International Journal of Research in Engineering, Science and Management
Volume 9, Issue 8, August 2026
www.ijresm.com | E-ISSN: 2581-5792 | RESAIM Publishing | www.resaim.com

5G Deployment in Modern Digital Ecosystems: Practical Implementation, Key Bottlenecks, and Emerging Paradigms

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***Abstract*: The evolution of wireless communication has significantly transformed the way information is generated, transmitted, and processed across various sectors. As the demand for high-speed, low-latency, and highly reliable communication continues to increase, Fifth Generation (5G) wireless technology has emerged as a key enabler of the future information era. Unlike previous generations of mobile communication, 5G offers enhanced mobile broadband, ultra-reliable low-latency communication, and massive machine-type communication, enabling seamless connectivity among billions of interconnected devices. These capabilities support the rapid growth of emerging technologies, including the Internet of Things (IoT) and Artificial Intelligence (AI) cloud computing, edge computing, autonomous transportation, Industry 4.0, smart healthcare, and smart city infrastructures. Despite its numerous Despite these benefits, several challenges persist, including the high costs associated with implementation, cybersecurity threats, spectrum scarcity, interoperability issues, energy consumption, and privacy concerns. This paper presents a comprehensive review of 5G technology and its applications in the future information era. It discusses the architecture of 5G networks, analyzes major application domains, examines current technical and economic challenges, identifies existing research gaps, and explores future research directions. The study concludes that although 5G provides the technological foundation for next-generation digital transformation, continued research is required to improve network security, intelligent resource allocation, sustainable deployment, and integration with future sixth-generation (6G) communication systems.**

***Keywords*: 5G Networks, Internet of Things (IoT), Artificial Intelligence, Smart Cities, Industry 4.0, Smart Healthcare, Edge Computing, Future Information Era.**

1. Introduction

The rapid advancement of digital technologies has created an information-driven society in which communication networks serve as the backbone of economic growth, industrial automation, healthcare services, education, transportation, and government operations. The increasing adoption of smart devices and intelligent applications has resulted in unprecedented growth in mobile data traffic and connected devices. Traditional wireless communication technologies such as 3G and 4G have significantly improved mobile communication; however, they face limitations in supporting emerging applications that require extremely low latency, high bandwidth, massive connectivity, and high reliability.

The future information era is characterized by the integration of Artificial Intelligence (AI), Internet of Things (IoT), cloud computing, edge computing, big data analytics, autonomous systems, and cyber-physical systems. These technologies require communication networks capable of processing enormous volumes of real-time data while maintaining reliable connectivity among millions of heterogeneous devices. Fifth Generation (5G) wireless communication has been developed to address these challenges by providing enhanced network capacity, flexible architecture, intelligent resource management, and significantly improved Quality of Service (QoS).

Compared with previous generations, 5G introduces three major service categories: Enhanced Mobile Broadband (eMBB), Ultra-Reliable Low-Latency Communication (URLLC), and Massive Machine-Type Communication (mMTC). These service models enable numerous applications, including autonomous vehicles, remote robotic surgery, smart agriculture, intelligent transportation systems, industrial automation, virtual reality (VR), augmented reality (AR), and smart energy management. Furthermore, technologies such as network slicing, Software Defined Networking (SDN), Network Function Virtualization (NFV), and Multi-access Edge Computing (MEC) improve the flexibility and efficiency of modern communication networks.

Although 5G offers considerable technological advancements, several implementation challenges remain unresolved. The deployment of dense small-cell infrastructures requires significant financial investment. Security vulnerabilities introduced by virtualization and cloud-native architectures create new cyber threats. Privacy protection, spectrum allocation, interoperability among heterogeneous devices, and energy-efficient network management remain active areas of research. Addressing these challenges is essential for realizing the full potential of the future information era.

This paper presents a comprehensive review of 5G applications, current research trends, implementation

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challenges, and future research opportunities. The objective is to provide researchers, engineers, and policymakers with a broad understanding of how 5G technologies contribute to digital transformation across multiple application domains.

A. Problem Statement

The rapid growth of the future information era, driven by Emerging digital technologies, including the Internet of Things (IoT), Artificial Intelligence (AI), and cloud computing, and smart infrastructure, demands communication networks that provide ultra-high speed, low latency, massive device connectivity, and high reliability. Existing fourth-generation (4G) and legacy wireless networks are increasingly unable to satisfy these requirements, thereby limiting the performance of real-time applications such as autonomous transportation, remote healthcare, industrial automation, and smart city services. Although 5G technology significantly improves network performance through enhanced bandwidth, intelligent resource allocation, and flexible network architectures, challenges including high deployment costs, cybersecurity risks, spectrum management, interoperability, and energy efficiency continue to restrict its widespread adoption. Consequently, there is a need for a comprehensive analysis of 5G applications, implementation challenges, and future research directions to support sustainable digital transformation in the future information era.

B. Research Objectives

1. To study the architecture and key features of 5G communication networks.
2. To analyze the applications of 5G in smart cities, healthcare, Industry 4.0, transportation, agriculture, and education.
3. To compare the capabilities of 5G with previous wireless communication technologies.
4. To identify the major technical, economic, and security challenges associated with 5G deployment.
5. To discuss future research opportunities toward intelligent 6G communication systems.

2. Literature Review

The development of 5G wireless communication has attracted extensive research interest due to its capability to support high-speed data transmission, massive connectivity, and ultra-low latency services. Researchers have investigated various enabling technologies such as millimeter-wave communication, massive Multiple Input Multiple Output (MIMO), network slicing, Software Defined Networking (SDN), Network Function Virtualization (NFV), and Multi-access Edge Computing (MEC) to satisfy the diverse requirements of future applications.

A number of studies have focused on the integration of 5G with IoT systems. Since billions of IoT devices are expected to generate large volumes of real-time data, conventional cloud-based processing introduces latency and bandwidth limitations. Multi-access Edge Computing (MEC) has been identified as an important technology that brings computation and storage capabilities closer to end users, improving response time for applications such as autonomous vehicles, augmented reality, robotics, and industrial automation.

Network slicing has also emerged as a fundamental technology in 5G networks. It enables a single physical infrastructure to support multiple virtual networks, each optimized for specific application requirements. For example, autonomous transportation requires extremely low latency and high reliability, whereas massive IoT applications require high device density and energy efficiency. Studies have investigated SDN-based and cloud-native network slicing approaches to improve flexibility, scalability, and resource utilization in 5G environments.

Research on smart city applications demonstrates that 5G provides the communication foundation required for intelligent urban infrastructure. Smart transportation, public safety, healthcare monitoring, and energy management are among the major application areas benefiting from 5G connectivity. However, researchers have highlighted challenges related to network deployment complexity, security, and management of heterogeneous devices.

The integration of Artificial Intelligence (AI) with 5G networks has become another important research direction. AI-based solutions are being explored for intelligent network optimization, traffic prediction, automated resource allocation, anomaly detection, and security enhancement. The combination of AI, IoT, and 5G is expected to create intelligent communication ecosystems capable of autonomous decision-making.

From the literature analysis, it is observed that existing studies mainly focus on individual aspects of 5G technology, such as architecture, edge computing, or specific applications. However, a comprehensive analysis combining multiple application domains with deployment challenges and future research directions is still required. This paper addresses this gap by providing an integrated review of 5G applications in the future information era.

3. 5G Network Architecture

The architecture of 5G networks is designed to provide

Table 1
Summary of existing research on 5G technologies

Reference	Research Area	Major Contribution	Identified Limitation
Pham et al.	Multi-access Edge Computing	Presented MEC architecture and integration with 5G networks	Resource management remains challenging
Shah et al.	Network Slicing and MEC	Studied cloud-native slicing frameworks for 5G	Security and orchestration issues require further research
Debbabi et al.	Network Slicing	Reviewed slicing algorithms and modeling techniques	Dynamic allocation complexity
Yang et al.	Smart Cities	Analyzed 5G-enabled smart city applications	Limited industrial deployment studies
Filali et al.	Edge Computing	Reviewed MEC frameworks and applications	Scalability challenges

flexible, scalable, and intelligent communication services compared with previous generations. Unlike traditional cellular networks that rely mainly on hardware-based infrastructure, 5G introduces a software-driven architecture using virtualization technologies, cloud computing, and intelligent network management.

A simplified 5G architecture consists of three major layers:

1. User Equipment (UE) Layer
2. Radio Access Network (RAN) Layer
3. Core Network Layer

A. User Equipment Layer

The User Equipment layer includes smartphones, IoT sensors, autonomous machines, industrial devices, and smart healthcare equipment. These devices communicate with the network through advanced wireless interfaces based on 5G New Radio (NR) technology.

The increasing number of connected devices requires efficient management of:

- Device authentication
- Energy consumption
- Data transmission
- Mobility management

B. Radio Access Network (RAN)

The 5G Radio Access Network provides wireless connectivity between user devices and the core network. It introduces several improvements over 4G systems:

1) Massive MIMO

Massive MIMO uses multiple antennas at base stations to improve spectral efficiency and increase network capacity. It enables simultaneous communication with multiple users while reducing interference.

2) Millimeter Wave Communication

5G uses higher frequency bands, including millimeter-wave spectrum, to achieve higher data rates. However, these frequencies experience greater propagation loss and require dense small-cell deployment.

3) Small Cell Networks

Small cells improve coverage and capacity by deploying low-power base stations closer to users. They are essential for supporting high-density urban environments.

C. 5G Core Network

The 5G core network provides intelligent service management and supports advanced features such as:

1) Software Defined Networking (SDN)

SDN separates network control functions from hardware devices, enabling centralized and programmable network management.

2) Network Function Virtualization (NFV)

NFV replaces dedicated hardware appliances with software-based network functions running on cloud platforms.

3) Network Slicing

Network slicing creates multiple logical networks over a common physical infrastructure. Each slice can be customized according to application requirements.

Examples:

Application	**Required Network Feature**
Autonomous Vehicles	Ultra-low latency and high reliability
Smart Healthcare	Secure and reliable communication
IoT Sensors	Massive connectivity
Video Streaming	High bandwidth

D. Multi-Access Edge Computing (MEC)

MEC is a key component of 5G architecture that reduces latency by processing data closer to users instead of sending all information to centralized cloud servers. It enables real-time applications including autonomous driving, industrial robotics, and immersive multimedia.

The combination of 5G, MEC, and AI creates an intelligent network environment capable of handling future information-era applications efficiently.

4. Applications of 5G in the Future Information Era

The future information era is characterized by the integration of intelligent technologies, connected devices, and real-time data-driven decision-making systems. 5G acts as a fundamental communication platform that enables these technologies by providing high bandwidth, ultra-low latency, high reliability, and support for massive numbers of connected devices. The following sections discuss major application areas where 5G technology is expected to create significant impact.

A. 5G Applications in Smart Cities

Smart cities aim to improve urban living by integrating digital technologies into transportation, energy management, public safety, healthcare, and infrastructure monitoring. The rapid increase in urban population requires efficient communication networks capable of handling large-scale connectivity among sensors, devices, and intelligent systems.

5G enables smart city applications through massive machine-type communication (mMTC), allowing millions of IoT devices to communicate simultaneously with low power consumption. Sensors deployed across cities can continuously collect information related to traffic conditions, air quality, waste management, electricity consumption, and public safety.

Major smart city applications supported by 5G include:

1) Intelligent Transportation Systems

5G enables real-time communication between vehicles, traffic infrastructure, and control centers. Vehicle-to-Everything (V2X) communication improves traffic management, reduces congestion, and enhances road safety.

Applications include:

- Autonomous vehicles
- Smart traffic signals
- Real-time navigation systems
- Accident prevention systems

The ultra-low latency capability of 5G is essential for autonomous vehicles because safety-critical decisions must be processed within milliseconds.

2) Smart Energy Management

Traditional power grids are being transformed into intelligent

smart grids through IoT sensors and 5G connectivity. Smart meters can transmit real-time energy consumption information, allowing efficient electricity distribution and reducing energy wastage.

5G supports:

- Remote monitoring of power systems
- Renewable energy integration
- Demand-based energy management
- Fault detection

B. 5G Applications in Smart Healthcare

Healthcare is one of the most promising sectors benefiting from 5G technology. The increasing demand for remote healthcare services requires reliable and secure communication networks capable of transmitting medical data with minimum delay.

5G enables healthcare transformation through:

1) Remote Patient Monitoring

Wearable medical devices equipped with sensors can continuously monitor patient health parameters such as:

- Heart rate
- Blood pressure
- Oxygen level
- Body temperature

The collected data can be transmitted through 5G networks to healthcare providers for real-time analysis.

2) Remote Surgery and Telemedicine

Ultra-Reliable Low-Latency Communication (URLLC) enables remote surgical operations using robotic systems. Surgeons can control robotic equipment from distant locations while receiving real-time video and sensory feedback.

Benefits include:

- Access to specialized healthcare in remote areas
- Reduced response time during emergencies
- Improved healthcare accessibility

However, security and reliability remain critical concerns because healthcare applications involve highly sensitive patient information.

C. 5G Applications in Industry 4.0

Industry 4.0 represents the transformation of manufacturing industries through automation, artificial intelligence, robotics, and cyber-physical systems. Traditional industrial networks often lack the flexibility and scalability required for modern manufacturing environments.

5G supports Industry 4.0 by providing:

- High-speed wireless connectivity
- Low communication delay
- Reliable machine-to-machine communication
- Real-time industrial monitoring

Major Industrial Applications:

1) Smart Factories

In smart factories, machines, robots, and sensors communicate continuously to optimize production processes.

5G enables:

- Automated assembly lines
- Predictive maintenance
- Real-time quality control
- Remote equipment monitoring

2) Industrial Robotics

Industrial robots require precise and fast communication. 5G allows robots to exchange information with control systems with minimal delay, improving manufacturing accuracy and productivity.

D. 5G Applications in Autonomous Transportation

Autonomous transportation systems require continuous communication between vehicles, infrastructure, pedestrians, and cloud platforms. Even a small delay in communication can affect safety.

5G supports autonomous transportation through:

1. Vehicle-to-Everything (V2X) Communication

V2X allows vehicles to communicate with:

- Other vehicles (V2V)
- Road infrastructure (V2I)
- Pedestrians (V2P)
- Network systems (V2N)

Benefits include:

- Collision avoidance
- Traffic optimization
- Improved passenger safety

2. Connected Public Transportation

5G enables intelligent transportation systems by supporting:

- Connected buses
- Smart railway systems
- Fleet management
- Real-time passenger information

E. 5G Applications in Smart Agriculture

Agriculture is increasingly adopting digital technologies to improve productivity and reduce resource consumption. 5G enables precision agriculture by connecting sensors, drones, autonomous equipment, and monitoring systems.

Applications include:

1. Precision Farming

IoT sensors collect information about:

- Soil moisture
- Temperature
- Crop health
- Weather conditions

Farmers can use this information for accurate irrigation and fertilizer management.

2. Agricultural Drones

5G-connected drones can provide:

- Crop monitoring
- Pest detection
- Field mapping
- Automated spraying

Low latency communication allows faster analysis and decision-making.

F. 5G Applications in Education and Entertainment

The education and entertainment sectors are also influenced by 5G capabilities. High-speed connectivity enables immersive and interactive digital experiences.

Applications include:

1. Virtual Reality (VR) and Augmented Reality (AR)

5G provides the bandwidth and latency required for:

- Virtual classrooms
- Remote laboratories
- Immersive training environments

2. Cloud Gaming and High-Quality Streaming

5G enables cloud-based gaming and ultra-high-definition video streaming by reducing buffering and improving user experience.

G. Summary of Applications

The integration of 5G with emerging technologies is expected to transform multiple sectors by enabling intelligent, connected, and automated systems. While each application domain has different communication requirements, 5G provides flexible network capabilities through eMBB, URLLC, and mMTC services.

However, successful implementation requires solving challenges related to security, infrastructure cost, energy efficiency, and regulatory issues. These challenges are discussed in the next section.

5. Challenges and Research Gaps in 5G Deployment

Although 5G technology provides significant improvements in communication speed, latency, connectivity, and network flexibility, its large-scale deployment introduces several technical, economic, and operational challenges. Addressing these challenges is essential for achieving the vision of a fully connected future information era. This section discusses the major challenges associated with 5G implementation and identifies important research gaps.

A. Security and Privacy Challenges

Security is one of the most critical concerns in 5G networks because of the massive increase in connected devices and the adoption of cloud-based network architectures. Unlike previous generations, 5G networks rely heavily on virtualization technologies such as Software Defined Networking (SDN), Network Function Virtualization (NFV), and cloud computing. Although these technologies improve flexibility, they also introduce new security vulnerabilities.

Major security concerns include:

1. Increased Attack Surface

The connection of billions of IoT devices creates a larger attack surface for cyber attackers. Compromised devices can be used for unauthorized access, data theft, or distributed denial-of-service (DDoS) attacks.

2. Data Privacy

5G applications such as healthcare monitoring, smart homes, and autonomous vehicles generate sensitive personal information. Protecting user data during collection, transmission, and processing is a major challenge.

3. Network Slicing Security

Although network slicing enables multiple virtual networks over a shared infrastructure, improper isolation between slices may result in security breaches. Advanced security mechanisms are required to ensure secure resource sharing.

Possible Solutions:

- Artificial Intelligence-based intrusion detection systems
- Blockchain-based authentication mechanisms
- Advanced encryption techniques
- Secure network slice management

B. Spectrum Management Challenges

5G requires a large amount of spectrum to support high data rates and massive connectivity. To achieve multi-gigabit communication, 5G utilizes different frequency bands, including sub-6 GHz and millimeter-wave (mmWave) frequencies.

However, spectrum utilization creates several challenges:

1. Limited Spectrum Availability

The increasing demand for wireless services creates competition for available frequency resources. Efficient spectrum allocation methods are required to avoid interference and improve utilization.

2. Millimeter-Wave Limitations

Although mmWave frequencies provide high bandwidth, they suffer from:

- Short communication range
- Atmospheric absorption
- Poor penetration through buildings and obstacles
- Possible Solutions:
- Dynamic spectrum sharing
- Cognitive radio techniques
- Advanced beamforming algorithms
- Intelligent spectrum management using AI

C. Infrastructure and Deployment Cost

The implementation of 5G requires major changes in existing network infrastructure. Unlike 4G systems, 5G requires dense deployment of small cells, advanced antennas, fiber backhaul networks, and edge computing facilities.

Major deployment challenges include:

Table 2
Major applications of 5G and their benefits

Application Domain	5G Technology Used	Major Benefits
Smart Cities	IoT, mMTC, Edge Computing	Efficient urban management
Healthcare	URLLC, IoT, AI	Remote diagnosis and surgery
Industry 4.0	Industrial IoT, Network Slicing	Automation and productivity improvement
Transportation	V2X Communication	Safer autonomous mobility
Agriculture	IoT Sensors, Drones	Improved crop management
Education	AR/VR, Cloud Computing	Interactive learning experience

1. High Capital Investment

Operators need significant financial resources for:

- Base station installation
- Spectrum acquisition
- Fiber connectivity
- Network upgrades

2. Rural Area Connectivity

Providing 5G coverage in rural and remote regions remains challenging due to low population density and high infrastructure costs.

Possible Solutions:

- Shared infrastructure models
- Low-cost small cell technologies
- Satellite-assisted communication
- Public-private partnerships

C. Energy Efficiency Challenges

The increasing number of connected devices and network components increases overall energy consumption. Since future networks are expected to support billions of IoT devices, energy-efficient communication is essential.

Major energy-related issues include:

- High power consumption of base stations
- Energy requirements of massive MIMO systems
- Increased data center workload
- Battery limitations of IoT devices
- Possible Solutions:
- AI-based energy optimization
- Energy-aware network management
- Renewable energy-powered base stations
- Low-power IoT communication protocols

D. Interoperability and Standardization Issues

The future information era requires communication between heterogeneous devices, networks, and applications. Ensuring interoperability among different manufacturers and technologies remains a challenge.

Important issues include:

- Compatibility between legacy and 5G networks
- Standardization of IoT communication protocols
- Integration of multiple network architectures

International standardization organizations such as 3rd Generation Partnership Project (3GPP) continue to develop specifications for global 5G deployment.

E. Artificial Intelligence Integration Challenges

Artificial Intelligence is expected to improve network automation, optimization, and security. However, integrating AI into 5G networks introduces new challenges.

Challenges include:

- Requirement for large amounts of training data
- Computational complexity
- Explainability of AI decisions
- Protection against adversarial attacks

Future intelligent networks require lightweight and trustworthy AI models capable of operating in distributed environments.

F. Research Gap Analysis

Based on the literature review and analysis of existing 5G implementations, the following research gaps have been identified as in table 3

G. Transition Toward 6G Networks

The limitations of current 5G systems have encouraged research toward sixth-generation (6G) communication networks. Future 6G systems are expected to provide:

- Terabit-per-second data rates
- Extremely low latency
- Intelligent autonomous networks
- Integrated sensing and communication
- Advanced AI-native architectures

5G serves as the foundation for these developments by introducing flexible network architectures and intelligent communication frameworks.

6. Future Research Directions

The future development of 5G networks will focus on improving intelligence, reliability, security, and sustainability. Several important research directions are discussed below.

A. AI-Enabled Autonomous Networks

Future networks will increasingly depend on Artificial Intelligence and Machine Learning techniques for automatic network configuration, fault detection, and resource optimization.

AI-based network management can enable:

- Self-organizing networks
- Predictive maintenance
- Intelligent traffic management
- Automated security response

B. Integration of Edge Intelligence

Edge computing will continue to evolve by bringing artificial intelligence processing closer to users. This will reduce latency and improve performance for real-time applications.

Potential applications include:

- Autonomous vehicles
- Industrial robots

Table 3
Research gap analysis

Research Area	Existing Limitation	Required Future Improvement
Network Security	Increasing cyber threats due to virtualization	AI-driven security and privacy mechanisms
Network Slicing	Efficient resource allocation remains difficult	Intelligent automated slice management
Edge Computing	Limited scalability for large-scale applications	Distributed edge intelligence
Energy Efficiency	High power consumption of infrastructure	Green communication technologies
Rural Connectivity	Expensive deployment requirements	Affordable and sustainable solutions
AI Integration	Limited transparency of AI decisions	Explainable and secure AI models

- Smart healthcare systems
- Augmented reality applications

C. *Green and Sustainable 5G Networks*

Future communication systems must reduce energy consumption and environmental impact. Research efforts are focusing on:

- Energy-efficient hardware
- Renewable-powered communication systems
- Intelligent power management
- Low-energy IoT devices

D. *Advanced Security Frameworks*

Future 5G and 6G networks require stronger security mechanisms to protect increasingly connected systems.

Research areas include:

- Blockchain-based security
- Quantum-resistant encryption
- AI-driven threat detection
- Privacy-preserving communication

E. *Integration with Emerging Technologies*

Future 5G ecosystems will integrate with:

- Digital twins
- Autonomous systems
- Extended Reality (XR)
- Intelligent transportation
- Smart manufacturing

This integration will create highly connected and intelligent environments.

7. Conclusion

The emergence of 5G technology represents a significant advancement in wireless communication and provides the foundation for the future information era. Unlike previous generations of mobile networks, 5G is designed to support diverse communication requirements through enhanced mobile broadband (eMBB), ultra-reliable low-latency communication (URLLC), and massive machine-type communication (mMTC). These capabilities enable the development of intelligent applications involving billions of connected devices, real-time data processing, and automated decision-making.

This paper presented a comprehensive review of 5G technology, including its architecture, enabling technologies, applications, challenges, and future research directions. The study highlighted how 5G contributes to various domains such as smart cities, healthcare, Industry 4.0, autonomous transportation, agriculture, and education. Technologies such as network slicing, edge computing, massive MIMO, millimeter-wave communication, and artificial intelligence provide the necessary infrastructure for supporting these emerging applications.

Despite its advantages, widespread adoption of 5G still faces several challenges. Security threats, privacy concerns, high infrastructure costs, spectrum limitations, energy consumption, and interoperability issues require further research and innovation. Effective solutions involving artificial intelligence, advanced security mechanisms, sustainable network design, and intelligent resource management are necessary to overcome these limitations.

Future communication systems will increasingly depend on the integration of 5G with emerging technologies such as artificial intelligence, digital twins, extended reality, and autonomous systems. Furthermore, the evolution toward 6G networks will build upon the capabilities introduced by 5G to achieve highly intelligent, secure, and sustainable communication environments.

In conclusion, 5G serves as a critical enabling technology for digital transformation in the future information era. Continued research and collaboration among researchers, industries, and policymakers will be essential to maximize the benefits of 5G and prepare communication networks for future generations.

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 Commun. Surv. Tuts.*, vol. 18, no. 3, pp. 1617–1655, 3rd Quart., 2016.

[3] W. Xiang, K. Zheng, and X. S. Shen, Eds., *5G Mobile Communications*. Cham, Switzerland: Springer, 2017.

[4] J. G. Andrews *et al.*, "What will 5G be?" *IEEE J. Sel. Areas Commun.*, vol. 32, no. 6, pp. 1065–1082, Jun. 2014.

[5] P. Schulz *et al.*, "Latency critical IoT applications in 5G: Perspective on the design of ultra-reliable and low-latency communications," *IEEE Commun. Mag.*, vol. 55, no. 2, pp. 70–78, Feb. 2017.

[6] M. Bennis, M. Debbah, and H. V. Poor, "Ultrasmall cell networks: A paradigm shift in 5G," *IEEE Commun. Mag.*, vol. 52, no. 12, pp. 67–73, Dec. 2014.

[7] S. Mumtaz, J. Rodriguez, and R. L. Aguiar, "Millimeter wave communications for 5G: A technical overview," *IEEE Commun. Mag.*, vol. 52, no. 9, pp. 40–46, Sep. 2014.

[8] T. Taleb *et al.*, "On multi-access edge computing: A survey of the emerging 5G network edge cloud architecture," *IEEE Commun. Surv. Tuts.*, vol. 19, no. 3, pp. 1657–1681, 3rd Quart., 2017.

[9] Y. Mao, C. You, J. Zhang, K. Huang, and K. B. Letaief, "A survey on mobile edge computing: The communication perspective," *IEEE Commun. Surv. Tuts.*, vol. 19, no. 4, pp. 2322–2358, 4th Quart., 2017.

[10] X. Foukas, G. Patounas, A. Elmokashfi, and M. K. Marina, "Network slicing in 5G: Survey and challenges," *IEEE Commun. Mag.*, vol. 55, no. 5, pp. 94–100, May 2017.

[11] NGMN Alliance, "5G white paper," Next Generation Mobile Networks Alliance, Frankfurt, Germany, Tech. Rep., Feb. 2015. [Online]. Available: https://www.ngmn.org/wp-content/uploads/NGMN_5G_White_Paper_V1_0.pdf

[12] 3rd Generation Partnership Project (3GPP), "System architecture for the 5G System (5GS)," 3GPP Technical Specification 23.501, Rel. 15, 2017. [Online]. Available: https://www.3gpp.org/dynareport/23501.htm

[13] E. Hossain and M. Hasan, "5G cellular: Key enabling technologies and research challenges," *IEEE Instrum. Meas. Mag.*, vol. 18, no. 3, pp. 11–21, Jun. 2015.

[14] H. Viswanathan and P. E. Mogensen, "Communications in the 6G era," *IEEE Access*, vol. 8, pp. 57073–57089, 2020.

[15] F. Tariq *et al.*, "A speculative study on 6G," *IEEE Wireless Commun.*, vol. 27, no. 4, pp. 118–125, Aug. 2020.

[16] C. Zhang *et al.*, "Deep learning for wireless communications: A comprehensive survey," *IEEE Commun. Surv. Tuts.*, vol. 22, no. 4, pp. 2837–2887, 4th Quart., 2020.

[17] M. Chen *et al.*, "Artificial intelligence meets 5G networks," *IEEE Netw.*, vol. 32, no. 6, pp. 46–53, Nov./Dec. 2018.

[18] H. Zhang *et al.*, "Network slicing based 5G and future mobile networks: Mobility, resource management, and challenges," *IEEE Commun. Mag.*, vol. 55, no. 8, pp. 138–145, Aug. 2017.

[19] P. Popovski *et al.*, "Wireless access in ultra-reliable low-latency communication systems," *IEEE Trans. Commun.*, vol. 67, no. 8, pp. 5783–5801, Aug. 2019.

[20] K. Zheng *et al.*, "5G wireless communication systems: Prospects and challenges," *IEEE Wireless Commun.*, vol. 23, no. 3, pp. 2–5, Jun. 2016.