learning models to perform adaptive and dynamic channel estimation under varying propagation conditions. The proposed methodology not only minimizes estimation errors but also reduces computational complexity compared to conventional estimation methods. Simulation results demonstrate significant improvements in spectral efficiency, bit error rate, and overall system throughput, validating the potential of the AI–NOMA hybrid approach for next-generation wireless networks. This work highlights the importance of intelligent channel estimation techniques in realizing the performance requirements of 6G communication systems.

Keywords: 6G MIMO, channel estimation, interference alignment, heterogeneous network, deep learning, OFDM, resource allocation.

I. INTRODUCTION

The fifth generation (5G) wireless communication networks are being standardized and deployed worldwide from 2020. The three major communication scenarios of 5G are enhanced mobile broadband (eMBB), massive machine type communications (mMTC), and ultra-reliable and low latency communications (uRLLC). The key capabilities include 20 Gbps peak data rate, 0.1 Gbps user experienced data rate, 1 ms end-to-end latency, supporting 500 km/h mobility, 1 million devices/km2 connection density, 10 Mbps/m2 area traffic capacity, 3 times spectrum efficiency, and 100 times energy efficiency compared to the fourth generation (4G) wireless communication systems. Various key technologies such as the millimeter wave (mmWave), massive multiple-input multiple-output (MIMO), and ultra-dense network (UDN) have been proposed to achieve the goal of 5G [1]. However, 5G will not meet all requirements of the future in 2030+. Researchers now start to focus on the sixth generation (6G) wireless communication networks. One of the main distinguishing features of 5G is low latency or more specifically guaranteed (deterministic) latency, which needs deterministic networking (DetNet) to guarantee end-to-end latency with punctuality and accuracy that future use cases demand.

The 6G will have additional requirements of high time and phase synchronization accuracy beyond what 5G can deliver. Additionally, 6G will have to provide near 100% geographical coverage, sub-centimeter geo-location accuracy and millisecond geo-location update rate to meet use cases. As 5G networks are still limited to some typical scenarios, remote areas such as villages and motorways are not well covered, which limits some applications such as driverless vehicles. Non-terrestrial and specifically satellite communication networks are needed to complement the terrestrial networks for cost-effective, seamless, and ubiquitous service availability.

Unmanned aerial vehicle (UAV) communication network is important for fast response in harsh and difficult environments.

Maritime communication network is needed to provide ships with high quality communication services. While mmWave can provide Gbps level transmission data rate in 5G, Tbps level transmission data rate will be needed for applications such as high quality three-dimensional (3D) video, virtual reality (VR), and mix of VR and augmented reality (AR), where teraherhz (THz) and optical frequency bands can be candidate bands. Faced with the big datasets generated by using extremely heterogeneous networks, diverse communication scenarios, large numbers of antennas, wide bandwidths, and new service requirements, 6G networks will enable a new range of smart applications with the aid of artificial intelligence (AI) and machine learning (ML) technologies.

One automation level is for improving the network performance itself in many aspects, for example, quality of service (QoS), quality of experience (QoE), security, fault management, and energy efficiency. Up to 5G, traffic on the network is dominated by video or streaming applications. Besides all applications and requirements mentioned above, we can learn from 5G tactile Internet applications [2] that wireless networked control of robotic objects (as e.g., automated driving or factory logistics) is a new exciting application for cellular technology, but this also generates new challenges. When analyzing the network traffic generated by these applications, many mobile objects must share sensor as well as control information, which overburdens a centralized control system. Instead, distributed control systems using AI are becoming a focus in research and development.

In particular federated learning shows to be a promising approach, where dataset correlation algorithms are distributed over mobile robotic objects and aggregated learning happens over the cloud. Interestingly, this generates a completely new class of network traffic, with large bandwidth and widely varying latency demands. It is highly likely to assume that these and equivalent AI applications will not only overtake but dominate the network traffic demands of 6G.

This is untouched soil, which makes it exciting and very challenging at the same time! In comparison with the 5G network, 6G wireless communication networks are expected to provide much higher spectral/energy/cost efficiency, higher data rate (Tbps), 10 times lower latency, 100 times higher connection density, more intelligence for full automation, sub-centimeter geo-location accuracy, near 100% coverage, and sub-millisecond time synchronization. New air interface and transmission technologies are essential to achieve high spectrum efficiency and energy efficiency, including new waveforms, multiple access approaches, channel coding methods, multi-antenna technologies, and proper combination of all these diversity techniques. In the meanwhile, novel network architectures are needed, for example, software defined network/network functions virtualization (SDN/NFV), dynamic network slicing, service-based architecture (SBA), cognitive service architecture (CSA), and cell-free (CF) architectures.

However, softwarization comes at a cost, as we can learn from 5G deployment. The use of commercial off-the-shelf (COTS) servers versus domain specific chips in a virtualized radio access network (RAN) implies a large increase in energy consumption, countering measures for improving energy efficiency. This results in the current fact that 5G networks consume more power than 4G networks, but of course at a delivery of a higher bandwidth. In contrast, we should deliver networks that at the time of their introduction do not exceed the previous generation’s power needs. For 6G we therefore will require a new computing paradigm to support all benefits of softwarization without bearing the costs of energy consumption.

II. 6G-STANDARD

With 5G availability fast expanding worldwide and a “mid-generation” evolution cycle anticipated in 3GPP Release-18, now is the right time to lay down the foundations for the next generation, global 6G standard. MediaTek has played a leading role in the design, standardization and ongoing evolution of 5G. It has led the way in bringing to the market mature 5G devices that can operate in new groundbreaking 5G systems (i.e. both Radio and Core).

As the world's leading smart phone chip supplier1 and an undisputed 5G commercial product leader, Media Tek is in a prime position to define and drive the vision and realization of next generation mobile technologies for 6G. 5G was engineered and has evolved around three core sets of use cases: enhanced mobile broadband (eMBB), ultra-reliable & low-latency communications (URLLC) and massive machine-type communications (mMTC). It has been purpose-built not only to embrace the mobile broadband revolution unleashed by 4G in the consumer space, but also to enable new growth opportunities beyond this market. Capitalizing on the foundations laid by 4G evolution into the cellular IoT market, 5G took a further, more significant leap to address the stringent requirements of industrial IoT.

5G has been conceived to bring the transformative power of mobile communications into every sector of our society; for the first time ever, a single communication system was designed not only to cater for a very diverse range of consumer and professional use cases in licensed and unlicensed spectrum, across sub-6 GHz and mmW bands, but also to provide connectivity beyond the traditional reach of terrestrial networks through airborne and satellite infrastructure that altogether integrates seamlessly. However, this ambitious design has translated into significant complexity for both networks and devices, leading to higher deployment costs and power consumption. As a result, the 5G rollout has been incremental, focusing mostly on eMBB consumer applications, in sub-6 GHz. Achieving ubiquitous mmW coverage has been a challenge, especially from network economic perspectives.

Further, while it is encouraging to see the rise of open RAN architecture coming together for 5G deployments to bring more flexibility and intelligence, the fundamental network design is still based on traditional mobile networks and layering. Significant enhancement will be expected to drive the architecture into the age of artificial intelligence and machine learning. While industry continues to evolve current 5G technology to address the aforementioned challenges, 6G technology is on the horizon to not only address these issues but also to bring fundamental transformation to mobile networks. Our 6G vision is of one global standardized technology to significantly outclass 5G and its evolution from the outset. 6G will deliver extreme performance using native adaptive radio and networking technologies that can support consumer and professional markets with diverse data consumption models, in a fully secure and sustainable manner.

III. SYSTEM MODEL

Computing technologies such as the cloud computing, fog computing, and edge computing are important for network resilience, distributed computing and processing, and lower latency and time synchronization. In order to solve the limitations of 5G including the drawback of short-packet, provide the delivery of high-reliability, low-latency services with high data rates, system coverage and Internet of everything (IoE) [3], and to meet the demands of mobile communications of the year 2030 and beyond [4], 6G network should make the human-centric, instead of machine-centric, application-centric, or data-centric, as the vision [5].

To meet these requirements, 6G wireless communication networks will have new paradigm shifts. Our vision of 6G network is illustrated in Fig. 1. First of all, 6G wireless communication networks will be space-air-ground-sea integrated networks to provide a complete global coverage. The satellite communication, UAV communication, and maritime communication will largely extend the coverage range of wireless communication networks. To provide a higher data rate, all spectra will be fully explored, including sub-6 GHz, mmWave, THz, and optical frequency bands. To enable full applications, AI and ML technologies will be efficiently combined with 6G wireless communication networks to have a better network management and automation.

Furthermore, AI technology can enable the dynamic orchestration of networking, caching, and computing resources to improve the performance of next-generation networks. The last but not the least trend is the strong or endogenous network security for both physical layer and network layer when developing it. Industry verticals, such as cloud VR, Internet of things (IoT) industry automation, cellular vehicle to everything (C-V2X), digital twin body area network, and energy efficient wireless network control and federated learning systems will largely boost the developments of 6G wireless communication networks. An overview of 6G wireless networks is shown in Fig. 1, where the performance metrics, application scenarios, enabling technologies, new paradigm shifts, and industry verticals are given.

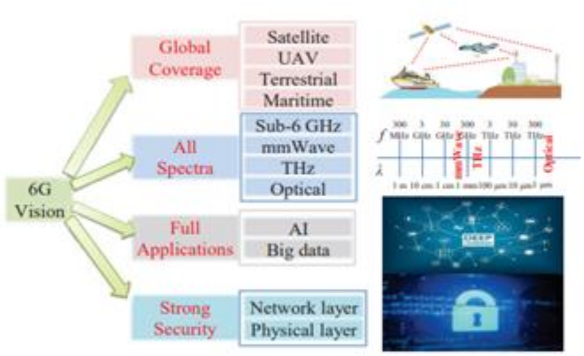

Fig. 1. A vision of 6G wireless communication networks.

IV. RESULT AND SIMULATION

Examined neural network (NN) for combined channel estimation and signal detection in an OFDM system. This approach considered OFDM system and fading channel as a black box and the presented NN network is trained offline using simulated data. The simulation results revealed that the proposed DL approach had the capability to learn and investigate the complicated attributes of the wireless channels. In addition, the results of the DL approach proved its dominance over conventional methods when fewer pilot symbols were utilized, and cyclic prefix was ignored.

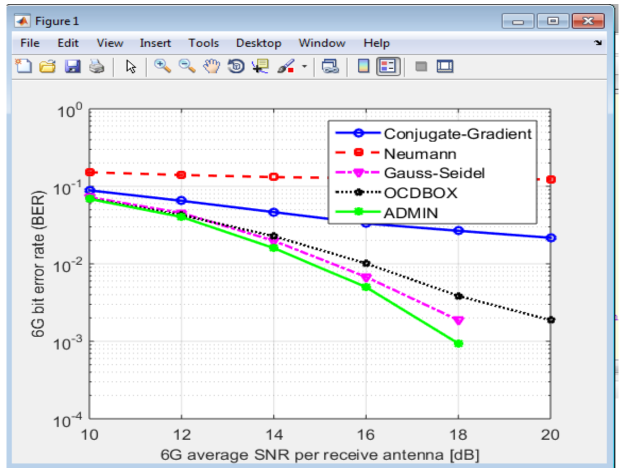

Fig.2 BER in NOMA.

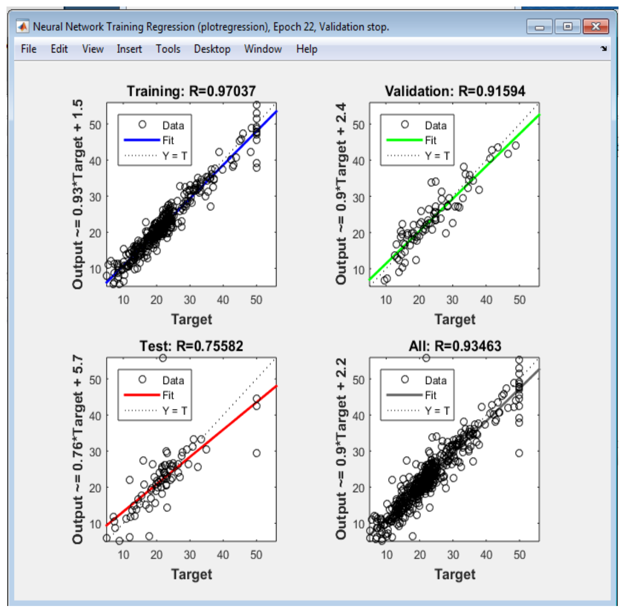

Fig.3 Regression.

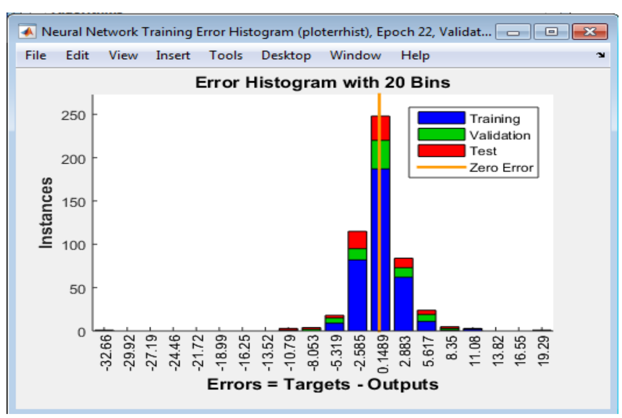

Fig.4 MSE.

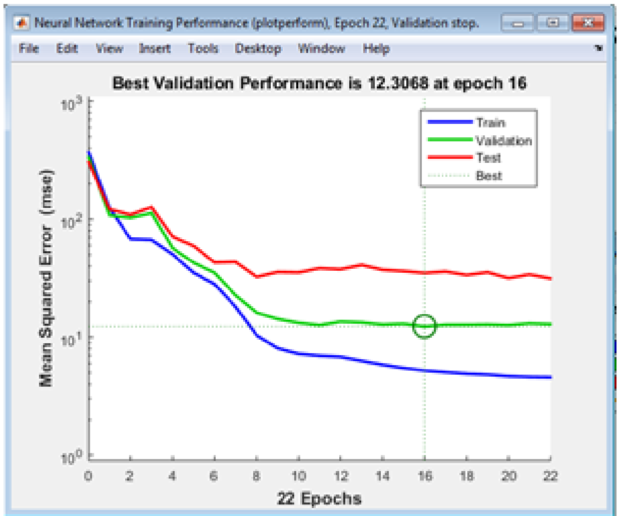

Fig.5 Performance plot.

V. CONCLUSION AND FUTURE SCOPE

CONCLUSION

The application of deep learning in MIMO-NOMA communication systems is a promising approach to address the shortcomings of the SIC method. Instead of the complicated algorithm design and interference cancellation process, the deep learning approach can search for the optimal solution of the hyperparameters of the multilayer neural network with machine learning.

In this work, we designed an MIMO-NOMA-DL signal-detection system to perform signal recovery. The proposed technique can simultaneously complete the processes of channel estimation and MIMO-NOMA signal detection. The detailed construction and learning algorithm have been provided. We first compared the SER performance of the proposed method and the SIC algorithm via simulations. The highest performance gain reached 3.6 dB. Then, the impact of the crucial parameters, including the modulation type and power allocation, were studied. Numerical results showed that the MIMO-NOMA-DL method had powerful detection performance. Finally, mini-batch gradient descent simulations were conducted to accelerate the training step of the MIMO-NOMA-DL algorithm. The results indicate that the mini-batch size is a key parameter for balancing the convergence speed and loss precision.

Future works will explore the DL-based approach to detect other types of NOMA signals, such as the sparse code multiple access (SCMA), multi-user shared access (MUSA), and pattern-division multiple access (PDMA). Moreover, we also consider an extension assessing the performance under different channel situations and the multiple clusters situation. Additionally, detecting the communication signal with memory using RNNs will be explored. CNNs, another advanced DL approach, could be deeply developed in terms of their potential in signal detection as our following work.

REFERENCES

1. B. Di, L. Song, and Y. Li, “Sub-channel assignment, power allocation and user scheduling for non-orthogonal multiple access networks,” IEEE Trans. Wireless Commun., vol. 15, no. 11, pp. 7686–7698, Nov. 2016.
2. F. Tang et al., “On removing routing protocol from future wireless networks: A real-time deep learning approach for intelligent traffic control,” IEEE Wireless Commun. Mag., vol. 25, no. 1, pp. 154–160, Feb. 2018.
3. Y. Zhou, Z. M. Fadlullah, B. Mao, and N. Kato, “A deep learning based radio resource assignment technique for 5 G ultra dense networks,” IEEE Netw. Mag., vol. 32, no. 6, pp. 28–34, Nov. 2018.
4. B. Xu, Y. Chen, J. R. Carrion, and T. Zhang, “Resource allocation in energy-cooperation enabled two-tier NOMA HetNets towards green 5G,” IEEE Commun. Lett., vol. 35, no. 12, pp. 2758–2770, Dec. 2017.
5. N. Yang, H. Zhang, K. Long, C. Jiang, and Y. Yang, “Spectrum management scheme in fog IoT networks,” IEEE Commun. Mag., vol. 56, no. 10, pp. 101–107, Oct. 2018.
6. H. Zhang, N. Liu, K. Long, J. Cheng, V. C. M. Leung, and L. Hanzo, “Energy efficient subchannel and power allocation for software-defined heterogeneous VLC and RF networks,” IEEE J. Sel. Areas Commun., vol. 36, no. 3, pp. 658–670, Mar. 2018.
7. H. Zhang, S. Huang, C. Jiang, K. Long, V. C. M. Leung, and H. V. Poor, “Energy efficient user association and power allocation in millimeter-wave-based ultra dense networks with energy

harvesting base stations," IEEE J. Sel. Areas Commun., vol. 35, no. 9, pp. 1936–1947, Sep. 2017.

8. B. Di, L. Song, Y. Li, and G. Li, "Non-orthogonal multiple access for high-reliable and low-latency V2X communications in 5 G systems," IEEE J. Sel. Areas Commun., vol. 35, no. 10, pp. 2383–2397, Oct. 2017.
9. L. Song, Y. Li, Z. Ding, and H. V. Poor, "Resource management in nonorthogonal multiple access networks for 5G and beyond," IEEE Netw., vol. 31, no. 4, pp. 8–14, Jul. 2017.
10. N. Kato et al., "The deep learning vision for heterogeneous network traffic control proposal, challenges, and future perspective," IEEE Wireless Commun., vol. 24, no. 3, pp. 146–153, Dec. 2016.
11. J. Choi, "Effective capacity of NOMA and a suboptimal power control policy with delay QoS," IEEE Trans. Commun., vol. 65, no. 4, pp. 1849– 1858, Apr. 2017.
12. Z. Ding, Z. Yang, P. Fan, and H. V. Poor, "On the performance of nonorthogonal multiple access in 5 G systems with randomly deployed users," IEEE Signal Process. Lett., vol. 21, no. 12, pp. 1501–1505, Dec. 2014.
13. M. Jia, Z. Yin, D. Li, Q. Guo, and X. Gu, "Toward improved offloading efficiency of data transmission in the IoT-cloud by leveraging secure truncating OFDM," IEEE Internet Things J., vol. 6, no. 3, pp. 4252–4261, Jun. 2019.
14. M. Jia, Z. Yin, Q. Guo, G. Liu, and X. Gu, "Downlink design for spectrum efficient IoT network," IEEE Internet Things J., vol. 5, no. 5, pp. 3397– 3404, Oct. 2018.
15. A. S. Bedi and K. Rajawat, "Network resource allocation via stochastic subgradient descent: Convergence rate," IEEE Trans. Commun., vol. 66, no. 5, pp. 2107–2121, May 2018.