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Research paper

The Role of Machine Learning in 6G Wireless Networks: A Comprehensive Overview

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Abstract

The development of 6G networks marks a major step forward in wireless communication technology, aiming to provide extremely fast data speeds, ultra-low latency, high reliability, and greater energy efficiency. Unlike previous generations, 6G is expected to be much more than just faster internet—it will enable new and advanced services like real-time remote surgery, immersive augmented and virtual reality, autonomous transportation, and smart cities. At the heart of this transformation is the use of machine learning (ML), which will be deeply integrated into the core of 6G systems. Machine learning gives networks the ability to learn from data, make decisions, and adapt to changing situations without needing constant human guidance. This will help networks become more intelligent, flexible, and efficient in delivering services to users. For example, ML can help predict when and where network traffic will be high, allowing the system to automatically allocate resources where they are needed most. It can also help detect and respond to security threats in real-time, improve the quality of service by adjusting settings based on user behavior, and reduce energy usage by optimizing the use of network devices. These capabilities will be especially important in supporting the billions of connected devices expected in the future, including sensors, robots, drones, and smart appliances. Despite these difficulties, the opportunities offered by ML in 6G are enormous. It can bring better user experiences, smarter management of network operations, and the ability to support entirely new types of services. As research and development continue, collaboration between engineers, data scientists, and policymakers will be essential to ensure that the benefits of 6G are realized while minimizing the risks. In conclusion, the integration of machine learning into 6G is not just an upgrade—it is a fundamental shift in how wireless networks are designed and operated. By making networks smarter and more responsive, ML will play a key role in shaping the future of communication and digital services around the world.

***Keywords**: Machine Learning, Fifth Generation, sixth Generation, Wireless Network, Algorithms.*

1. Introduction

The emergence of 6G networks promises a revolutionary leap in wireless communication by introducing transformative advancements that go beyond the capabilities of current networks [1]. One of the most distinctive characteristics of 6G is much higher data speeds, ranging to terabit-per-second levels, which will allow almost instant download of big files, interruption-free streaming of high-definition content, and extremely responsive applications. The most important feature is the ultra-low latency of 6G networks, which should be around microseconds [2]. This will provide real-time communication and interaction for use cases like autonomous cars, remote surgery, and industrial automation, where a split-second response is important. 6G networks will offer higher reliability, ensuring consistent connectivity even in challenging environments [3]. This reliability will be crucial for mission-critical applications such as emergency services, disaster response, and remote monitoring. 6G, the sixth generation of cellular networks, is poised to revolutionize wireless connectivity, offering ubiquitous wireless intelligence. Expected to debut in the early 2030s, 6G research is already in full swing [4]. The vision for 6G revolves around seamlessly merging the digital and physical worlds, opening up novel avenues for social interactions, remote work, and immersive cultural experiences [5]. This future reality promises a transformative impact, enabling people to connect, collaborate, and explore in ways previously unimaginable. By providing constant, intelligent communication, 6G aims to foster a more human-centric, sustainable, and efficient society [6]. Figure 1.6 G networks shall offer extensive connectivity to an incredible number of devices so that there will be billions of devices effortlessly plugged into the network [7]. With this, IoT can unfold fully and lead to the formation of intelligent, integrated ecosystems with intelligent communication and co-work of the devices.

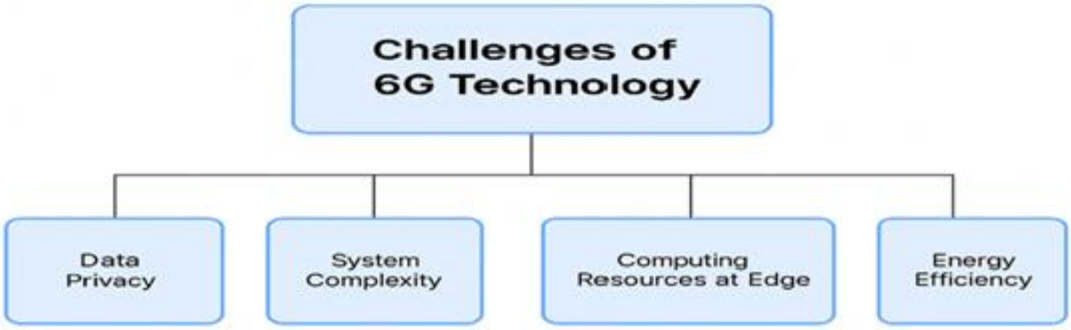

Fig.1: Challenges of 6G Technology

Figure 1 highlights some key challenges of 6G technology, such as data privacy, system complexity, edge computing, and energy efficiency. As 6G aims to use AI and machine learning, protecting user data becomes a serious concern. The systems are also expected to be more complex, requiring advanced infrastructure and coordination. Managing computing tasks at the edge of the network (close to users) is difficult due to limited resources. Additionally, 6G may use high-frequency bands like terahertz, which can increase energy usage. These issues raise not only technical but also ethical and regulatory challenges that need to be addressed in future research.

Coupled with more progressive technologies like terahertz communications, AI, holographic communication, and quantum communications, there will be an augmentation in the competence of the 6G network. Terahertz communication will support very high data rates, AI will make the network highly efficient and performant, holographic communications will provide highly directional and secure communication, and quantum communication will offer ultra-secure communication links [8].

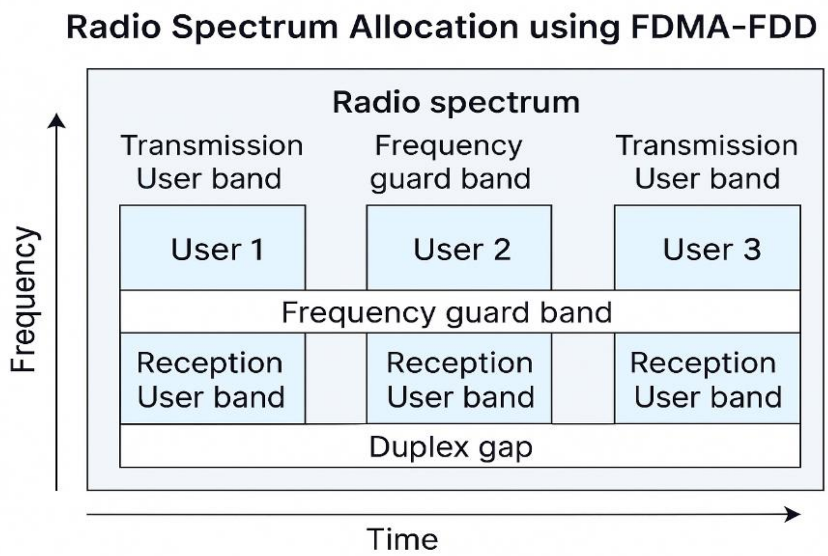

Fig. 2: FDMA-FDD Spectrum Allocation

In 6G networks, advanced deep learning models can play a big role in improving performance and intelligence [9]. These models help the system make smarter decisions by learning from large amounts of data.

- Convolutional Neural Networks (CNNs) are useful for identifying signal patterns. They can help detect interference and classify signals in real time, which is important for managing wireless resources.
- Recurrent Neural Networks (RNNs), especially LSTM and GRU models, are good at understanding time-based data. They can predict network traffic and user movements, helping to avoid delays and improve connectivity.
- Transformer models, like those used in natural language processing, can analyze complex data from devices. They are helpful in predicting user needs and managing different network services efficiently.
- Graph Neural Networks (GNNs) are ideal for modeling the structure of a 6G network. Since 6G involves many devices talking to each other, GNNs can help with intelligent routing and detecting network issues.
- Autoencoders are used to remove noise from data and compress it for faster sharing. This is useful in large antenna systems and when sending data over a limited bandwidth.
- Generative Adversarial Networks (GANs) can create synthetic data for training models. This is helpful when real 6G data is not yet available. They can also simulate different user behaviors and network conditions.
- Variational Autoencoders (VAEs) help in sharing data securely. They compress data while keeping important information, supporting tasks like privacy protection and efficient storage.
- Hybrid models that combine CNNs, RNNs, or Transformers can handle more complex tasks. These are useful in applications like self-driving cars, virtual reality, and edge computing in 6G.

1.1 Existing Methodologies and Identified Gaps

Many existing research papers on 6G use traditional machine learning methods like Support Vector Machines (SVM), Decision Trees, and K-Means for basic tasks such as signal classification, intrusion detection, or traffic prediction. While these models are easy to implement, they struggle to handle complex and large-scale 6G data efficiently.

1.2 Gaps Identified:

- Limited use of advanced models like Transformers, GNNs, or hybrid architectures.
- Most works rely on small or simulated datasets, reducing generalization.
- Lack of real-time implementation or deployment at the edge level.
- Security and privacy are often overlooked or only partially addressed.
- Few studies integrate AI with network slicing, massive MIMO, or ultra-low latency needs of 6G.

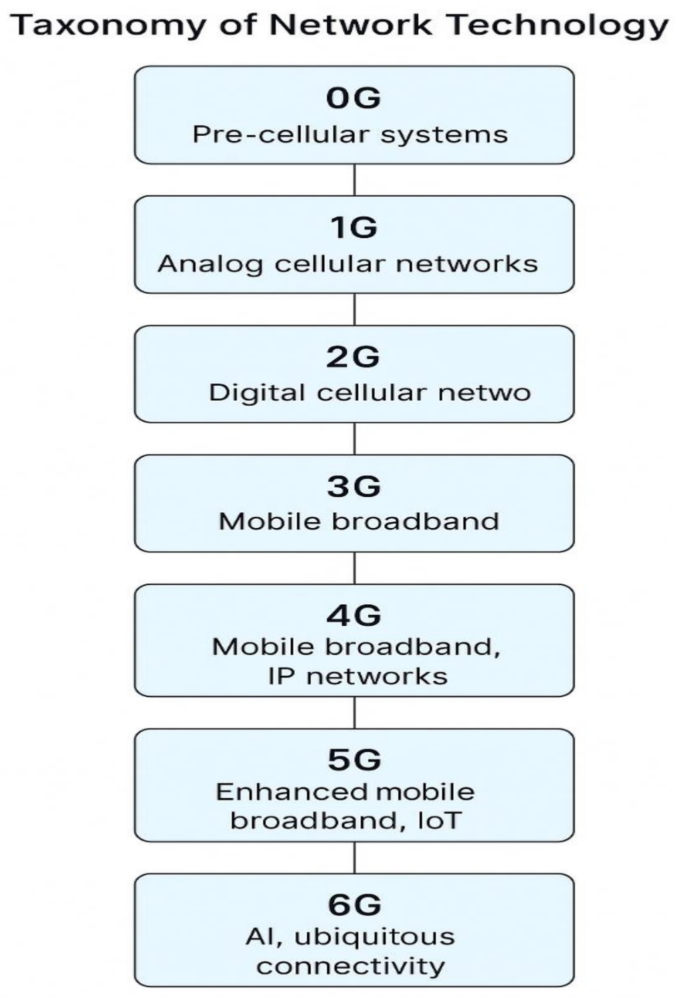

Fig. 3: taxonomy of Network Technology

Figure 3 shows how mobile network technology has evolved, starting from 0G to 6G. 0G was used before mobile phones and included basic radio communication. 1G introduced the first mobile phones with analog signals. 2G moved to digital signals, which made texting and better call quality possible. 3G brought mobile internet, allowing people to browse and use apps. 4G made the internet faster and supported video calls and streaming. 5G improved speed even more and connected many smart devices. The upcoming 6G is expected to use AI and provide even smarter and faster connections everywhere.

2. Understanding 6g

6G heralds the next leap forward in wireless technology, poised to revolutionize our devices and connectivity. It represents a significant upgrade from the current 5G technology, promising faster and more reliable internet. With 6G, we can expect quicker downloads, seamless streaming, and exciting advancements such as immersive augmented reality experiences. The goals of 6G are ambitious, aiming to deliver super-fast data speeds, minimal delays, and overall improved performance [8]. This upgrade addresses current challenges, such as the increasing demand for handling large volumes of data. Understanding 6G is crucial as it marks a new era in how our devices communicate, offering not just better technology, but also opening exciting possibilities for the future. Machine Learning (ML) with 6G represents a significant advancement in the field of wireless communication, where sophisticated algorithms are integrated into the sixth generation of wireless technology to create smarter and more efficient networks. In essence, ML with 6G involves training mobile networks and devices to learn from data and adapt to various challenges autonomously, leading to improved performance and user experience [9].

One of the key aspects of ML with 6G is its ability to optimize network resources. By analyzing data on network traffic, user behavior, and environmental conditions, ML algorithms can dynamically allocate resources such as bandwidth, power, and spectrum, maximizing network capacity and efficiency. This optimization is crucial in ensuring that users receive the best possible service, especially in densely populated areas or during peak usage times important application of ML with 6G is in predicting and preventing network issues [10]. By analyzing historical data and monitoring real-time network conditions, ML algorithms can identify potential problems before they occur and take proactive measures to prevent them. This predictive maintenance approach can help reduce downtime and improve overall network reliability. ML with 6G plays a crucial role in enhancing network security. By analyzing network traffic patterns and identifying anomalies, ML algorithms can detect and mitigate security threats in real-time, protecting against cyber-attacks and unauthorized access. ML with 6G enables the customization of services based on individual user needs. By analyzing user behavior and preferences, ML algorithms can tailor services such as data plans, content recommendations, and network settings to provide a personalized experience for each user [11]. ML with 6G has the potential to revolutionize how we experience and interact with wireless communication. By making networks smarter, more efficient, and more secure, ML with 6G promises to deliver not only faster but also more intelligent and customized wireless communication services for users around the world. In the envisioned 6G landscape, a connected and sustainable physical world is poised to emerge, seamlessly blending digital and programmable elements, where intelligent machines and the Internet of Senses (IoS) converge to enhance human experiences [12]. This convergence is set to revolutionize various sectors, offering transformative use cases that can be categorized into three main scenarios: The Internet of Senses, connected intelligent machines, and a connected, sustainable world. personal immersive devices empowered with precise body interaction capabilities will unlock remote experiences and actions, enhancing human communication in unprecedented ways. These advancements will introduce novel communication modes with stringent access control and identity management, ensuring secure and personalized interactions [13]. In parallel, 6G will drive the proliferation of connected intelligent machines, fostering a new era of automation and collaboration. Use cases like cobots and robot navigation will benefit from seamless connectivity, enabling machines to work alongside humans efficiently. This synergy will lead to enhanced productivity and operational efficiency across various industries. 6G will contribute to building a connected, sustainable world, offering solutions for smart agriculture, earth monitoring, and digital twins. These applications will leverage advanced sensing and communication technologies to optimize resource utilization, monitor environmental conditions, and enable precise decision-making, thereby promoting sustainability and resilience. 6G's vision encompasses a harmonious blend of digital innovation and sustainable practices, empowering humans with intelligent machines and immersive experiences through the Internet of Senses [14]. Within the Internet of Senses scenario, 6G aims to enable immersive communication experiences that transcend traditional boundaries, offering full telepresence capabilities. This level of connectivity demands high data rates, capacity, and ultra-low latency, coupled with spatial mapping and precise positioning technologies. One compelling application is the integration of extended reality (XR) technology in public transport, where passengers can individually engage in virtual experiences, run errands, receive XR guidance, and play games overlaid on the physical world [15].

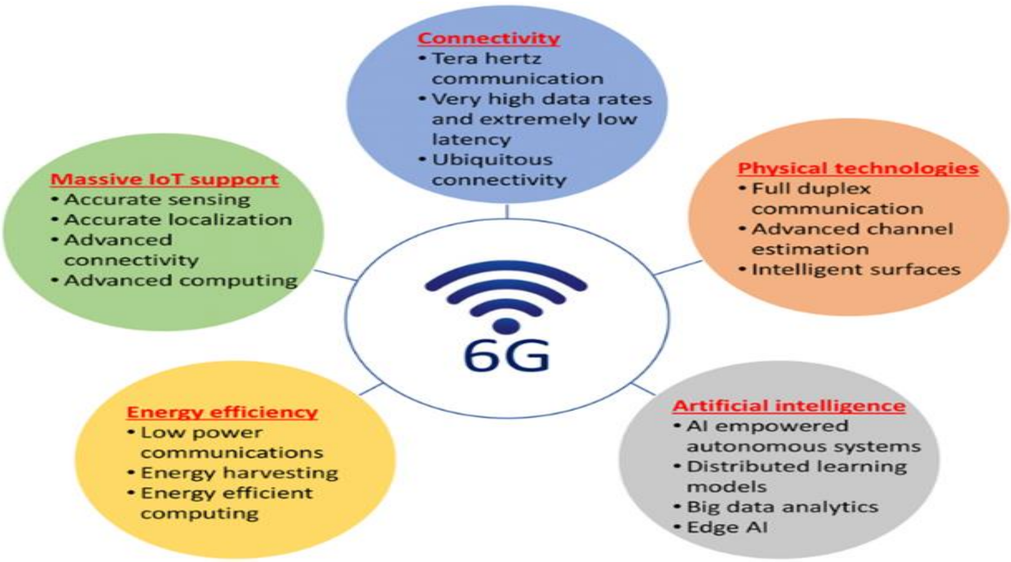

Fig. 4: 6G Connectivity

Figure 4 illustrates the future 6G connectivity landscape, where everything is seamlessly connected—including people, devices, machines, and environments. It shows how advanced technologies like AI, IoT, satellite networks, drones, and smart sensors will work together to provide ultra-fast, reliable, and intelligent communication. The figure highlights the vision of 6G as a fully integrated system supporting smart cities, autonomous vehicles, remote healthcare, and immersive experiences.

Table 1: ML-Driven 6G Trade-Offs

Sno	ML-Driven 6G Trade-Offs: Energy Cost vs. Efficiency Gain
1	High computational power vs. faster network optimization
2	Increased energy usage vs. intelligent resource allocation
3	Heavy model training load vs. long-term network automation
4	Frequent inference at the edge vs. ultra-low latency services
5	Power-hungry deep models vs. accurate traffic prediction
6	Continuous learning overhead vs. adaptive communication systems
7	Device-level energy drain vs. real-time fault detection
8	Costly federated learning vs. improved data privacy
9	Model update energy cost vs. dynamic network adaptability
10	Thermal and battery impact vs. enhanced user experience

3. Machine Learning in Wireless Communications

Machine learning (ML) plays a crucial role in revolutionizing wireless communications, offering significant improvements in efficiency, reliability, and performance. One key area where ML excels is in optimizing resource allocation, a complex task in wireless networks. By analyzing data on network traffic, user behavior, and channel conditions, ML algorithms can dynamically allocate resources such as bandwidth, power, and spectrum, maximizing network capacity and improving user experience. This dynamic resource allocation is particularly beneficial in environments with varying traffic loads, ensuring that resources are allocated where they are most needed. ML also enhances the security of wireless communications by detecting and mitigating threats in real-time. ML algorithms can analyze network traffic patterns to identify suspicious activities, such as unauthorized access attempts or malware propagation, and take immediate action to protect the network. Additionally, ML can improve the reliability of wireless communications by predicting and preventing network failures. By analyzing historical data on network performance and failures, ML algorithms can identify potential issues before they occur and take proactive measures to prevent them, ensuring uninterrupted service for users. ML enables intelligent antenna systems in wireless communications, improving signal quality and coverage. ML algorithms can optimize antenna configurations based on environmental factors and user locations, ensuring that signals are transmitted and received efficiently. This optimization leads to better coverage, fewer dropped calls, and improved data rates, enhancing the overall quality of service. A significant application of ML in wireless communications is in the field of spectrum management. ML algorithms can analyze spectrum usage patterns and predict future demands, enabling more efficient spectrum allocation. This dynamic spectrum management improves the utilization of available spectrum, reduces interference, and increases overall network capacity. ML is transforming wireless communications by enabling dynamic resource allocation, enhancing security and reliability, optimizing antenna systems, and improving spectrum management. As wireless networks continue to evolve, ML will play an increasingly vital role in maximizing the efficiency and performance of these networks, benefiting both service providers and users.
A. Supervised Learning: Supervised learning is a machine learning approach in which the model is trained on labeled data, i.e., input data is combined with the correct output. The aim is for the model to acquire a mapping function between the input and output using the training data, so it can correctly predict the output for new, unseen data.
Related work of Machine Learning in Wireless Communications:
In his book Machine Learning for Future Wireless Communications (2020), F.L. Luo explains how machine learning (ML) is being used to improve wireless communication systems. In one part of the book, he focuses on deep learning (DL) methods that help manage network traffic and improve system performance. This section is made up of five chapters and looks at both basic and advanced ML techniques. F.L. Luo shows how these methods can make future wireless networks faster, smarter, and more efficient [16].
In the book Deep Learning for Wireless Communications (2019), T. Erpek, T.J. O'Shea, Y.E. Sagduyu, Y. Shi, and others explain how deep neural networks (DNNs), like feedforward networks, can be used to understand and process wireless communication data. In Chapter 3, they show how these networks help extract hidden features from complex wireless signals. Because the wireless environment is often unpredictable and noisy, the authors demonstrate how deep learning can improve the way wireless systems handle such challenges, making communication more reliable and efficient [17].
In their paper Machine Learning for Wireless Communication Channel Modeling: An Overview (2019), S.M. Aldossari and K.C. Chen discusses how machine learning (ML) techniques are being used to model wireless communication channels more accurately. They explain that ML goes beyond just matching data—it helps understand the complex behavior of wireless channels. According to the authors, using ML in this area can improve prediction, adaptability, and performance in wireless systems, making it a powerful tool for modern communication technologies [18].
In their paper Machine Learning Paradigms for Next-Generation Wireless Networks (2016), C. Jiang, H. Zhang, Y. Ren, Z. Han, and others review different types of machine learning algorithms and how they apply to future wireless networks. They categorize these algorithms into three main types: supervised learning, unsupervised learning, and reinforcement learning. The authors also provide examples of how each type is used in wireless communication tasks. They include a summary table (Table 3) to clearly show the connection between each ML method and its real-world applications in next-generation networks [19].
In their article Machine Learning and Intelligent Communications (2018), X.L. Huang, X. Ma, and F. Hu explore how machine learning can be integrated into modern communication systems to enhance mobile network performance. They point out that as mobile communication technologies grow, the demand for high-quality wireless services increases. The authors express optimism that combining machine learning algorithms with communication systems will lead to smarter, more efficient, and more reliable wireless networks [20].

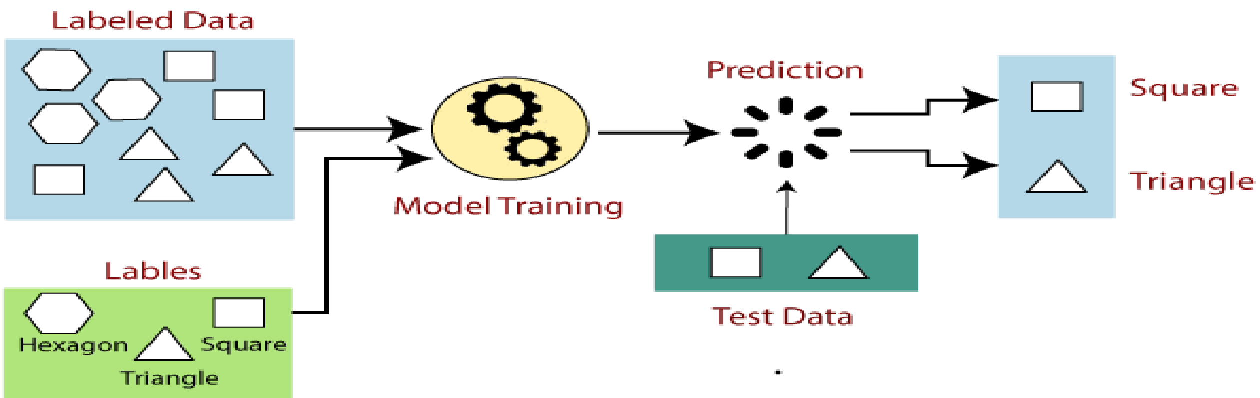

Fig. 5: Supervised Learning

Figure 5 explains the concept of supervised learning, where a machine learning model is trained using labeled data. In this process, the input data is already paired with the correct output, allowing the model to learn the relationship between them. After training, the model can predict outputs for new, unseen inputs based on what it has learned.
In a simple linear regression model, the equation can be written as

$y = mx + c$

where y is the output, x is the input, m is the slope, and c is the intercept.
B. Unsupervised Learning: Unsupervised learning is an approach to machine learning where the model learns on unlabeled data. The idea is for the model to develop an understanding of the structure or patterns within the data without instructions. Dimensionality reduction and clustering are typical unsupervised tasks.

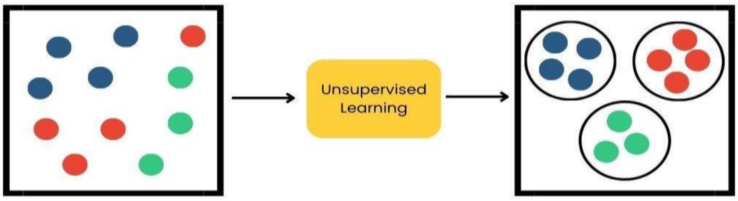

Fig. 6: Unsupervised Learning

Figure 6 shows how unsupervised learning works, where the model is given input data without any labels or predefined outputs. The goal is to find hidden patterns, groupings, or structures in the data—such as clustering similar items together or reducing dimensionality for easier analysis
For clustering using K-means, the algorithm aims to minimize the sum of squared distances between data points and their corresponding cluster centroids:

$$\sum i = 1k \sum x \in Si \parallel x - \mu i \parallel 2(x + a)^n$$

C. Reinforcement Learning: Reinforcement learning is an area of machine learning where a decision-making agent learns through interaction with its environment. Feedback is given as rewards or penalties on the agent's actions and aims to derive a policy through which it would gain maximum total reward in the long run.
The Q-learning algorithm updates the Q-value for a state-action pair based on the reward received and the maximum Q-value of the next state:

$$Q(s,a) \leftarrow Q(s,a) + \alpha[r + \gamma \max a' Q(s',a') - Q(s,a)]$$

Where $Q(s,a) is\ the\ Q\ value\ for\ the\ state$
$s\ and\ activation\ a$
$r\ is\ the\ reward\ receivedalpha\ is\ the\ learning\ rate$
Federated Learning, Kernel Hilbert Space, Blockchain Technology, Cognitive Radio, Symbiotic Radio, THz Technology, Full Duplex, Index Modulation.

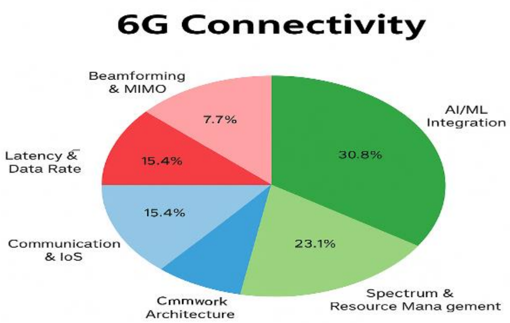

Fig. 7: 6G Connectivity Percentage allocation

Figure 7 illustrates the percentage distribution of key components in 6G connectivity. The largest share is dedicated to AI/ML Integration (30.8%), highlighting the importance of intelligent automation in future networks. This is followed by Spectrum & Resource Management (23.1%), which ensures efficient use of communication resources. Communication & IoS and Latency & Data Rate each hold 15.4%, reflecting their critical roles in delivering high-speed, low-latency services. Cmmwork Architecture supports the structural framework, while Beamforming & MIMO contribute 7.7%, indicating their role in enhancing signal strength and coverage.
Machine learning (ML) has the potential to be central in improving 6G networks' capabilities and achieving the elaborate needs of the envisaged application scenarios. Let us see the potential of ML to improve 6G as follows: Resource Management: Machine learning algorithms may better manage 6G resources by adjusting resources like bandwidth, latency, and power consumption, considering real-time network conditions. This dynamic optimization can increase network performance and user experience. Improvement of QoS: ML models can forecast and alleviate network congestion, optimize routing, and prioritize traffic to provide high QoS to mission-critical applications in 6G networks. This can improve reliability and reduce latency for end users. Security Improvement: Machine learning-based intrusion detection systems and anomaly detection systems can improve the security of 6G networks by detecting and countering threats in real-time. Such systems can evolve in response to emerging threats and increase network resilience. Network Slicing: ML-based algorithms can help

realize effective network slicing in 6G to allow virtualized networks to be developed for unique use cases. The versatility will provide the ability to support a wide range of applications with different needs on a common physical infrastructure at the same time. Table 1 comparison table for the application of machine learning (ML) in 5G and future 6G networks, with reading references: Spectrum Management: Spectrum usage in 6G networks can be optimized using ML by dynamically allocating frequency based on interference patterns and demand. This method, called cognitive radio, has the potential to increase spectral efficiency and enhance network performance. Edge Computing Optimization: ML models can optimize edge computing resources in 6G networks, providing quicker processing of data and lower latency for edge applications. Optimization can enhance IoT device and real-time application performance. Beamforming and MIMO: ML algorithms can optimize beamforming and multiple-input multiple-output (MIMO) methods in 6G networks, enhancing signal quality, coverage, and capacity. This optimization is likely to boost the overall efficiency of wireless communications in 6G.

3.1 Research Review Questions

1. How can ML address computational constraints at the 6G edge?

ML can be optimized for edge deployment using lightweight models, pruning, quantization, and knowledge distillation. Edge-specific federated learning can also reduce communication and computation overhead.

2. What models are optimal for dynamic spectrum sharing in terahertz bands?

Reinforcement learning (e.g., Deep Q-Networks) and graph neural networks are well-suited for real-time, adaptive spectrum management in highly dynamic THz environments.

3. What are the ethical implications of ML-driven personalization in ultra-reliable 6G networks?

ML-based personalization may lead to privacy breaches and algorithmic bias. Ensuring transparency, fairness, and user consent will be critical in ethical 6G deployments.

Table 2 provides a comparison between 5G and 6G technologies, highlighting how 6G is expected to significantly surpass 5G in performance, speed, and intelligence. While 5G offers fast data rates, low latency, and supports smart applications like autonomous cars and AR/VR, 6G aims to deliver even faster speeds (in terabits per second), ultra-low latency, and fully integrated AI for real-time decision-making. It will use advanced frequency bands such as terahertz and support massive device connectivity, improved energy efficiency, and smarter, more secure network architectures.

Table 2: comparison table of 5G vs. 6G technologies

Aspect	5G	6G (Anticipated)
Primary Focus	Enhanced Mobile Broadband (eMBB), IoT, URLLC	Immersive communication, IoS, intelligent machines, sustainable world
Latency	Sub-10ms	Sub-1ms
Data Rate	10 Gbps	1 Tbps
Frequency Bands	Up to mmWave (30-300 GHz)	Beyond mmWave to Terahertz frequencies
Network Architecture	Centralized, Cloud-RAN	Decentralized, AI-driven
ML Integration	ML is used in network optimization, QoS, and security	Deeper integration for resource management, QoS, security, and network slicing
Resource Management	Basic AI for resource optimization	ML-based dynamic resource allocation, spectrum management
Quality of Service	Limited AI for QoS improvement	ML-driven QoS enhancements, congestion prediction, and mitigation
Security	AI-based security solutions	ML-enhanced security, anomaly detection, and real-time threat mitigation
Network Slicing	Basic slicing capabilities	Advanced, dynamic network slicing for diverse applications
Spectrum Management	Some cognitive radio features	Enhanced cognitive radio, ML-driven spectrum optimization
Edge Computing	Basic edge computing integration	ML-optimized edge computing for low-latency applications
Beamforming, MIMO	Basic optimizations	ML-driven optimization for beamforming, MIMO

4. Conclusion

This convergence of Machine Learning (ML) and 6G is not merely a technological advancement; it signifies a profound shift towards an internet that is more intuitive and enriching for users. By integrating advanced AI techniques, including ML algorithms, with 6G wireless technology, we are paving the way for transformative change. Beyond the substantial speed enhancements that 6G promises, this fusion of technologies equips mobile networks and devices with autonomous learning, adaptability, and anticipatory capabilities. This marks the dawn of a new era characterized by unparalleled efficiency and intelligence in our connected world. Imagine a future where your devices intuitively understand your preferences and needs, anticipating them before you even express them. Picture a world where networks seamlessly adapt to changing conditions, optimizing resources and performance in real-time. This future is not just a distant dream; it's a tangible reality on the horizon with the integration of ML and 6G. This synergy opens doors to a myriad of possibilities, from revolutionizing healthcare with personalized treatments to enhancing urban living through smart city infrastructure. It's about creating a digital ecosystem that not only meets our needs but also delights us with its intelligence and responsiveness. As we continue this journey of innovation, the integration of ML and 6G stands as a beacon of progress, ushering in a future where our online experiences are more personalized, efficient, and engaging than ever before.

References

[1] Mahmood, M. R., Matin, M. A., Sarigiannidis, P., & Goudos, S. K. (2022). A comprehensive review on artificial intelligence/machine learning algorithms for empowering the future IoT toward 6G era. IEEE Access, 10, 87535-87562.

[2] Alsabah, M., Naser, M. A., Mahmmod, B. M., Abdulhussain, S. H., Eissa, M. R., Al-Baidhani, A., ... & Hashim, F. (2021). 6G wireless communications networks: A comprehensive survey. Ieee Access, 9, 148191-148243.

[3] Shi, Y., Lian, L., Shi, Y., Wang, Z., Zhou, Y., Fu, L., ... & Zhang, W. (2023). Machine learning for large-scale optimization in 6g wireless networks. IEEE Communications Surveys & Tutorials, 25(4), 2088-2132.

[4] Ozpoyraz, B., Dogukan, A. T., Gevez, Y., Altun, U., & Basar, E. (2022). Deep learning-aided 6G wireless networks: A comprehensive survey of revolutionary PHY architectures. IEEE Open Journal of the Communications Society, 3, 1749-1809.

[5] Noman, H. M. F., Hanafi, E., Noordin, K. A., Dimyati, K., Hindia, M. N., Abdrabou, A., & Qamar, F. (2023). Machine learning empowered emerging wireless networks in 6G: Recent advancements, challenges and future trends. IEEE Access, 11, 83017-83051.

[6] Abd Elaziz, M., Al-qaness, M. A., Dahou, A., Alsamhi, S. H., Abualigah, L., Ibrahim, R. A., & Ewees, A. A. (2024). Evolution toward intelligent communications: Impact of deep learning applications on the future of 6G technology. Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery, 14(1), e1521.

[7] Sejan, M. A. S., Rahman, M. H., Shin, B. S., Oh, J. H., You, Y. H., & Song, H. K. (2022). Machine learning for intelligent-reflecting-surface-based wireless communication towards 6G: A review. Sensors, 22(14), 5405.

[8] Strinati, E. C., Barbarossa, S., Gonzalez-Jimenez, J. L., Ktenas, D., Cassiau, N., Maret, L., & Dehos, C. (2019). 6G: The next frontier: From holographic messaging to artificial intelligence using subterahertz and visible light communication. IEEE Vehicular Technology Magazine, 14(3), 42-50.

[9] Puspitasari, A. A., An, T. T., Alsharif, M. H., & Lee, B. M. (2023). Emerging technologies for 6G communication networks: Machine learning approaches. Sensors, 23(18), 7709.

[10] Rekkas, V. P., Sotiroudis, S., Sarigiannidis, P., Wan, S., Karagiannidis, G. K., & Goudos, S. K. (2021). Machine learning in beyond 5G/6G networks—State-of-the-art and future trends. Electronics, 10(22), 2786.

[11] Jagannath, A., Jagannath, J., & Melodia, T. (2021). Redefining wireless communication for 6G: Signal processing meets deep learning with deep unfolding. IEEE Transactions on Artificial Intelligence, 2(6), 528-536.

[12] Iliadis, L. A., Zaharis, Z. D., Sotiroudis, S., Sarigiannidis, P., Karagiannidis, G. K., & Goudos, S. K. (2022). The road to 6G: a comprehensive survey of deep learning applications in cell-free massive MIMO communications systems. EURASIP Journal on Wireless Communications and Networking, 2022(1), 68.

[13] Shahraki, A., Abbasi, M., Piran, M. J., & Taherkordi, A. (2021). A comprehensive survey on 6G networks: Applications, core services, enabling technologies, and future challenges. arXiv preprint arXiv:2101.12475.

[14] Samad, A., Saad, W., Nandana, R., Kapseok, C., Steinbach, D., Sliwa, B., ... & Malik, H. (2020). White Paper on Machine Learning in 6G Wireless Communication Networks: 6G Research Visions, No. 7, 2020. University of Oulu.

[15] Shafi, M., Jha, R. K., & Jain, S. (2024). 6G: Technology evolution in future wireless networks. IEEE Access.Chen, Z., Zhang, Z., & Yang, Z. (2024). Big AI models for 6G wireless networks: Opportunities.

[16] Luo, F. L. (Ed.). (2020). Machine learning for future wireless communications.

[17] Erpek, T., O'Shea, T. J., Sagduyu, Y. E., Shi, Y., & Clancy, T. C. (2019). Deep learning for wireless communications. In Development and Analysis of Deep Learning Architectures (pp. 223-266). Cham: Springer International Publishing.

[18] Aldossari, S. M., & Chen, K. C. (2019). Machine learning for wireless communication channel modeling: An overview. Wireless Personal Communications, 106(1), 41-70.

[19] Jiang, C., Zhang, H., Ren, Y., Han, Z., Chen, K. C., & Hanzo, L. (2016). Machine learning paradigms for next-generation wireless networks. IEEE Wireless Communications, 24(2), 98-105.

[20] Huang, X. L., Ma, X., & Hu, F. (2018). Machine learning and intelligent communications. Mobile Networks and Applications, 23(1), 68-70.