

AI + 6G Networks for Smart Connectivity

Ritika S. Verma¹, Sonu S Lohiya², Chetan Sriwastav³

Students^{1,2}, Associate Professor³

Department of CSE

KLS Gogte Institute of Technology

Email ID: *Ritikasverma02@rediffmail.com¹, lohiyasonu_ss@yahoo.com², chetansriwasta040v@gmail.com³*

ABSTRACT

The evolution of wireless communication is entering a new phase with the development of sixth-generation (6G) networks, which aims to provide ultra-high data rates, near-zero latency, and seamless connectivity for intelligent applications. Artificial Intelligence (AI) is expected to play a central role in enabling smart connectivity by optimizing network operations, managing spectrum efficiently, and supporting autonomous decision-making in future communication environments. This paper presents a comprehensive review of the integration of AI techniques with 6G network architectures to achieve smart connectivity. It discusses enabling technologies, architecture frameworks, AI-driven networking functions, application domains, and challenges. Additionally, comparative analysis and future research directions are presented. The study concludes that AI-native 6G networks will form the backbone of next-generation smart societies, enabling applications such as autonomous systems, immersive communication, and intelligent Internet of Things (IoT).

KEYWORDS: *6G networks, artificial intelligence, smart connectivity, intelligent communication, wireless networks, AI-driven networking*

INTRODUCTION

The increasing demand for ubiquitous connectivity, intelligent services, and real-time digital interaction is pushing wireless networks beyond the capabilities of 5G. Emerging applications such as autonomous vehicles, holographic communication, tactile internet, and massive IoT require communication systems that are not only fast but also intelligent and adaptive. Sixth-

generation (6G) networks are envisioned to address these requirements by integrating advanced communication technologies with artificial intelligence.

Unlike earlier generations, 6G networks are expected to be AI-native, meaning intelligence will be embedded into the network fabric rather than added as an external component. AI can enable networks to learn from data, predict traffic patterns, optimize routing decisions, and autonomously manage resources. Such capabilities lead to the concept of smart connectivity, where devices, services, and users are seamlessly connected through intelligent communication infrastructure.

EVOLUTION TOWARD 6G NETWORKS

Wireless communication technology has progressed through several generations over the past four decades, with each generation introducing new capabilities and addressing the limitations of previous systems. This evolution reflects the increasing demand for higher data rates, wider coverage, lower latency, and more intelligent network services. The transition from 2G to 6G shows a shift from simple voice connectivity to fully intelligent and autonomous communication environments.

1. Second Generation (2G): Digital Voice Communication

Second-generation (2G) systems marked the transition from analog to digital cellular communication. Technologies such as GSM enabled reliable digital voice transmission, improved spectral efficiency, and enhanced security through encryption. Short Message Service (SMS) also emerged during this generation, allowing basic text communication between users.

However, 2G networks were primarily designed for voice services and had very limited data capabilities, typically below 100 kbps. Multimedia services and internet connectivity were not practical in this generation.

2. Third Generation (3G): Mobile Internet and Multimedia

Third-generation (3G) networks introduced mobile data services and enabled the early mobile internet experience. Technologies such as UMTS and CDMA2000 allowed data rates up to a

few Mbps, supporting applications like web browsing, video calling, and multimedia messaging.

3G represented a major step toward mobile computing, but it still faced challenges including high latency, limited bandwidth, and inefficient handling of rapidly growing data traffic. As smartphones and mobile applications expanded, the need for faster broadband mobile networks became clear.

3. Fourth Generation (4G): Mobile Broadband Era

Fourth-generation (4G) systems, particularly LTE and LTE-Advanced, transformed mobile communication into a true broadband platform. With data rates reaching hundreds of Mbps, 4G enabled high-definition video streaming, cloud services, mobile gaming, and app-based ecosystems.

4G networks introduced packet-switched architecture and all-IP networking, improving efficiency and reducing latency compared to 3G. This generation supported the explosive growth of smartphones and digital services worldwide.

Despite its success, 4G was mainly optimized for human-centric communication (human-to-human and human-to-content). It was not designed for large-scale machine communication or ultra-reliable real-time control systems.

4. Fifth Generation (5G): Intelligent Connectivity and Massive IoT

Fifth-generation (5G) networks expanded communication beyond mobile broadband to include machine-type communication and mission-critical services. 5G introduced three major service categories:

- Enhanced Mobile Broadband (eMBB)
- Ultra-Reliable Low-Latency Communication (URLLC)
- Massive Machine-Type Communication (mMTC)

These capabilities enabled applications such as smart cities, connected vehicles, remote surgery, and industrial automation. Technologies such as millimeter-wave spectrum, massive MIMO, and network slicing improved capacity and flexibility.

5G also began incorporating artificial intelligence for tasks like traffic prediction, network optimization, and anomaly detection. However, AI in 5G is mostly applied as an add-on feature rather than being deeply embedded into network architecture.

5. Limitations of 5G Networks

Although 5G represents a major advancement, several limitations remain that restrict its ability to support future intelligent services and global digital ecosystems.

a) Network Congestion in Dense Environments

Urban areas, stadiums, and large-scale events create extremely high device density. Even with small cells and mmWave spectrum, maintaining consistent performance under such density is challenging.

b) Limited Spectrum Efficiency

5G still relies heavily on sub-6 GHz and millimeter-wave bands, which have finite bandwidth. Spectrum scarcity and interference issues limit scalability for future ultra-high data applications.

c) High Energy Consumption

Massive MIMO, dense base station deployment, and continuous connectivity significantly increase energy demand. Sustainable and green networking remains a major concern.

d) Insufficient Support for AI-Native Services

Future applications such as autonomous systems, digital twins, and holographic communication require networks that can learn, adapt, and make decisions in real time. 5G networks are not fully designed for AI-native operation or distributed intelligence.

e) Limited Integration of Sensing and Communication

5G primarily focuses on data transmission, whereas future systems need simultaneous sensing, localization, and environmental awareness capabilities.

These limitations indicate that a new communication paradigm is required, leading to the concept of 6G.

6. Vision and Requirements of 6G Networks

Sixth-generation (6G) networks aim to create a fully intelligent and immersive communication environment connecting humans, machines, and digital worlds. The key performance targets of 6G significantly exceed those of 5G:

- Peak data rates up to 1 Tbps

- End-to-end latency below 1 millisecond
- Sub-centimeter localization accuracy
- Massive device density (10^7 devices/km²)
- Ultra-high reliability (99.99999%)

6G will extend communication into new domains including terahertz spectrum, satellite-air-ground integration, and AI-driven network automation. Unlike previous generations, 6G is expected to integrate communication, sensing, computing, and intelligence into a unified platform.

ENABLING TECHNOLOGIES OF 6G FOR SMART CONNECTIVITY

The realization of smart connectivity in 6G networks depends on several advanced communication and computing technologies working together with artificial intelligence. These enabling technologies extend beyond conventional wireless communication and introduce new capabilities such as ultra-high-frequency transmission, programmable environments, integrated sensing, distributed intelligence, and quantum-level security. Each of these technologies contributes to the performance, intelligence, and adaptability required for next-generation connectivity systems.

1. Terahertz Communication

Terahertz (THz) communication is considered one of the core technologies of 6G networks due to its ability to provide extremely large bandwidth and ultra-high data rates. The terahertz spectrum ranges approximately from 0.1 THz to 10 THz, positioned between microwave and infrared frequencies. Compared to millimeter-wave bands used in 5G, THz bands offer significantly wider contiguous spectrum, enabling wireless links with terabit-per-second capacity.

Such extremely high data rates are necessary for emerging applications including holographic communication, immersive extended reality, and ultra-high-resolution sensing systems. However, THz communication faces several technical challenges. Signal attenuation at THz frequencies is very high due to molecular absorption, atmospheric losses, and blockage by obstacles. Coverage range is therefore limited, and reliable communication requires highly directional transmission and precise beam alignment.

Artificial intelligence plays an important role in overcoming these limitations. AI-based beamforming algorithms can dynamically adjust antenna arrays to maintain directional links even in mobile environments. Machine learning models can also estimate THz channel characteristics, which are highly variable and difficult to model using conventional methods. AI can predict blockage events, optimize beam tracking, and adapt transmission parameters in real time, improving reliability and efficiency of THz communication systems.

Thus, THz communication combined with AI enables ultra-high-speed short-range wireless connectivity, forming the backbone for indoor and hotspot 6G services.

2. Intelligent Reflecting Surfaces (IRS)

Intelligent Reflecting Surfaces (IRS), also called reconfigurable intelligent surfaces, are programmable meta-materials capable of manipulating electromagnetic waves in a controlled manner. An IRS consists of many passive reflecting elements whose phase, amplitude, or polarization properties can be electronically adjusted. By configuring these elements, wireless signals can be reflected toward desired directions, effectively shaping the radio propagation environment.

Traditional wireless systems treat the environment as uncontrollable, and signal quality depends on obstacles, fading, and interference. IRS technology transforms the environment into a controllable component of the communication system. This capability can improve coverage in shadowed areas, enhance signal strength, reduce interference, and increase energy efficiency by redirecting signals instead of transmitting with higher power.

AI is essential for optimizing IRS operation because the configuration space of reflecting elements is extremely large and depends on dynamic environmental conditions. Machine learning algorithms can determine optimal reflection coefficients based on user location, channel conditions, and network requirements. Reinforcement learning can continuously adapt IRS parameters to maximize signal quality or minimize interference.

In smart connectivity scenarios such as smart cities or indoor environments, AI-controlled IRS panels can be deployed on buildings or infrastructure to create programmable wireless

coverage zones. This approach reduces infrastructure cost while improving connectivity performance, making IRS a key technology for future 6G networks.

3. Integrated Sensing and Communication (ISAC)

Integrated Sensing and Communication (ISAC) represents a paradigm shift where wireless networks perform both data communication and environmental sensing simultaneously using shared signals and hardware. In conventional systems, sensing (e.g., radar, localization) and communication operate separately. 6G aims to merge these functions to achieve efficient spectrum usage and enhanced situational awareness.

ISAC enables devices and networks to detect object location, motion, velocity, and environmental characteristics while transmitting information. This capability supports applications such as autonomous driving, drone navigation, smart surveillance, and industrial automation. For example, a 6G base station can track vehicle movement while also providing communication links, eliminating the need for separate radar systems.

Artificial intelligence is crucial for processing the large volume of sensing data generated by ISAC systems. AI algorithms can fuse sensing and communication information to optimize beamforming, resource allocation, and interference mitigation. Context-aware AI models can adapt communication parameters based on detected environmental conditions, such as obstacles or user movement.

Furthermore, AI-enabled ISAC allows networks to become perception-aware, meaning they understand the physical world around connected devices. This perception capability is fundamental for smart connectivity, where communication decisions depend on environmental context and user behavior.

4. Edge Intelligence

Edge intelligence refers to the deployment of artificial intelligence processing capabilities at the network edge, close to end devices and users. In 6G networks, edge nodes such as base stations, access points, and gateways will include computing resources capable of running AI models locally. This approach reduces latency, bandwidth consumption, and dependence on centralized cloud processing.

Real-time applications such as autonomous vehicles, industrial control, and remote healthcare require immediate decision-making that cannot rely solely on distant cloud servers. Edge intelligence enables local processing of sensor data, user context, and network conditions, allowing fast and autonomous responses.

Examples of edge AI functions in 6G include:

- Traffic prediction and congestion control
- Local resource allocation
- Anomaly and intrusion detection
- Mobility prediction
- Context-aware service adaptation

Edge intelligence also supports federated learning, where distributed devices collaboratively train AI models without sharing raw data. This improves privacy and scalability while enabling continuous learning across the network.

In smart connectivity ecosystems, edge intelligence ensures that devices and services remain responsive and adaptive even under dynamic conditions. It also distributes computational load efficiently across the network hierarchy (device–edge–cloud), improving overall system performance.

5. Quantum Communication and Security

Security and privacy are critical requirements for future 6G networks due to the massive scale of connected devices and sensitive applications such as healthcare, finance, and autonomous infrastructure. Quantum communication technologies, particularly quantum key distribution (QKD), are expected to provide fundamentally secure communication based on quantum physics principles rather than computational complexity.

Quantum cryptography allows secure key exchange that is theoretically immune to eavesdropping, since any interception attempt alters the quantum state and becomes detectable. Integrating quantum communication into 6G networks can enable ultra-secure links for critical data transmission across terrestrial and satellite networks.

However, quantum channels are fragile and sensitive to noise, loss, and environmental disturbances. Managing quantum communication networks requires precise control and monitoring. Artificial intelligence can assist in optimizing quantum channel selection, predicting channel degradation, and detecting anomalies or attacks in quantum communication systems. AI can also coordinate hybrid classical-quantum networks where conventional and quantum links operate together.

In addition, AI-based cybersecurity techniques are necessary to protect 6G infrastructure from advanced threats such as AI-driven cyberattacks, data poisoning, and adversarial interference. Combining quantum security with AI-based threat detection provides a multi-layered defense strategy for smart connectivity environments.

AI-DRIVEN NETWORKING FUNCTIONS IN 6G

Artificial intelligence is expected to be deeply embedded across all layers of 6G networks, transforming network management from static rule-based configuration to dynamic data-driven decision making. Traditional wireless networks rely on predefined algorithms and manual optimization, which becomes inefficient in highly complex and heterogeneous 6G environments involving terahertz links, dense devices, and integrated sensing.

AI enables networks to learn from traffic patterns, environmental conditions, and user behavior, allowing autonomous adaptation and optimization. Major AI-driven networking functions that enable smart connectivity in 6G are described below.

1. Intelligent Resource Allocation

Efficient allocation of wireless resources such as spectrum, transmission power, bandwidth, and time slots is a fundamental challenge in communication networks. In 6G, the scale and diversity of connected devices, services, and frequency bands make static allocation strategies inadequate. AI-based resource allocation allows networks to dynamically distribute resources according to real-time demand and predicted conditions.

Machine learning models can analyze historical traffic data and predict future network load across different locations and time periods. Based on these predictions, the network can proactively allocate spectrum and bandwidth to avoid congestion. Deep reinforcement learning

is particularly suitable for resource management because it can learn optimal allocation policies through interaction with dynamic network environments.

For example, an AI agent deployed at a base station can continuously observe user density, channel quality, and service requirements, and adjust transmission power or bandwidth accordingly. In terahertz communication scenarios, AI can allocate directional beams and frequency blocks to maximize throughput while minimizing interference.

Thus, intelligent resource allocation improves spectrum efficiency, energy efficiency, and quality of service, which are critical for smart connectivity applications such as XR streaming and industrial automation.

2. Self-Organizing Networks

Self-organizing networks (SON) refer to communication systems capable of autonomous configuration, optimization, and healing without human intervention. While SON concepts were introduced in 4G and partially adopted in 5G, 6G networks require much more advanced autonomy due to their complexity and scale. AI provides the intelligence required to realize fully autonomous networks.

AI-enabled SON functions include:

- Automatic network deployment and configuration
- Adaptive parameter tuning (power levels, frequency reuse, beam patterns)
- Congestion prediction and mitigation
- Fault detection and self-healing

Machine learning models can monitor network performance indicators such as latency, packet loss, and signal strength. When abnormal patterns are detected, AI can identify root causes such as hardware failure, interference, or traffic overload. The network can then automatically reconfigure itself, for example by activating backup nodes, adjusting transmission parameters, or redistributing traffic.

In dense 6G environments such as smart cities or industrial campuses, manual management of thousands of nodes becomes impractical. AI-driven SON ensures continuous service availability and optimal performance, enabling reliable smart connectivity infrastructure.

3. Predictive Mobility Management

Mobility management is critical in wireless networks because users and devices frequently move across coverage areas. Traditional handover mechanisms react to signal degradation after it occurs, which introduces latency and packet loss. In 6G, applications such as autonomous vehicles, drones, and high-speed trains require seamless connectivity with near-zero interruption.

AI enables predictive mobility management by forecasting user movement patterns based on historical location data, trajectory models, and contextual information such as time, traffic conditions, or user behavior. By predicting where a device will move next, the network can proactively reserve resources and prepare target base stations before the actual handover occurs.

For example, in vehicle-to-everything communication, AI models can predict a vehicle's path along roads and allocate communication channels along the route. This reduces handover delay and ensures continuous low-latency connectivity required for autonomous driving decisions. Predictive mobility management also reduces signaling overhead and improves energy efficiency, since unnecessary handovers and scanning operations can be avoided. This capability is essential for smart connectivity scenarios involving highly mobile devices and mission-critical communication.

4. Intelligent Routing and Traffic Control

Routing in 6G networks becomes significantly more complex due to heterogeneous architectures including terrestrial, aerial, satellite, and device-to-device links. Selecting optimal communication paths requires considering latency, bandwidth, reliability, energy consumption, and network congestion simultaneously. Static routing protocols cannot efficiently handle such dynamic and multi-layered environments.

AI-based routing uses machine learning to analyze network topology and traffic conditions in real time. Models can predict congestion levels, link quality variations, and traffic demands across different routes. Based on these predictions, the network selects optimal paths that minimize delay and maximize throughput.

Reinforcement learning can also be applied to adaptive routing, where network nodes learn routing policies through continuous interaction with network conditions. Such AI-driven routing enables:

- Load balancing across multiple paths
- Congestion avoidance
- Latency-aware path selection
- Energy-efficient communication

In integrated space-air-ground 6G architectures, intelligent routing is particularly important because data may travel across satellites, drones, and terrestrial nodes. AI ensures seamless and efficient traffic flow across these heterogeneous layers, supporting global smart connectivity.

5. Security and Anomaly Detection

Security is a major concern in 6G networks due to the massive number of connected devices, critical services, and open heterogeneous architectures. Traditional rule-based security mechanisms struggle to detect sophisticated cyberattacks such as distributed denial-of-service, spoofing, intrusion, and adversarial interference. AI-driven security provides adaptive and proactive protection mechanisms.

Machine learning and deep learning models can analyze network traffic patterns and identify anomalies that deviate from normal behavior. These anomalies may indicate cyberattacks, device compromise, or network malfunction. Unlike signature-based detection, AI can detect previously unseen threats by learning behavioral patterns.

AI-based security functions in 6G include:

- Intrusion detection and prevention
- Malware and botnet detection
- Jamming and interference identification
- Authentication and access control optimization

- Trust management in distributed networks

For example, in IoT-dense smart environments, AI can identify compromised devices generating abnormal traffic and isolate them automatically. In terahertz communication, AI can detect signal manipulation or spoofing attempts by analyzing channel characteristics.

However, AI models themselves can be attacked through adversarial inputs or data poisoning. Therefore, secure and robust AI techniques are required to ensure trustworthy AI-driven networking.

AI-NATIVE 6G NETWORK ARCHITECTURE

Future 6G architecture integrates AI across all network layers.

1. AI-Embedded Physical Layer

AI assists in modulation selection, channel estimation, and beamforming. Neural networks can approximate optimal communication strategies in complex environments.

2. AI-Enabled Network Layer

Routing, congestion control, and topology optimization are managed through machine learning models. Networks become adaptive to traffic changes and device density.

3. AI-Driven Application Layer

Applications interact directly with AI-managed network services. For example, autonomous vehicles request ultra-reliable connectivity with guaranteed latency.

4. Cloud-Edge-Device Intelligence Hierarchy

6G networks distribute AI processing across:

- Cloud: global optimization and training
- Edge: local decision making
- Device: real-time inference

This hierarchical intelligence ensures scalability and efficiency.

SMART CONNECTIVITY APPLICATIONS ENABLED BY AI + 6G

1. Autonomous Transportation

6G supports vehicle-to-everything (V2X) communication with ultra-low latency. AI predicts traffic and coordinates vehicles. Smart connectivity ensures safe autonomous driving.

2. Smart Cities

Sensors, cameras, and infrastructure devices generate massive data. AI-driven 6G networks manage traffic lights, energy grids, waste systems, and public safety services in real time.

3. Extended Reality (XR) and Holographic Communication

Immersive applications require gigabit data rates and minimal latency. AI optimizes network resources for high-quality AR/VR streaming and holographic presence.

4. Industrial Automation

Industry 4.0 systems rely on machine-to-machine communication. 6G enables real-time control of robots and production systems. AI predicts equipment failure and optimizes manufacturing processes.

5. Intelligent Healthcare

Remote surgery, wearable health monitoring, and medical robotics depend on reliable connectivity. AI-enabled 6G networks support real-time medical data transmission and diagnostics.

COMPARATIVE ANALYSIS: 5G VS 6G WITH AI INTEGRATION

Table 1: Comparison of 5G and AI-enabled 6G networks

Feature	5G Networks	AI-Driven 6G Networks
Peak Data Rate	20 Gbps	1 Tbps
Latency	1–10 ms	<1 ms
Intelligence	Limited AI support	AI-native
Spectrum	Sub-6 GHz & mmWave	THz + mmWave
Network Management	Semi-automated	Fully autonomous
Connectivity	Human-centric	Smart environment-centric
Applications	Mobile broadband, IoT	XR, holographic, autonomous systems

CHALLENGES IN AI-ENABLED 6G SMART CONNECTIVITY

1. Data Availability and Privacy

AI models require large datasets for training. Network data may contain sensitive user information, raising privacy concerns. Secure federated learning approaches are required.

2. Computational Complexity

AI algorithms demand high computational resources, especially deep learning models. Deploying them across large-scale networks can be costly.

3. Energy Consumption

AI processing and THz communication increase energy usage. Energy-efficient AI models and green communication strategies are necessary.

4. Standardization and Interoperability

6G standards are still under development. Integrating AI into communication protocols requires global coordination and compatibility across vendors.

5. Security Risks

AI models themselves can be attacked (adversarial attacks, data poisoning). Protecting AI-driven networks becomes critical.

FUTURE RESEARCH DIRECTIONS

1. AI-Native Protocol Design

Future communication protocols will embed learning capability directly into network operations. Networks will adapt automatically to new devices and environments.

2. Distributed and Federated Intelligence

Training AI models across distributed devices without sharing raw data can preserve privacy while improving learning.

3. Semantic Communication

Instead of transmitting raw data, networks will transmit meaning or intent. AI interprets and reconstructs information, reducing bandwidth requirements.

4. Digital Twin Networks

Virtual replicas of physical networks allow simulation and optimization using AI before deployment. This improves reliability and planning.

5. Human-Centric Connectivity

6G networks will consider human perception, cognition, and context to optimize communication experience. AI models will adapt connectivity to user needs.

CONCLUSION

The integration of artificial intelligence with 6G networks represents a transformative step toward smart connectivity. AI enables networks to become intelligent, autonomous, and adaptive, addressing the complexity and performance demands of future communication systems. Enabling technologies such as terahertz communication, intelligent reflecting surfaces, edge intelligence, and integrated sensing contribute to ultra-high-speed and reliable connectivity. AI-driven networking functions including resource allocation, routing, mobility management, and security provide efficient and resilient communication infrastructure.

Smart connectivity applications across transportation, healthcare, industry, and immersive communication demonstrate the societal impact of AI-enabled 6G networks. However, challenges related to data privacy, computational cost, energy consumption, and standardization must be addressed. Future research in AI-native protocols, semantic communication, federated intelligence, and digital twin networks will further advance this field.

In conclusion, AI-driven 6G networks will form the backbone of next-generation digital ecosystems, enabling intelligent connectivity for smart societies and autonomous systems.

REFERENCES

1. Saad, W., Bennis, M., & Chen, M. (2020). A vision of 6G wireless systems. *IEEE Network*, 34(3), 134-142.
2. Letaief, K. B., Chen, W., Shi, Y., Zhang, J., & Zhang, Y. J. (2019). The roadmap to 6G. *IEEE Communications Magazine*, 57(12), 84-90.
3. Zhang, Z., Xiao, Y., Ma, Z., et al. (2019). 6G wireless networks: Vision and requirements. *IEEE Vehicular Technology Magazine*, 14(3), 28-41.
4. Yang, P., Xiao, Y., Xiao, M., & Li, S. (2020). 6G wireless communications: Vision and potential techniques. *IEEE Network*, 33(4), 70-75.
5. Strinati, E. C., Barbarossa, S., et al. (2019). 6G: The next frontier. *IEEE Vehicular Technology Magazine*, 14(3), 42-50.
6. Mao, Q., Hu, F., & Hao, Q. (2018). Deep learning for intelligent wireless networks. *IEEE Wireless Communications*, 25(4), 52-57.
7. Chen, M., Saad, W., Yin, C., Debbah, M., & Hong, C. (2020). Artificial intelligence in

- 6G. *IEEE Communications Magazine*, 58(3), 126-132.
8. Dang, S., Amin, O., Shihada, B., & Alouini, M. (2020). What should 6G be? *Nature Electronics*, 3(1), 20-29.
9. Jiang, W., Han, B., Habibi, M. A., & Schotten, H. D. (2021). The road toward 6G: AI-empowered wireless networks. *IEEE Network*, 35(6), 147-153.
10. Gui, G., Liu, M., Tang, F., et al. (2021). AI-enabled 6G communications. *IEEE Wireless Communications*, 28(6), 10-17.