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Comparative Analysis Of 5G And 6G Technologies In Wireless Cellular Networks, Future Expectations

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ABSTRACT

The increased usage of mobile smartphones has accelerated the global development of wireless telecommunications networks. This expansion has fueled the advancement of wireless technologies, from 0G to the forthcoming 6G. Since the birth of mobile communications, a new generation of cellular technology has been released every decade, radically changing worldwide connectivity. While the fifth generation (5G) of wireless technology has significantly improved bandwidth, latency, and device density, new data demands and complicated network topologies have begun to reveal its fundamental limits. As the industry prepares for the sixth generation (6G), the emphasis shifts from straightforward speed gains to native network intelligence, decentralized trust models, and uncoordinated access protocols. This article conducts a thorough comparison of 5G and 6G cellular networks across a variety of crucial parameters, including spectrum efficiency, security architectures, and edge artificial intelligence (AI). This paper illustrates the key architectural alterations necessary to migrate from 5G's centralized, connection-oriented paradigms to 6G's highly autonomous, decentralized, and intelligent ecosystems by presenting a structured assessment approach.

Keywords: GSM, Cellular Networks, 5G, 6G, Massive MIMO, Long Term Evolution (LTE), Radio Access Technology (RAT), Modern Communication Technology

1 INTRODUCTION

Since the advent of mobile telephony that was used to replace fixed telephony, there have been a tremendous improvement in the various generations that was developed, starting from the first generation (1G) in the 1970s, that operates mainly on analogue mode for voice calls, and later the second generation (2G), and then the third generation (3G) was introduced as an improvement to 1G, with the introduction of digital mode of communication. The fourth and fifth generations (4G and 5G) followed up in the order as an improvement not only in voice services, but also greater speed in data streaming and internet services. Table 1.1 gives a summary of various generations of wireless networks (1G to 5G), and now 6G that is being considered to integrate the used of artificial intelligence (AI).

Table 1.1: Summary of Generations of Wireless Network (1G to 5G) (Sahoo *et al*, 2014).

Generation→ Features↓	**1G**	**2G**	**3G**	**4G**	**5G**
Deployment	1970 – 1980	1990 - 2001	2001-2010	2011	2015-20 onwards
Data Rates	2kbps	14.4-64kbps	2Mbps	200 Mbps to 1 Gbps	1Gbps and higher
Technology	Analog Cellular Technology	Digital Cellular Technology: Digital narrow band circuit data Packet data	Digital Broadband Packet data: CDMA 2000 EVDO UMTS EDGE	Digital Broadband Packet data: WiMax LTE Wi-Fi	wwww Unified IP seamless combination of broadband LAN PAN MAN WLAN
Service	Analog voice service No data service	Digital voice with higher clarity SMS, MMS Higher capacity packetized data	Enhanced audio video streaming video conferencing support Web browsing at higher speeds IPTV support	Enhanced audio, video streaming IP telephony HD mobile TV	Dynamic Information access, Wearable devices with AI Capabilities
Multiplexing Switching	FDMA	TDMA, CDMA	CDMA	CDMA	CDMA
Core Networks	PSTN	PSTN	Packet N/W	Internet	Internet
Standards	MTS AMTS IMTS	2G: GSM 2.5: GPRS 2.75: EDGE	IMT-2000 3.5G-HSDPA 3.75G: HSUPA	Single unified standard LTE, WiMAX	Single unified standard
WEB Standard		www	www (IPv4)	www (IPv4)	wwww (IPv6)
Handoff	Horizontal only	Horizontal only	Horizontal & Vertical	Horizontal & Vertical	Horizontal
Shortfalls	Low capacity, Unreliable handoff, Poor voice links, less secure	Digital signals were reliant on location & proximity, required strong digital signals to help mobile phones	Need to accommodate higher network capacity	Being deployed	Yet to be implemented

The Third Generation Partnership Project (**3GPP**), an industry organization, is responsible for designing and maintaining standards for mobile communication technology. Their success began with GSM standards and has continued through UMTS, HSDPA, HSUPA, LTE, LTE-Advanced, 5G NR, and now 6G. Each of these standards supports distinct wireless technologies, resulting in differing data speeds, coverage regions, subscriber densities, and unique advanced features (services) for consumers. In the year 1998, the 3rd Generation Partnership Project (3GPP) was established to standardize 3G cellular networks and other standards in future. Table 1.2 summarizes 3GPP releases and their main features up to 5G.

Table 1.2: 3GPP Project (Balapuwaduge and Li, 2018)

3GPP Release	Start / Release Date	Summary of Key Features
R99	1996/2000	First release of the UMTS standard
R4	1998/2001	This release added features including an all-IP core network. It was originally referred to as Release 2000
R5	2000/2002	IP Multimedia Subsystem and High-Speed Downlink Packet Access (HSDPA)
R6	2000/2004	Integrate the operation of UMTS with wireless LAN networks and added enhancements to IMS (including Push to talk over Cellular), and it added High Speed Uplink Packet Access
R7	2003/2007	Detailed improvements to QoS for applications such as VoIP and upgrades for High-Speed Packet Access Evolution, HSPA+, as well as changes for EDGE Evolution.
R8	2006/2008	Provide details for the LTE System Architecture Evolution, SAE, an all-IP flat network architecture providing the capacity and low latency required for Long Term Evolution (LTE)
R9	2008/2009	Further enhancements to the SAE as well as allowing for WiMax and LTE/UMTS interoperability
R10	2009/2011	Up to 3 Gbps downlink and 1.5 Gbps uplink, carrier aggregation (CA), relay nodes to support Heterogeneous Networks, higher order MIMO antenna configurations.
R11	2010/2012	Enhancements to Carrier Aggregation, MIMO, relay nodes, coordinated multipoint transmission and reception to enable simultaneous communication with multiple cells, introduction of
R12	2011/2015	Enhanced small cells for LTE, inter-site carrier aggregation, interworking between LTE and WiFi or HSDPA.
R13	2012/2016	LTE-U, LTE for machine type communication (MTC), full dimension
R14	2015/2017	Energy efficiency location services mission critical data and
R15	2016/2018	5G Phase 1 (new radio).
R16	2017/2019	5G Phase 2.

Since the early 1980s, mobile communication has transformed in a predictable decadal pattern, with each generation offering new features and resolving the inadequacies of its predecessor. (Routray & Mohanty, 2019). 5G networks, that provide ultra-reliable and low-latency communication (URLLC) combined with improved mobile broadband to serve a variety of applications including smart cities, autonomous cars, and the Internet of Things (IoT), are now being rapidly implemented globally. (Neha & Bhatia, 2025). A crucial first step toward future networks is the 3GPP-standardized transition from baseline 5G to 5G-Advanced, starting with Release 18. (Chen et al., 2023). It is generally doubted that 5G would be able to fully meet the intense needs of current and future information and communication technology (ICT) alternatives, despite these remarkable developments (Routray & Mohanty, 2019). As a result, both academic researchers and telecom engineers are now primarily concerned with defining the breadth and technological foundations of 6G.

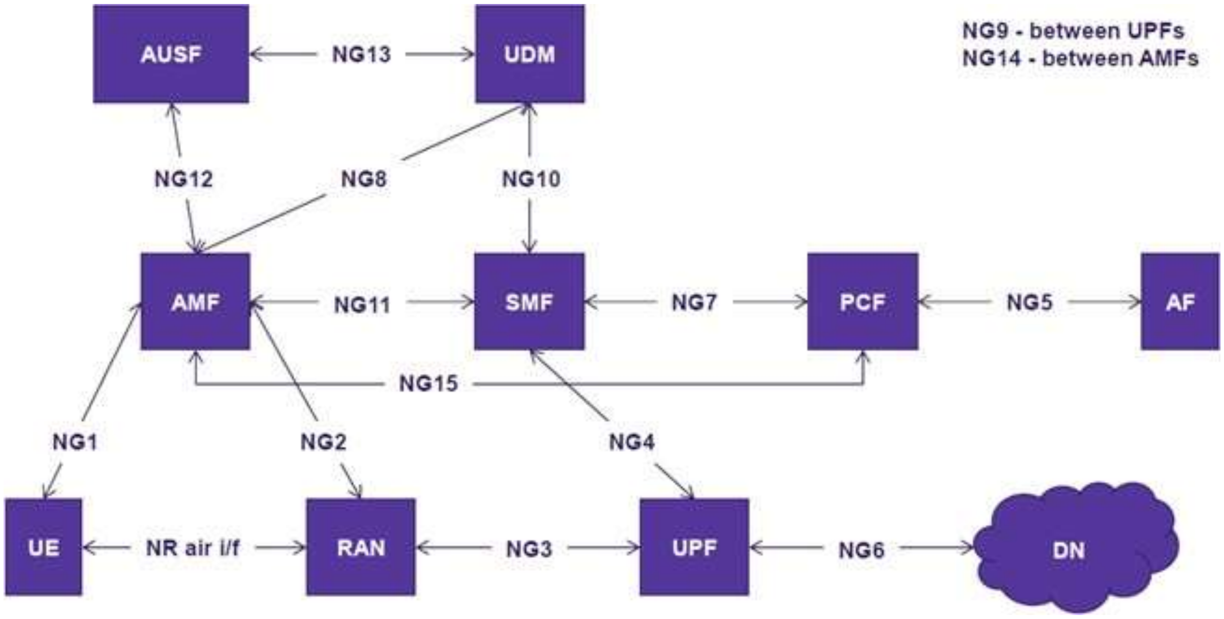
The core problem addressed in this paper is the systematic identification of the architectural and functional gaps between current 5G implementations and the projected requirements of 6G networks. For a number of fundamental reasons, current 5G techniques are becoming more and more unable to meet future needs. First, 5G is mostly dependent on connection-oriented random-access protocols, which necessitate resource-intensive negotiations and are thus extremely ineffective for the irregular, disorganized transmission patterns produced by large-scale IoT deployments. (Clazzer et al., 2019). This paper provides a systematic comparative review of 5G and 6G technologies to address these shortcomings and lay the groundwork for future research.

2 LITERATURE REVIEW

The review of focus mainly on 5G technology, and factors that gave rise to 6G technology, using parameters like Medium Access and Spectral Efficiency, Network Security and Identity Management, and Edge Intelligence / Network Automation.

Typical 5G GSM technology is shown in figures 2.1 and 2.2. Key technologies in 5G are massive Multi-Input/Multi-Output (Massive MIMO) in figure 2.3, Millimeter Wave Mobile Communications, small cells, Light Fidelity (Li-Fi) and so on. Facilities that might be seen with 5G technology has better levels of connectivity and coverage. The main focus of 5G was on world-Wireless World Wide Web (wwww). It is a complete wireless communication with no limitations, which has the following features;

i. Highly supportable to wireless www (World Wide Web).
ii. Will have high speed, high capacity with provision for large broadcasting of data in Gbps.
iii. Used for multi-media newspapers, watch TV programs with better clarity.
iv. Faster data transmission than previous generation.
v. Large phone memory, dialing speed, clarity in audio/video.
vi. Support interactive multimedia, voice, streaming video, internet and other.



Legends

AUSF – Authentication Server Function

UDM – Unified Data Management

AMF – Accesss and Mobility Management Function

Management Function RAN – Radio Access Network

UPF – User Plane Function

PCF – Policy Control Function

DN – Data Network

AF – Application Function

SMF – Session

UE – User Equipment

NR – New Radio

NG – Next Generation

Fig. 2.1: 5G Network Architecture of 3GPP (Sutton, 2018)

The 5G New Radio (NR) deployments occur in phases, according to 3GPP specifications published in December 2017. There are two main modes of operation: **Non-Standalone (NSA):** Operates in conjunction with Long Term Evolution (LTE) and **Standalone (SA):** Operates independently of LTE. In standalone mode, LTE RAT is not necessary; instead, the user equipment (UE) depends only on 5G radio access technology (RAT). While 5G NR only concentrates on the user plane (U-Plane), LTE manages control plane (C-Plane) activities including call origination, call termination, and location registration in non-standalone mode. All these features and improvements on 5G generation, are what the 6G generation of wireless cellular network intend to surpass.

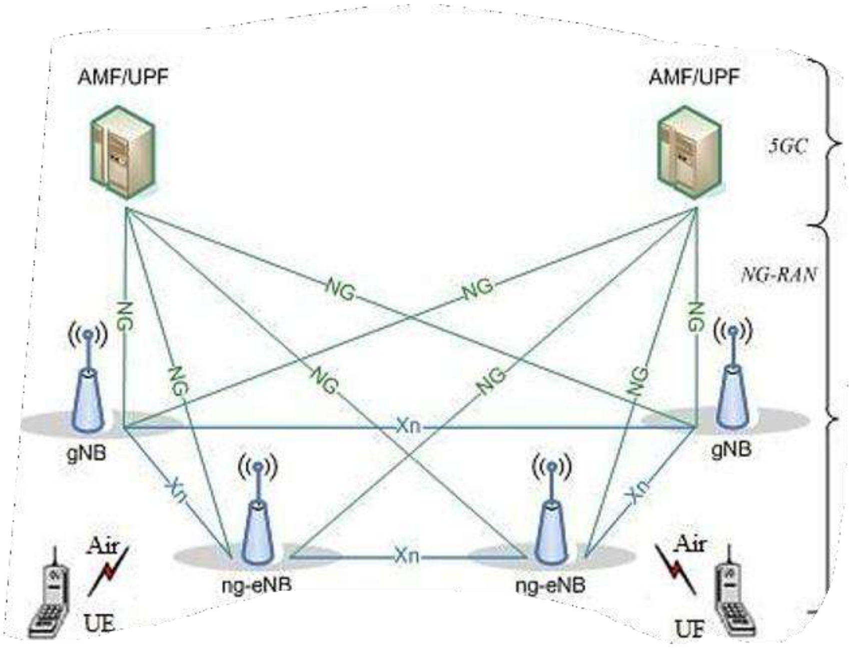


Fig. 2.2: 5G New Radio Overall Architecture © Rf Wireless World (2026)

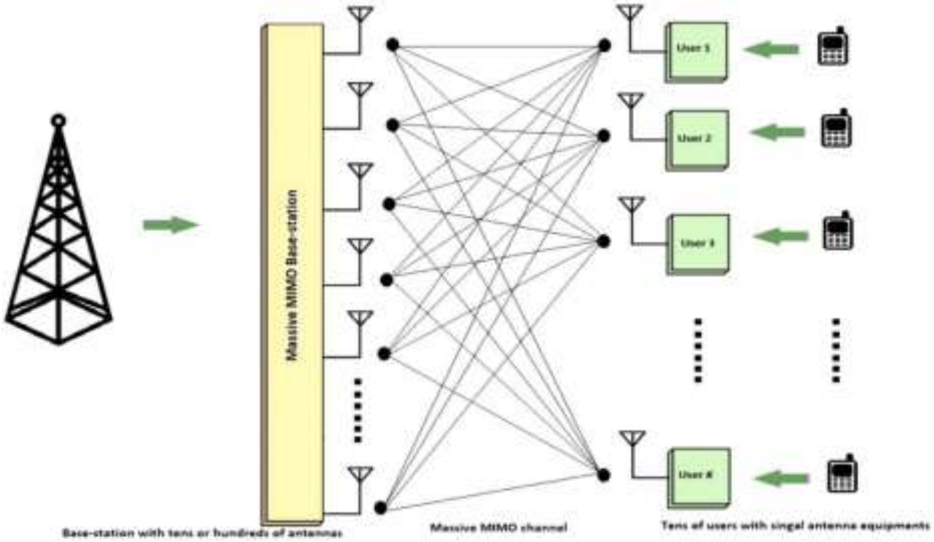


Fig. 2.3: Massive MIMO Structure (Albreem et al, 2019)

2.1 Medium Access and Spectral Efficiency

Improving cellular networks medium access methods and spectrum efficiency is a major focus of contemporary research. Power-domain non-orthogonal multiple access (NOMA), which uses superposition coding and successive interference cancellation (SIC) to serve many users on the same time and frequency resources, has been extensively studied for 5G systems (Islam et al., 2017).

NOMA greatly increases 5G spectrum efficiency, however it is unable to handle the vast, irregular access patterns of contemporary IoT ecosystems. In order to overcome this, researchers have developed cutting-edge uncoordinated random-access methods specifically designed for 6G. These schemes will do away with the connection-oriented paradigms of 5G and make use of sophisticated signal processing to manage enormous device connections without first negotiating resources (Clazzer et al., 2019). While 5G uses massive Orthogonal-Frequency Division Multiple - Access (OFDMA) technology, 6G will use Non-Orthogonal Multiple Access (NOMA) technology in their medium access. In their spectral efficiency, while 5G networks is from 1 – 10ms, 6G network is expected to be less than 1ms.

On the other hand, 5G offers a solid base with organized, dependable medium access and modest gains in spectral efficiency. 6G is anticipated to transform both: Medium access will be non- orthogonal, AI-powered, and more adaptable. THz, RIS, and ultra-massive MIMO will greatly increase spectral efficiency. Nevertheless, these improvements are accompanied by increased complexity, energy requirements, and implementation difficulties

2.2 Network Security and Identity Management

The integration of cellular networks with vital infrastructure has made resource policing and security crucial. Using Catalytic computing and Osmotic computing (CATMOSIS) as a framework based on Novel security models, 5G network offers flexible and edge-level security services (Choudhary & Sharma, 2019). Additionally, 5G/6G networks may be shielded against changing cyberthreats and dataset poisoning by adaptive intrusion detection systems (IDS) that use dynamic neural networks and adversarial training (Neha & Bhatia, 2025). However, a centralized network operator is frequently assumed by these 5G-focused architectures. Researchers contend that 6G would require decentralized identity management systems based on verified credentials rather than centralized trusted third parties since future networks will be jointly run by several stakeholders (Garzon et al., 2022). By clearly comparing the self-sovereign, decentralized identity paradigms needed for 6G with the centralized security systems of 5G, their compared analysis of both in network security and identity management is given in table 2.1.

Using Subscription Concealed Identifier (SUCI) and 5G Authentication and Key Agreement (5G- AKA), 5G security greatly enhances privacy and authentication; yet, virtualization and Application Programming Interface (API) exposure make it insecure.

Table 2.1: Analysis of 5G and 6G in Security and Identity Management

Feature	5G	6G
Architecture	SBA (centralized)	Distributed + AI-native
Authentication	5G-AKA	AI + multi-factor
Identity	SUPI/SUCI	Decentralized ID (DID)
Security Model	Perimeter-based	Zero-trust
Cryptography	Classical	Post-quantum
Threat Detection	Rule-based	AI-driven
Privacy	Improved	Context-aware, adaptive

AI-driven threat intelligence, zero-trust frameworks, decentralized identity systems, and quantum- resistant encryption will all be essential to 6G security. The transition from static defense mechanisms to intelligent, autonomous, and adaptive security systems is reflected in the development.

2.3 Edge Intelligence / Network Automation

The combination of Artificial Intelligence (AI) and Machine Learning (ML) is perhaps the most significant transition from 5G to 6G. In 5G networks, AI is often used for particular, localized enhancements, such as managing centralized handover choices between base stations in crowded beam-forming settings (Yajnanarayana et al., 2019). As we approach 6G, AI evolves from a supplemental tool to a core network component, allowing for paradigms such as Edge AI as a Service (E-AIaaS) (Talosi et al., 2026). Testbeds using Open Radio Access Networks (O-RAN) show how 6G will offload compute-intensive robotic perception models to edge servers, enabling semantic and goal-oriented communication (Talosi et al., 2026). While previous studies have evaluated these technologies in isolation, this study presents a comprehensive comparison, demonstrating how 6G transforms AI from a centralized optimization tool to a ubiquitous, distributed fabric. Table 2.2 shows the analysis between the edge intelligence and network automation.

Table 2.2: Analysis of 5G and 6G in Edge Intelligence / Network Automation

Feature	5G	6G
Edge Intelligence	MEC-based	AI-native distributed
Learning Model	Centralized ML	Federated + RL
Automation	Semi-automated	Fully autonomous
Decision Making	Reactive	Predictive
Latency	Low	Ultra-low
Energy Efficiency	Moderate	Optimized via AI
Scalability	Limited	Massive

3 METHOD

In order to assess the technical advancements from 5G to 6G in a methodical manner, a multi-layered, organized framework that is intended to separate and benchmark important performance categories was proposed. The framework is separated into three sections for analysis:

i. The Physical/Access Module,
ii. The Security/Trust Module, and
iii. The Intelligence/Automation Module.

These modules approach to the main design goal is to enable independent and collaborative analysis of interconnected technologies, such as how huge IoT access affects security susceptibility. Techno- Economic evaluation can be to support the huge investment required for deployment of 6G by opening the network architecture (Oughton & Lehr, 2022). The proposed comparative evaluation pipeline based on the three modules consists of the following numbered steps:

i. Initial Parameterization: Based on 3GPP Release 18 requirements, determine the most advanced 5G-Advanced baseline metrics, including the existing restrictions on massive MIMO, connection density, and centralized trust architectures. (Chen et al., 2023).

ii. Security Stress Testing: Implement a fictitious intrusion detection system in which adversarial data poisoning attempts are prevented while decentralized multi-stakeholder nodes use verifiable credentials (Garzon et al., 2022), (Neha & Bhatia, 2025).

iii. Edge AI Benchmarking: Instantiate an experimental O-RAN testbed topology that replicates Edge AI offloading for industrial robotics, measuring the latency and reliability gains of E- AIaaS (Talosi et al., 2026).

iv. Access Simulation Strategy: To compare contemporary 6G uncoordinated medium access methods with conventional ALOHA-like 5G random access protocols, model a dense, uncoordinated IoT ecosystem. (Clazzer et al., 2019).

In order to validate the method used, both real and imaginary datasets in the assessment plan are used. Similar to prior adaptive Intrusion Detection System (IDS) experiments, using an expanded, hypothetical version of the Network Security Laboratory for Knowledge Discovery in Databases (NSL-KDD) dataset enhanced with adversarial cases to evaluate the Security/Trust Module will also assist in the validation (Neha & Bhatia, 2025). This will help to assess how well dynamic neural networks installed at the network edge identify objects. The throughput and handover optimization advantages attained by distributed reinforcement learning agents will be assessed for the Intelligence Module using a hypothetical simulation of a dense urban manufacturing grid (Yajnanarayana et al., 2019). Designers can objectively measure the performance improvements needed to achieve the full potential of 6G wireless networks using this thorough technique.

4 DISCUSSIONS

In order to achieve goals at the individual and collective levels, the 6G is intended to include cutting- edge capabilities into the current 5G architecture. Holographic communications, artificial intelligence integration, IoTs, high-precision manufacturing assistance, and the use of novel technologies like sub- THz or VLC (Visible Light Communications) are some of the suggested 6G services. It will probably include a 3D coverage system that uses radio access points (APs) both on land and in the air to deliver cloud features. 6G employs a cell-less architecture where User Equipment (UE) connect directly to the RAN (Radio Access Network) instead of a single cell. The 6G network architecture is shown in figure 4.1.

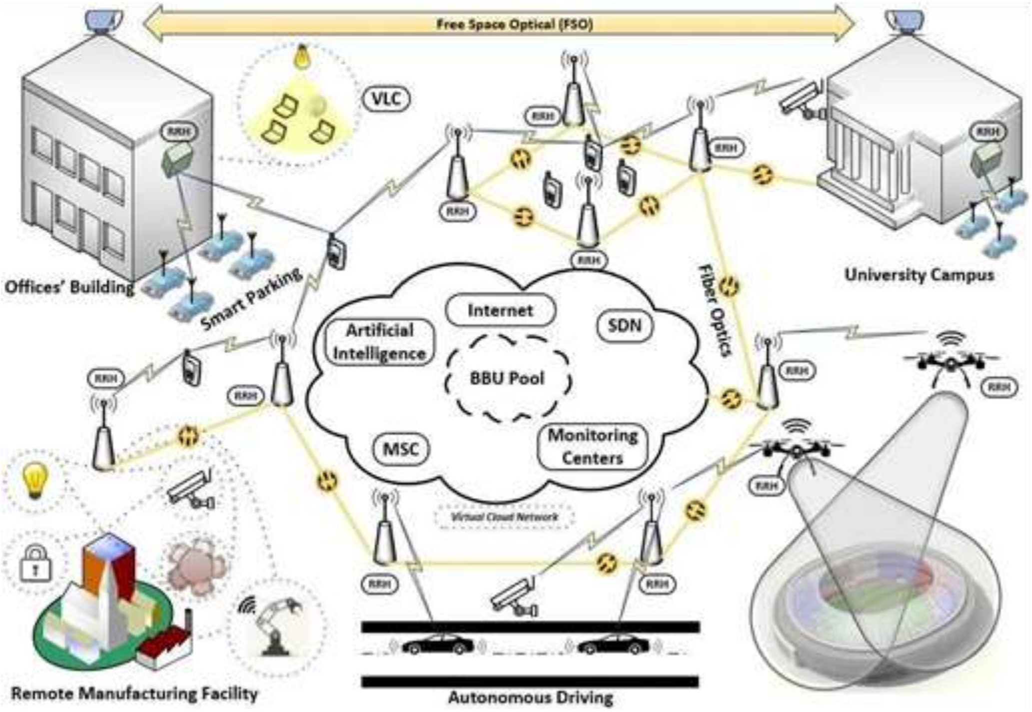


Fig. 4.1: 6G Network Architecture © Rf Wireless World (2026)

Key technical features introduced in 6G wireless are:

i. New Spectrum: Due to increased traffic demand and spectrum scarcity, THz (Terahertz) and Visible light bands are being explored for communication in 6G mobile communication systems.
ii. New Channel Coding: Based on Turbo, LDPC, Polar, etc.
iii. Sparse Theory (Compressed Sensing)
iv. Very Large-Scale Antenna Processing for THz
v. Advanced Signal Processing
vi. Flexible Spectrum: Full (free) spectrum, Spectrum sharing.
vii. AI-based Wireless Communication
viii. Space-Air-Ground-Sea Integrated Communication
ix. Wireless Tactile Network

It is anticipated that the sixth-generation (6G) wireless communication network would combine terrestrial, aerial, and marine communications into a strong network that will be faster, more dependable, and able to accommodate a large number of devices with extremely low latency needs. In order to realize beyond 5G (B5G) and 6G communications, researchers worldwide are proposing cutting-edge technologies like artificial intelligence (AI)/machine learning (ML), quantum communication/quantum machine learning (QML), blockchain, tera-Hertz and millimeter waves communication, tactile Internet, non-orthogonal multiple access (NOMA), small cells communication, fog/edge computing, etc. The dimensions of the 6G network with air interface and related prospective technologies are covered in detail in this article. (Akhtar et al, 2020)

For mobile network operators and equipment makers, the switch from 5G-Advanced to 6G has significant practical implications. In order to implement these Next Generation technologies, current core networks must be completely redesigned, moving from proprietary, hardware-centric designs to fully open, software-defined O-RAN architectures (Talosi et al., 2026). Additionally, techno- economic research shows that high-capacity, globally priced 6G connection would need significant capital investment, requiring new business models focused on shared infrastructure and multi- stakeholder collaboration (Oughton & Lehr, 2022). Deploying 6G without adequate economic planning runs the danger of widening the digital divide and trapping rural or underprivileged communities on outdated networks.

Despite its vast potential, the proposed 6G architecture introduces several critical limitations and failure modes. First, the reliance on dynamic neural networks and pervasive edge computing introduces massive computational overhead, which may lead to thermal throttling or energy depletion in miniaturized, uncoordinated IoT devices. Second, in physical access layers, the complex successive interference cancellation (SIC) required for advanced power-domain multiplexing can fail under conditions of high user mobility or severe channel degradation (Islam et al., 2017). Third, while decentralized identity management eliminates single points of failure, establishing trust among independent administrative domains via verifiable credentials may introduce significant consensus latency, severely hindering hyper-reliable low-latency applications (Garzon et al., 2022).

The pervasive nature of 6G also presents profound ethical considerations and risks. One major risk is the unprecedented exposure of user data; as 6G networks natively integrate AI at the edge to monitor semantic communication patterns, the granularity of observable user behavior could lead to severe privacy violations if not strictly regulated. Additionally, the network's reliance on dynamic, self- updating neural models creates vulnerabilities to adversarial machine learning attacks; if malicious actors successfully poison the training data of an automated network controller, it could trigger catastrophic, systemic outages across critical infrastructure (Neha & Bhatia, 2025).

To address these challenges, future work must proceed in several distinct directions. First, empirical validation of decentralized identity management systems must be conducted on massive-scale, physical 6G testbeds to accurately measure authentication latency in real-world, multi-operator environments. Second, researchers must conduct deeper techno-economic analyses to develop cost- sharing frameworks that incentivize MNOs to deploy 6G infrastructure in less profitable, low-density geographical regions (Oughton & Lehr, 2022). The comparative analyses are given in figures 4.2 and tables 4.1, and table 4.2

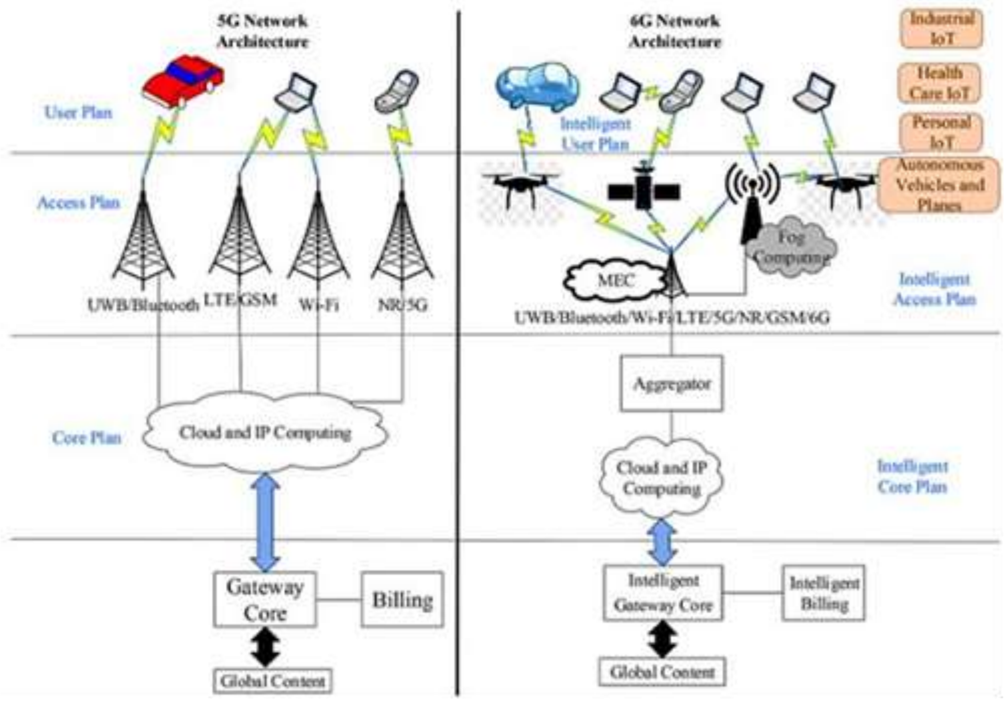
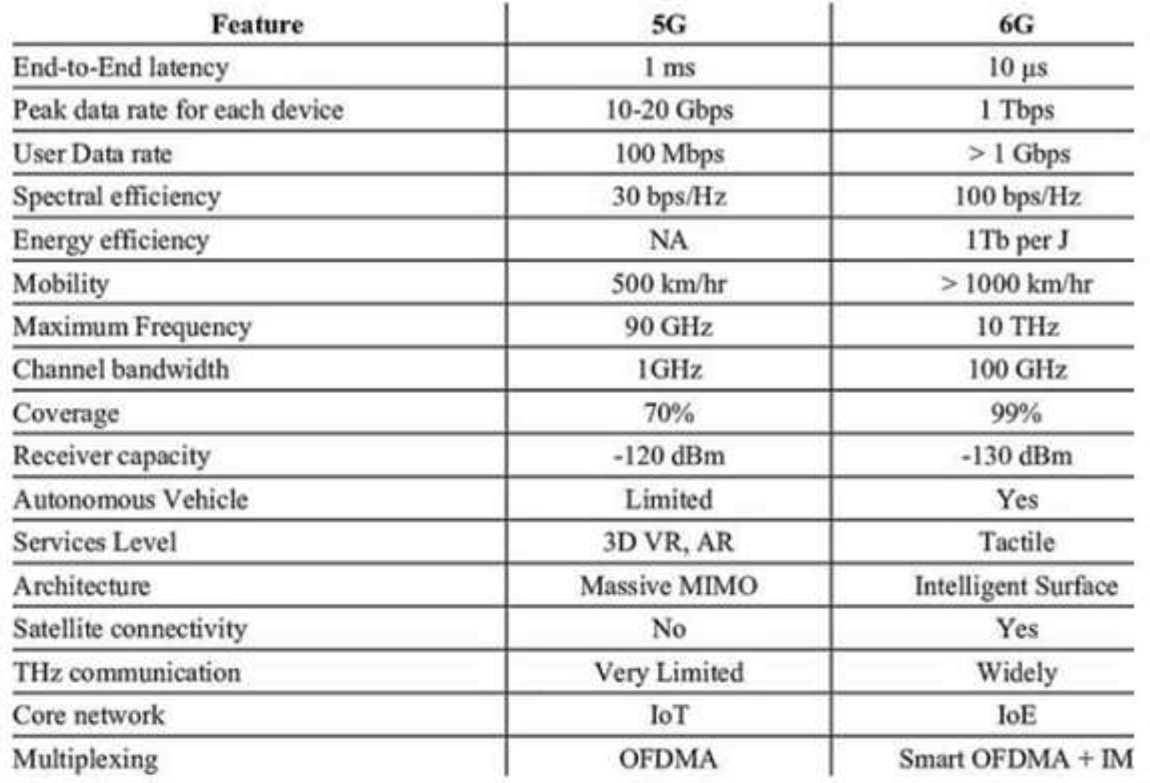


Fig. 4.2: Comparative Analyses of 5G Vs 6G Technologies (Akhtar et al, 2020)

Table 4.1: 6G vs 5G Network Performance © Tech Research (2026)

Feature	5G	6G
Max Speed	20Gbps	1 Tbps
Latency	1 – 10ms	< 1ms
Frequency	Up to 100 GHz	Up to 3 THz
Architecture	Centralized + Edge	Fully Distributed + AI-Driven
Key Focus	Connectivity	Intelligence + Cognition
Commercial Rollout	2020s	About 2030

Table 4.2: Features Comparison Between 5G and 6G Technologies (Shaikh et al, 2022)



Feature	5G	6G
End-to-End latency	1 ms	10 μs
Peak data rate for each device	10-20 Gbps	1 Tbps
User Data rate	100 Mbps	> 1 Gbps
Spectral efficiency	30 bps/Hz	100 bps/Hz
Energy efficiency	NA	1Tb per J
Mobility	500 km/hr	> 1000 km/hr
Maximum Frequency	90 GHz	10 THz
Channel bandwidth	1GHz	100 GHz
Coverage	70%	99%
Receiver capacity	-120 dBm	-130 dBm
Autonomous Vehicle	Limited	Yes
Services Level	3D VR, AR	Tactile
Architecture	Massive MIMO	Intelligent Surface
Satellite connectivity	No	Yes
THz communication	Very Limited	Widely
Core network	IoT	IoE
Multiplexing	OFDMA	Smart OFDMA + IM

With the switch from 5G to 6G, mobile network technology has improved both in terms of quantity and quality. While 5G laid the foundation for incredibly fast transmission and low latency, 6G aims to boost connections to previously unheard-of levels of precision, efficiency, and intelligence. The two generations differ significantly in terms of speed, latency, frequency spectrum, architecture, and technical integration. From tables 4.1 and 4.2, expectations from 6G are:

i. **6G Performance**: 6G is expected to achieve theoretical speeds of up to 1 terabit per second (Tbps), roughly 50 times faster than 5G. Large datasets could be sent in a matter of seconds at this speed, and whole corporate systems could instantly synchronize data. This is a component of the speed and latency comparison between 6G and 5G.

ii. **6G Latency**: 6G is expected to reduce this delay to below 1 millisecond, with air-interface latencies potentially reaching microsecond levels. Data transfers might therefore happen practically instantly, enabling communication systems to react with reflexes that are nearly human.

iii. **6G Spectrum**: 6G research, as outlined by Airtel and RantCell, focuses on sub-terahertz and terahertz (THz) frequencies, ranging from 95 GHz up to 3 THz. Large volumes of data may be sent at previously unheard-of speeds by operating in this range, which will significantly boost available bandwidth.

iv. **6G Architecture**: 6G will be built on a decentralized and intelligent network design, integrating edge computing and cloud-based processing more deeply into the network fabric. This will enable edge–cloud integration, self-optimizing networks, and dynamic resource management.

v. **6G Integration**: 6G aims to embed intelligence, automation, and adaptability within the network's operational framework. Predictive optimization, automatic fault detection and rectification, and adaptive traffic management will all be made possible by this. This highlights the main advantages of 6G over 5G and is crucial in determining which is preferable for businesses.

5 CONCLUSION

The evolution from 5G to 6G represents a fundamental paradigm shift in cellular network design, moving far beyond mere enhancements in data rates and latency. While 5G and its intermediate advancements have successfully laid the groundwork for mobile broadband and initial IoT integration, they remain constrained by connection-oriented access protocols, centralized security models, and overlaid artificial intelligence. As demonstrated through our comparative analysis, 6G is poised to overcome these limitations by natively embedding uncoordinated random-access mechanisms, fully decentralized identity management, and ubiquitous edge intelligence directly into the network fabric.

Ultimately, realizing the ambitious vision of 6G will require highly coordinated efforts across standardization bodies, network operators, and the broader academic community. The transition necessitates not only technological breakthroughs in machine learning and spectrum efficiency but also the resolution of complex ethical, security, and techno-economic challenges. By understanding the distinct architectural differences between 5G and 6G today, engineers and researchers can better navigate the complexities of next-generation wireless systems, ensuring that future networks are resilient, secure, and globally accessible.

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