Wireless Networks and Cloud: A New Era of Connectivity

1th Kiran Kumar
Computer Science and Engineering
Alva's Institute of Engineering and Technology
Moodbidri, Mangalore, India
Email: kirankumark1707@gmail.com

2nd K Jeevan Kumar
Computer Science and Engineering
Alva's Institute of Engineering and Technology
Moodbidri, Mangalore, India
Email: jeevanjeevan63643@gmail.com

3rd Kavyashree
Computer Science and Engineering
Alva's Institute of Engineering and Technology
Moodbidri, Mangalore, India
Email: kavyashreenayak8861@gmail.com

4th Mahima Nayak
Computer Science and Engineering
Alva's Institute of Engineering and Technology
Moodbidri, Mangalore, India
Email: nayakmahima632@gmail.com

5st Kiran B V
Computer Science and Engineering
Alva's Institute of Engineering and Technology
Moodbidri, Mangalore, India
Email: kiranbv@aiet.org.in

***Abstract*—The fusion of wireless networks with cloud computing has redefined modern communication, offering high-speed, low-latency, and scalable network solutions. Together with developments in edge computing, Open Radio Access Network (ORAN), and software-defined networking (SDN), technologies like 5G and soon-to-be 6G networks greatly improve data transfer, resource management, and network efficiency. These developments open the door for real-time applications with incredibly dependable performance by enabling smooth connectivity and automation in smart cities, Industry 5.0, and the Internet of Senses (IoS).**

However, the growing complexity of cloud-integrated wireless systems presents challenges related to security, energy consumption, and network scalability. Ensuring interoperability between diverse architectures while maintaining efficiency and data privacy remains a major research focus. Solutions such as AI-driven network optimization, intelligent edge computing, and energy-efficient protocols are actively being explored to address these issues. This paper offers an in-depth examination of the emerging wireless-cloud paradigm, emphasizing its technological progress, current limitations, and future developments. By using cloud-native architectures and smarter wireless strategies, new-generation networks focus on creating a sustain capable, adaptive, and highly responsive digital environment.

***Index Terms*—Wireless Networks, Cloud Computing, 5G/6G, Edge Computing, ORAN, Software-Defined Networking.**

I. Introduction

Digital communication has been transformed by the development of wireless networks and cloud computing, which have made it possible to provide scalable, high-speed, low-latency solutions for contemporary applications. [1].The integration of wireless networks with cloud infrastructure has significantly enhanced the efficiency, reliability, and accessibility of data-driven services. [1].As global connectivity demands continue to rise, sophisticated technologies including Open Radio Access Network (ORAN), 5G, 6G, edge computing, and Software-Defined Networking (SDN) are shaping the future of telecommunications. [1]. These technologies are essential to smart cities, autonomous systems, healthcare, Industry 5.0, and the Internet of Senses because they provide smooth data transmission, effective resource management, and real-time communication. [13].

A paradigm shift is occurring in the communication landscape as a result of the introduction of 5G and the upcoming 6G networks. While 6G is anticipated to bring AI-driven, intelligent networks with ultra-high bandwidth and nearly zero latency, 5G offers faster data rates, reduced latency, and enhanced network dependability. [1]. Additionally,non-terrestrial networks (NTN), such as high-altitude platforms and satellite-based communication, are extending wireless connectivity to remote and underserved areas. These advancements are paving the way for enhanced automation, remote healthcare, immersive experiences, and other next-generation applications. [14].

Cloud computing has simultaneously become a potent facilitator of contemporary network infrastructures. By providing on-demand computing resources, scalable storage, and AI-powered analytics, cloud platforms complement wireless networks, facilitating real-time decision-making and efficient data processing. [3].The integration of cloud computing with wireless technologies allows for intelligent edge computing, distributed network architectures, and improved resource utilization. [14].This shift toward cloud-native solutions ensures better performance in large-scale IoT deployments, vehicular networks, and smart industrial systems. [1].

However, several challenges hinder the seamless integration of wireless networks and cloud architecture. One of the primary concerns is network scalability, as increasing connectivity demands require more efficient spectrum utilization and dynamic resource allocation. [18].Energy efficiency is another critical factor, as modern communication networks consume substantial power, necessitating the adoption of green computing and sustainable networking techniques. Security and privacy risks also pose significant challenges, with threats such as cyberattacks, data breaches, and unauthorized access becoming more prevalent. Additionally, ensuring interoperability among diverse networking standards remains a key research focus.

To address these challenges, researchers are developing AI-driven network optimization techniques, including machine learning algorithms for predictive analytics, self-healing networks, and intelligent traffic management. [18].By processing data closer to the source and enhancing real-time application performance, edge computing significantly reduces network congestion. [3]. Furthermore, the Open Radio Access Network (ORAN) architecture enables vendor-neutral, flexible, and cost-efficient network deployment, enhancing adaptability in future wireless systems.

This paper provides a comprehensive review of wireless networks and cloud architecture, covering their key technological advancements, major challenges, and future research directions. [14]. The study explores the impact of 5G/6G, edge computing, ORAN, SDN, and other emerging technologies on modern networking paradigms. [14].By analyzing the latest trends, security concerns, and sustainable networking approaches, this research aims to highlight the potential of cloud-integrated wireless systems in creating a scalable, intelligent, and energy-efficient communication ecosystem. [1].

II. 5G Non-Terrestrial Networks

The evolution of 5G includes non-terrestrial networks (NTN), which use satellites and high-altitude platforms for enhanced coverage and connectivity. [4].The loss model of the free-space pathmodel is given by:

$$PL(d) = 20\log_{10}(d) + 20\log_{10}(f) + 20\log_{10}\left(\frac{4\pi}{c}\right) \quad (1)$$

where d is the distance, f is the frequency, and c is the speed of light.

The rapid evolution of 5G technology is not limited to terrestrial networks; Non-Terrestrial Networks (NTNs) play a crucial role in extending connectivity to remote, rural, and disaster-prone regions. [4]. NTNs employ unmanned aerial vehicles (UAVs), satellites, and high-altitude platforms (HAPs) to improve communication dependability and provide smooth worldwide coverage. [3].

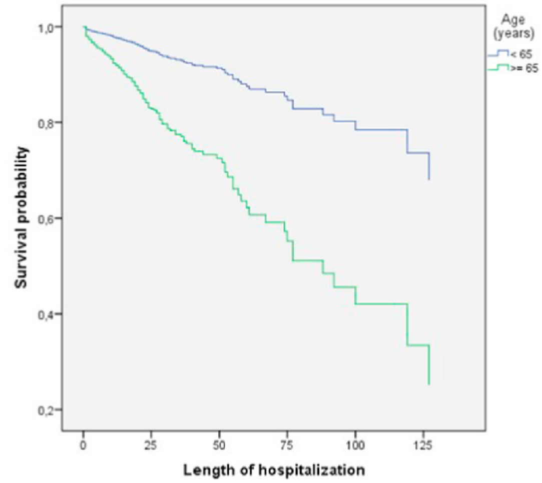

Fig. 1. 5G Non-Terrestrial Networks.

Key Advantages of NTNs Extended Connectivity: NTNs provide coverage where terrestrial networks are impractical.

Disaster Resilience: Satellites and airborne networks offer communication support during emergencies.

Low-Latency Communication: Advances in Low Earth Orbit (LEO) satellites enable reduced latency and higher data rates.

Support for IoT and Smart Applications: NTNs facilitate global IoT connectivity, maritime tracking, and autonomous systems.

Challenges and Future Trends NTNs face challenges such as latency, network handoffs, energy consumption, and spectrum management. Future research focuses on AI-driven network optimization, quantum-secured communication, and seamless 6G integration to enhance NTN performance. [13].

By bridging the digital divide, 5G Non-Terrestrial Networks are set to revolutionize global communication and drive innovation in space-based connectivity.

III. 5G SA/NSA Architectures

The deployment of 5G networks follows two major architectural paths: Standalone (SA) and Non-Standalone (NSA). [4].Each has distinct characteristics and plays a crucial role in the evolution from 4G to full-scale 5G deployment.
Non-Standalone (NSA) Architecture NSA architecture allows mobile operators to leverage existing 4G LTE infrastructure while integrating new 5G radio access technology (RAN). [4]. It is a cost-effective and quicker way to roll out 5G services, primarily targeting enhanced mobile broadband.

A. Benefits

- Faster Deployment – Enables rapid network rollout.
- Lower Initial Investment – Reduces costs by leveraging existing LTE infrastructure.
- Utilizes Dual Connectivity (4G + 5G) – Ensures seamless transition between LTE and 5G networks.

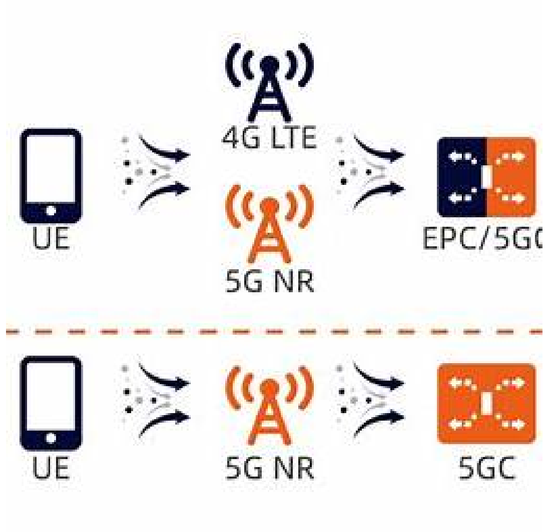

Fig. 2. 5G SA/NSA.

B. Limitations

- Limited Access to Full 5G Core Features – Some advanced capabilities are unavailable.
- Relies Heavily on LTE Core (EPC) – Performance constraints due to dependence on legacy infrastructure.

C. Standalone (SA) Architecture

SA architecture employs a standalone 5G Core (5GC) and new 5G RAN, supporting features such as ultra-reliable low-latency communication (URLLC) and network slicing.

IV. Green and Energy-Efficient Wireless Networks

With wireless communication developing at a fast pace, energy consumption has been a major issue. Green and energy-efficient wireless networks aim to reduce power usage while maintaining high performance and reliability. This is essential for sustainability, cost reduction, and environmental conservation. [13].

Energy-efficient protocols and green computing strategies optimize power consumption in wireless networks. [4]. The energy efficiency (EE) formula is:

$$EE = \frac{C}{P} \tag{2}$$

where C is the capacity in bits per second and P is the total power consumption in watts. [12].

A. Key Strategies for Energy Efficiency

- Energy-Aware Network Design – Optimizing network components such as base stations, antennas, and backhaul links to reduce energy wastage. [16] .
- Sleep Mode and Power Management – Implementing dynamic power management techniques that put unused network elements into low-power states. [12].
- Renewable Energy Integration – Using solar, wind, and other renewable sources to power wireless infrastructure, reducing dependence on fossil fuels. [16] .
- Efficient Radio Resource Management – Employing techniques like dynamic spectrum allocation and MIMO technology to maximize spectral efficiency and minimize power consumption.
- AI-Driven Optimization – Leveraging machine learning and AI for real-time power control, predictive maintenance, and traffic optimization. [16] .

V. Industry 5.0 with 6G

Industry 5.0 is the future stage of industrial trans formation, emphasizing human-machine cooperation, mass customization, and sustainability. By incorporating 6G, Industry 5.0 is projected to promote further automation, intelligence, and real-time decision-making in production and other fields. Human-Centric Automation– Improves human and intelligent machine collaboration ensuring a equilibrium between automation and human ingenuity. [12].

A. Key Features of Industry 5.0 with 6G

- Human-Centric Automation – Enhances collaboration between humans and intelligent machines, ensuring a balance between automation and human creativity.
- Ultra-Low Latency –6G networks deliver sub millisecond latency, making real-time data transfer and control possible in industrial settings. [16] .
- AI-Driven Decision Making – Advanced AI models powered by 6G enhance predictive maintenance, anomaly detection, and adaptive manufacturing.
- Mass Customization – Enables highly personalized and flexible production lines to cater to individual consumer demands.
- Sustainable Smart Factories – 6G-connected industries optimize energy usage and reduce waste, contributing to green manufacturing. [16] .

B. Applications of Industry 5.0 with 6G

- Smart Manufacturing – Real-time monitoring, predictive maintenance, and AI-driven optimization.
- Healthcare and Robotics – Remote surgeries, robotic assistants, and AI-powered diagnostics.
- Autonomous Supply Chains – Intelligent logistics with real-time tracking and decision-making.
- Cyber-Physical Systems (CPS) – Seamless integration between the physical and digital world, enabling real-time synchronization. [13].

VI. Intelligence Edge Computing in 6G

Edge computing in 6G is a revolutionary technology that enables computational power near the source of data, latency reduction and real-time application improvement. [12]. As opposed to conventional cloud computing, which uses central ized data processing, edge computing spreads workloads over several edge nodes, with quicker response times and enhanced network efficiency. [13].

A. Advantages

- Low Latency: By processing data closer to the user, edge computing minimizes transmission delays,making it perfect for real-time use such as autonomous cars and factory automation.
- Optimisation of Bandwidth: Reducing data transmission to centralized cloud servers significantly decreases bandwidth consumption.
- Enhanced Security: Localized processing mitigates risks related to data breaches and unauthorized access.
- Improved Reliability: Edge devices can continue operating even in cases of intermittent cloud connectivity. [13].

B. Latency Analysis

The total processing time in an edge computing environment can be mathematically represented as:

$$T_{\text{total}} = T_{\text{computation}} + T_{\text{transmission}} \tag{3}$$

[13].

where T_{total} represents the overall delay, $T_{\text{computation}}$ is the time taken for processing the data at the edge node, and $T_{\text{transmission}}$ accounts for the time required to transmit data between the source and the edge server. [12].

VII. Internet of Senses

The Internet of Senses (IoS) represents the next evolution of digital interaction, where human sensory experiences such as touch, taste, smell, and even emotions are transmitted over the internet. [12].IoS leverages advancements in 6G, artificial intelligence, haptic feedback, and extended reality (XR) to create an immersive digital world.

A. Key Technologies Enabling IoS

- Haptic Feedback: Enables touch-based interactions through wearable devices, allowing users to feel virtual objects.
- Olfactory and Gustatory Transmission: Uses digital scent and taste technology to replicate real-world experiences remotely.
- Brain-Computer Interfaces (BCI): Facilitates direct communication between the human brain and digital systems, enhancing sensory perception.
- Extended Reality (XR): combines mixed reality (MR), augmented reality (AR), and virtual reality (VR) to create immersive worlds.
- Sensory Processing Driven by AI:: Uses artificial intelligence to interpret and generate sensory inputs for a seamless experience. [12].

B. Potential Applications

- Healthcare: Remote surgeries with haptic feedback and digital olfaction for early disease detection.
- Education: Immersive learning experiences with multisensory simulations.
- Entertainment and Gaming: Enhanced VR experiences with real-time touch and smell integration.
- E-Commerce: Virtual product testing, where users can touch and smell items before purchasing. [12].

C. Challenges and Future Prospects

Despite its potential, IoS faces challenges such as high bandwidth requirements, security concerns, and the need for specialized hardware. Future research will focus on reducing latency, improving AI-driven sensory replication, and developing standardized protocols for seamless global adoption. [10]

VIII. New radios for 5G and LTE-A-PRO

5G New Radio (5G NR) and LTE-Advanced Pro (LTE-A-Pro) are key technologies driving modern wireless communication. LTE-A-Pro acts as a bridge between LTE and 5G, offering enhanced spectral efficiency and higher data rates. 5G NR introduces a new air interface with low latency and massive connectivity. [12].

- LTE-A-Pro: Supports Carrier Aggregation (CA), massive MIMO, and enhanced IoT connectivity.
- 5G NR: Works in sub-6 GHz and mmWave bands, supporting ultra-reliable low-latency communication (URLLC) and high-speed data transmission.

IX. Network Coding

Network coding is a method that increases data trans mission efficiency by enabling intermediate nodes to mix multiple data packets prior to forwarding. This improves network throughput, reliability, and resilience to packet loss. [10]

- Linear Network Coding: Encodes multiple input packets into a single output packet to maximize bandwidth utilization. [10]
- Random Network Coding: Uses random coefficients to encode data, improving robustness in dynamic networks. [10] [10]

X. Open Stack 5G/6G Protocols

Open Stack 5G/6G protocols are critical to facilitating flexible, scalable, and open-source implementations of next-generation networks. These protocols support seamless integration of cloud-native architectures with telecommunication infrastructure.

- Cloud-Native Deployment: Utilizes containerized microservices for efficient and scalable network operations.
- Multi-Vendor Interoperability: Enables seamless collaboration among various hardware and software vendors. [8]
- Programmability and Automation: Supports (Software-Defined Networking) and NFV (Network Function Virtualization) to enable dynamic resource partitioning

XI. ORAN (Open Radio Access Network)

Open Radio Access Network (ORAN) promotes flexible, vendor-neutral RAN deployment, reducing costs and enhancing network adaptability. [8]. It enables disaggregation of hardware and software components, allowing multi-vendor interoperability and cloud-native implementations. [12]. ORAN uses a modular architecture that improves efficiency and scalability by separating network operations like the Radio Unit (RU), Distributed Unit (DU), and Centralized Unit (CU).

ORANemploys new-age techniques such as software-defined network function virtualization (NFV) and networking (SDN) to optimize resource allocation dynamically. [8].One of the key enhancements in ORAN is intelligent beamforming, which improves signal transmission and reception for better network performance. The beamforming optimization equation is:

$$\mathbf{w} = \arg\max_{\mathbf{w}} \frac{|\mathbf{h}^H \mathbf{w}|^2}{\|\mathbf{w}\|^2} \tag{4}$$

where $\mathbf{w}$ is the beamforming vector and $\mathbf{h}$ is the channel vector. [12].

This equation ensures optimal beamforming to maximize the received signal strength while minimizing interference, leading to enhanced spectral efficiency and network coverage. ORAN's open interface and AI-driven network management further enhance adaptability, making it a critical enabler for next-generation 5G and 6G wireless networks. [8].

XII. Software Defined Radio and Networks

Software Defined Radio (SDR) and Software Defined Net working (SDN) are revolutionary technologies that introduce f lexibility and efficiency to contemporary wireless com munication. [12].

SDR replaces traditional hardware-based radio systems with software-driven implementations, allowing dynamic reconfiguration of frequency bands, modulation schemes, and transmission parameters. [14] .This adaptability makes SDR ideal for applications in military communications, cognitive radio networks, and next-generation wireless technologies. [11].

SDN, on the other hand, decouples the control and data planes in networking, enabling centralized management of network resources. It allows operators to dynamically adjust network traffic, optimize bandwidth usage, and implement security policies in real-time. [12].

The integration of SDR and SDN enhances wireless network efficiency, reduces operational costs, and paves the way for 5G and 6G advancements by enabling software-based network customization and intelligent automation. [14] .

XIII. Testbeds for 6G

6G testbeds serve as experimental platforms for evaluating and validating next-generation wireless technologies before large-scale deployment. [6] These test environments enable researchers to simulate real-world scenarios and analyze the performance of emerging 6G technologies.

Testbeds for 6G focus on key areas such as ultra-high-speed connectivity, sub-terahertz (THz) communication, AI-driven network optimization, and quantum security. [6] They integrate advanced hardware and software components to facilitate testing of novel network architectures, including Open Radio Access Networks (ORAN), intelligent edge computing, and holographic communications.

Universities, research institutions, and industries collaborate in developing these testbeds, ensuring interoperability and standardization for global adoption. [6]. The insights gained from 6G testbeds help in refining network protocols, enhancing energy efficiency, and addressing security challenges, ultimately shaping the future of wireless communication. [18].

XIV. Challenges and Future Trends

A. Challenges

- Scalability Issues – Managing the rising number of connected devices and network demands effectively. [11].
- Security and Privacy Issues –Mitigating cyber threats, data breaches, and secure communica tion ensuring.
- Energy Consumption – Developing energy-efficient network components to reduce environmental impact. [11]
- Infrastructure Costs – High investment required for deploying 6G, AI-driven networks, and advanced cloud systems.
- Standardization and Interoperability – Need for global standards to ensure seamless integration across diverse technologies. [14] .

B. Future Trends

- AI and Automation – AI-driven network management for predictive maintenance, dynamic resource allocation, and intelligent decision-making.
- Quantum Communication – Enhancing security through quantum key distribution and ultra-secure encryption methods. [14] .
- Sustainable Networking – Adoption of renewable energy-powered base stations and energy-efficient hardware for eco-friendly operations.
- Holographic and Immersive Communication – Advancements in holographic displays and augmented reality for real-time interactive experiences.
- Integration of 6G with IoT and Smart Cities – Seamless connectivity between IoT devices, smart cities, and next-gen applications. [14] .

XV. Conclusion

This paper reviewed the role of wireless networks in cloud architecture, focusing on technological advancements and emerging challenges. The integration of 5G/6G, edge computing, and SDN will continue to drive innovation in global connectivity. As the demand for high-speed, low-latency networks increases, the adoption of ORAN, intelligent edge computing, and AI-based optimizations will be pivotal in optimizing network performance and efficiency.

While challenges such as security, scalability, and energy consumption persist, continuous advancements in sustainable technologies and network automation will shape the future of wireless communication. The evolution of these technologies will drive digital transformation, supporting next-generation applications in IoT, smart industries, and immersive experiences.

XVI. Acknowledgement

We would like to gratefully thank Mr. Kiran B.V. of Alva's Institute of Engineering and Technology's Department of Computer Science and Engineering for his continued guidance , insightful feedback, and unwavering support throughout the development of this review paper. His expertise and dedication played a crucial role in refining and shaping this work to its success. We also like to express our gratitude to Alva's Institute of Engineering and Technology for supplying the essential Resources and research facilities to conduct this review. In particular, we would like to acknowledge the Department of Library and Information Centre, IEEE Xplore,Google Scholar and SpringerLink for granting access to academic literature that was invaluable in gathering relevant material for this review. We are also deeply appreciative of the Computer Science and Engineering Department's peers and colleagues for their valuable discussions and constructive suggestions. The collaborative spirit fostered within the department greatly contributed to creating an enriching research environment.

References

[1] A. Gupta and R. K. Jha, "A survey of 5G network: Architecture and emerging technologies," *IEEE Access*, vol. 3, pp. 1206–1232, 2015.

[2] M. Agiwal, A. Roy, and N. Saxena, "Next generation 5G wireless networks: A comprehensive survey," *IEEE Communications Surveys & Tutorials*, vol. 18, no. 3, pp. 1617–1655, 2016.

[3] J. G. Andrews, S. Buzzi, and W. Choi, "What will 5G be?" *IEEE Journal on Selected Areas in Communications*, vol. 32, no. 6, pp. 1065–1082, 2014.

[4] T. Nakamura et al., "Trends in small cell enhancements in LTE advanced," *IEEE Communications Magazine*, vol. 51, no. 2, pp. 98–105, 2013.

[5] F. Bonomi, R. Milito, J. Zhu, and S. Addepalli, "Fog computing and its role in the Internet of Things," in *Proceedings of the First Edition of the MCC Workshop on Mobile Cloud Computing*, 2012, pp. 13–16.

[6] X. Xu, H. Zhang, X. Lin, and Y. Chen, "ORAN: Open Radio Access Network architecture for 5G and beyond," *IEEE Wireless Communications*, vol. 27, no. 3, pp. 66–73, 2020.

[7] N. McKeown et al., "OpenFlow: Enabling innovation in campus networks," *ACM SIGCOMM Computer Communication Review*, vol. 38, no. 2, pp. 69–74, 2008.

[8] M. Giordani, M. Polese, M. Mezzavilla, S. Rangan, and M. Zorzi, "Towards 6G networks: Use cases and technologies," *IEEE Communications Magazine*, vol. 58, no. 3, pp. 55–61, 2020.

[9] H. Huang, J. Yang, Y. Song, and G. Gui, "Deep learning for super-resolution channel estimation and DOA estimation-based massive MIMO system," *IEEE Transactions on Vehicular Technology*, vol. 67, no. 9, pp. 8549–8562, 2018.

[10] J. Gubbi, R. Buyya, S. Marusic, and M. Palaniswami, "Internet of Things (IoT): A vision, architectural elements, and future directions," *Future Generation Computer Systems*, vol. 29, no. 7, pp. 1645–1660, 2013.

[11] P. Schulz et al., "Latency-critical IoT applications in 5G: Perspective on the design of radio interface and network architecture," *IEEE Communications Magazine*, vol. 55, no. 2, pp. 70–78, 2017.

[12] M. Latva-aho and K. Leppänen, "Key drivers and research challenges for 6G ubiquitous wireless intelligence," *6Genesis Flagship Program*, 2019.

[13] S. Tombaz, P. Monti, and J. Zander, "Impact of backhauling power consumption on the deployment of heterogeneous mobile networks," in *Proceedings of IEEE Global Telecommunications Conference (GLOBECOM)*, 2011, pp. 1–5.

[14] P. Rost et al., "Network slicing to enable scalability and flexibility in 5G mobile networks," *IEEE Communications Magazine*, vol. 55, no. 5, pp. 72–79, 2017.

[15] R. Ferrús, H. Koumaras, and N. Nikaein, "5G network slicing: A security perspective," *IEEE Communications Standards Magazine*, vol. 3, no. 3, pp. 32–38, 2019.

[16] I. F. Akyildiz, W. Lee, M. C. Vuran, and S. Mohanty, "NeXt generation/dynamic spectrum access/cognitive radio wireless networks: A survey," *Computer Networks*, vol. 50, no. 13, pp. 2127–2159, 2006.

[17] Y. Zeng, P. H. J. Nardelli, and M. Latva-aho, "Energy-efficient UAV communication with trajectory optimization," *IEEE Transactions on Wireless Communications*, vol. 18, no. 3, pp. 1366–1379, 2019.

[18] A. Bazzi, G. Cecchini, B. M. Masini, and A. Zanella, "Survey on vehicle-to-everything (V2X) communication for 5G and beyond," *IEEE Access*, vol. 8, pp. 39436–39463, 2020.

[19] F. H. P. Fitzek and M. D. Katz, *Mobile Clouds: Exploiting Distributed Resources in Wireless, Mobile, and Social Networks*, John Wiley & Sons, 2014.

[20] T. S. Rappaport et al., "Wireless communications and applications above 100 GHz: Opportunities and challenges for 6G and beyond," *IEEE Access*, vol. 7, pp. 78729–78757, 2019.

[21] H. Zhang, N. Liu, X. Chu, K. Long, A. Aghvami, and V. C. M. Leung, "Network slicing based 5G and future mobile networks: Mobility, resource management, and challenges," *IEEE Communications Magazine*, vol. 55, no. 8, pp. 138-145, 2017.

[22] S. Chen, Y. Wang, W. Zhang, M. Chen, and M. Bennis, "Artificial intelligence for 6G: Challenges, opportunities, and future directions," *IEEE Wireless Communications*, vol. 28, no. 2, pp. 10-17, 2021.

[23] X. You, C. Wang, J. Huang, X. Gao, Z. Zhang, and M. Zhong, "Towards 6G wireless communication networks: Vision, enabling technologies, and new paradigm shifts," *Science China Information Sciences*, vol. 64, no. 1, pp. 1-74, 2021.