

6G Technology: Survey of Mobile Technologies (Review Paper)

Anita Subhash Bhandare¹
Maharashtra, India

Abstract: 6G is the proposed and upcoming sixth generation of the mobile communications technology and the planned successor to 5G (ITU-R IMT-2020). Development is coordinated by the International Telecommunication Union (ITU-R) within its IMT-2030 framework, defined in Recommendation ITU-R M.2160-0. 6G aims to achieve higher data rates, lower latency, and greater energy efficiency than 5G. 6G aims to achieve higher data rates, lower latency, and greater energy efficiency than 5G.^[1]

In November 2020, China launched a Long March 6 vehicle that carried a satellite testing components for potential 6G communication. Chinese state media described it as "the world's first 6G satellite", a claim not independently verified. The mission studied terahertz-band transmission and other 6G-related technologies.^[2]

6G will be based on three fundamental elements: wireless, artificial intelligence (AI), and the Internet of Everything (IoE). Consequently, 6G can ultimately become *the Intelligent Network of Everything* while serving as an enabling platform for the next major disruption in mobile communication, called *mobile intelligence*. The potential of mobile intelligence is that anything can be made connected, intelligent, and aware of its environment. This will revolutionize the way how devices, systems, and applications are designed; how they operate and interact with humans and each other; and how they can be used for the benefit of people, society, and the world in general. After high-level visioning, the main details of 6G are discussed, including fundamental elements, disruptive applications, key use cases, main performance requirements, potential technologies, and defining features.^[3]

Index Terms:

5G, 6G, 7G, Artificial Intelligence, Beyond 6G, Mobile Networks, Smart Society, Transfer Learning, NTN integration.

Introduction:

This section takes a glance at the past, present, and future of mobile communications by introducing the evolution from 1G to 6G. After that, a special attention is given on 5G by providing a brief overview on its fundamentals, background, and standardization. The focus is then shifted to 6G. A generic development process and its timeline is discussed first. Then, an up-to-date review is given on the worldwide research activities toward 6G, followed by a contemporary survey of the main 6G vision and survey articles. Finally, the contributions of the article are presented.

6G in simple terms

- 6G is expected to be the next major mobile-generation step after 5G and 5G-Advanced.
- It is not available today as a finalized, globally deployed standard.
- Current 6G work is about framework goals, research results, and early standards studies.
- Its vision goes beyond speed and includes AI, sensing, automation, resilience, and broader connectivity.
- ITU-R IMT-2030 and 3GPP are the main standards paths to watch.

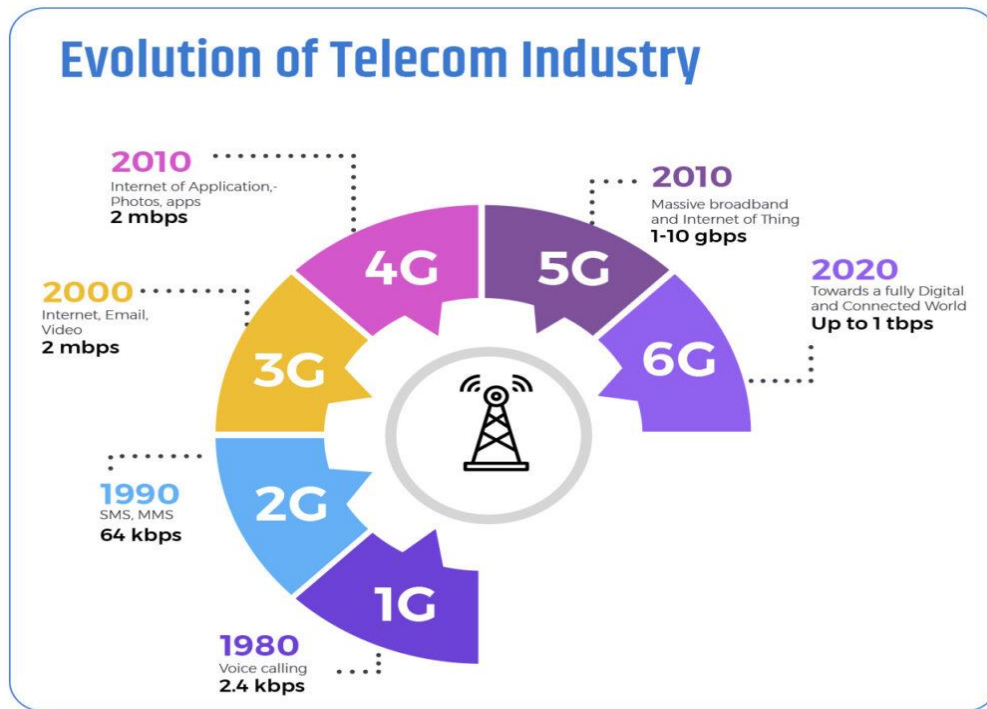


Figure1: Evaluation of mobile networks from 1G to 6G

1G: 1st Generation of mobile Technology

1G, or the first generation of mobile communication, was the first system to allow mobile voice calls using Analog signals. It marked the beginning of mobile telephony as we know it today, but it had limitations in terms of coverage, data support, and sound quality.

- Introduced mobile voice calling for the first time.
- Used Analog signals for communication.
- Employed an FDD (Frequency Division Duplex) scheme with a typical bandwidth allocation of 25 MHz
- Coverage areas were relatively small, requiring many base stations for larger regions.
- Roaming between different operators was not supported.
- Low sound quality compared to later generations.
- Supported very low data speeds, approximately 2.4 kbps, mainly for signalling purposes.

2G: 2nd Generation of mobile Technology

2G, or the second generation of mobile communication, marked the transition from Analog to digital signals, improving voice quality, security, and efficiency. It introduced basic data services like SMS and email, enabling mobile devices to do more than just make calls. 2G networks laid the foundation for mobile internet and multimedia services that would develop in later generations.

- Shifted from Analog to digital communication, improving voice clarity and reducing interference.
- Supported both voice calls and SMS services.
- Provided moderate mobile data services, enabling limited internet access.
- Technologies like GSM, CDMA, and TDMA were widely used in 2G networks.
- Typical data speeds ranged around 64 kbps, sufficient for SMS and basic browsing.

- 2.5G (GPRS) introduced packet-switched data, enabling mobile internet, email, and basic streaming services.
- 2.75G (EDGE) offered faster data transfer, up to ~128 kbps, improving mobile internet speed and reliability.

3G: 3rd Generation of mobile Technology

3G, or the third generation of mobile communication, introduced high-speed data services alongside voice, enabling mobile internet, video calls, and multimedia applications. It improved network capacity and system reliability compared to earlier generations, paving the way for modern mobile services.

- Improved mobile internet system, allowing users to access websites, emails, and streaming services on the go.
- Offered better system capacity, supporting more simultaneous users in a given area.
- Provided high-speed wireless internet, enabling multimedia applications and mobile video calls.
- Common technologies used in 3G networks include UMTS (Universal Mobile Telecommunications System) and CDMA (Code Division Multiple Access).
- Typical data speeds were around 2 Mbps, although actual speeds could vary depending on network conditions.

4G: 4th Generation of mobile Technology

4G, or the fourth generation of mobile communication, is based on all-IP architecture, providing high-speed internet and advanced multimedia services. It allows simultaneous support for voice, data, and video applications with better quality, efficiency, and flexibility than earlier generations. 4G networks enabled HD video streaming, VoIP services, and faster internet access for smartphones, tablets, and other devices.

- Uses IP-based protocols to provide efficient and flexible communication for data, voice, and multimedia services.
- LTE (Long Term Evolution) is mainly used to provide high-speed internet access.
- VoLTE (Voice over LTE) allows users to make voice calls while simultaneously using the internet.
- Offers freedom and flexibility to select any desired service with reasonable Quality of Service (QoS).
- Provides high usability for a wide range of mobile and internet applications.
- Supports multimedia services at a low transmission cost, making it efficient for data-heavy applications.
- Enables HD-quality video streaming and smooth online media experiences.
- Typical data speeds range around 100 Mbps, though actual speeds can vary depending on network conditions.

5G: 5th Generation of mobile Technology

5G, or the fifth generation of mobile communication, is the latest generation of wireless technology, designed to provide ultra-high data speeds, low latency, and massive device connectivity. It supports advanced applications such as autonomous vehicles, smart cities, industrial IoT, and immersive multimedia experiences, offering a significant improvement over 4G networks.

- Provides higher data rates, with speeds up to 10 Gbps under ideal conditions.
- Offers faster and more secure connectivity, supporting a massive number of devices simultaneously.
- Data latency is significantly reduced, potentially as low as 1 millisecond, enabling real-time applications.
- Supports massive network capacity, allowing millions of connected devices in smart cities and industrial networks.
- Offers greater flexibility in network management, supporting features like network slicing for customized services.

- Enables enhanced applications such as AR/VR, remote surgery, autonomous vehicles, and industrial automation.
- 5G is generally considered 10–30 times faster than 4G, depending on deployment conditions and frequency bands.

6G: 6th Generation of mobile Technology

The 6th generation mobile technology, 6G, is expected to deliver extraordinary performance and a multi-purpose platform. Key features of 6G include:

- Ultra-High Data Speeds
- Low Latency
- AI-Powered Connectivity
- Massive MIMO
- Network Slicing
- Security
- Ultra-Reliable Low Latency Communication (URLLC)

Comparative Study:

Generation	Technology	Data Speed	Coverage & Features
1G	Analog cellular, FDD	~2.4 kbps	Small coverage area, first mobile voice calls, low sound quality, no roaming, Analog signals
2G	GSM, CDMA, TDMA; 2.5G (GPRS); 2.75G (EDGE)	9.6 kbps – 384 kbps	Moderate coverage, digital voice, SMS, basic data, improved security
3G	UMTS, HSPA, CDMA2000	Hundreds of kbps – 2 Mbps	Wide coverage, high-speed data, video calls, multimedia services
4G	LTE, WiMAX, VoLTE	100 Mbps – 1 Gbps	Wide coverage, all-IP network, HD streaming, low latency, VoLTE support
5G	mmWave, sub-6 GHz, network slicing	Up to 10 Gbps	Very wide & dense coverage, ultra-low latency, massive connectivity, high reliability, flexible networks
6G	The exact working of 6G technology is not yet known	100 Gb/s	Ultra-high frequencies, AI and machine learning integration, Edge computing and distributed intelligence

APPLICATIONS OF 6G :

Following are the applications in the categories of human-machine interactions, smart environments, and connected autonomous systems. The most useful way to read 6G use cases is to ask what problem they are trying to solve. The current vision focuses on applications that need stronger coordination between communication performance, intelligence, sensing, timing, and reliability.

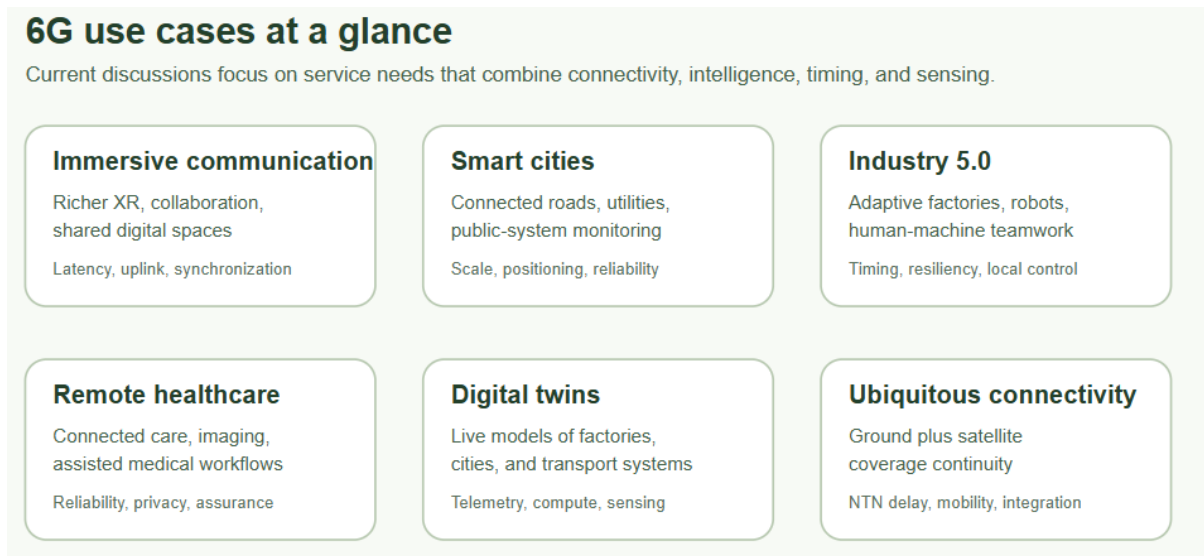


Figure 3:6G use cases at a glance

A1. Immersive communication:

This includes richer extended reality, highly interactive remote collaboration, and shared digital spaces that feel more natural and responsive.

Why it matters: Better interaction quality can improve education, design review, training, and remote teamwork.

What matters technically: Uplink performance, latency stability, synchronization, edge compute, and session continuity all matter.

A2. Smart cities and infrastructure:

Networks may help roads, utilities, public systems, and safety platforms collect and act on data more quickly and with more context.

Why it matters: Better monitoring can improve traffic flow, safety response, and infrastructure efficiency.

What matters technically: Scale, positioning, sensing accuracy, and reliable machine connectivity become important.

A3. Industrial automation and Industry 5.0

6G discussions often include factories where machines, robots, and humans work together with more adaptive automation.

Why it matters: Production systems benefit from lower error rates, better coordination, and faster adaptation.

What matters technically: Deterministic behaviour, local compute, resiliency, and precise timing remain central.

A4. Remote healthcare

Future networks may support richer remote diagnostics, connected care, and better-assisted medical collaboration.

Why it matters: Healthcare systems can extend expertise further when the network is trustworthy and predictable.

What matters technically: Privacy, reliability, latency control, and service assurance are more important than headline peak speed.

A5. Digital twins

A digital twin is a virtual model of a physical system that is updated using real-world data from sensors, machines, and networks.

Why it matters: Operators can test, predict, optimize, and troubleshoot physical systems more effectively.

What matters technically: Telemetry quality, sensing inputs, positioning, timing, and compute orchestration shape usefulness.

A6. Ubiquitous connectivity

6G may aim for service continuity across more environments by integrating terrestrial networks with non-terrestrial links such as satellites.

Why it matters: Coverage can improve for remote regions, transport corridors, maritime zones, and disaster scenarios.

What matters technically: NTN integration adds new delay, mobility, link-budget, and interoperability questions.

6G key technologies

The objective of 6G is to enhance communication systems by amalgamating communication, sensing, computing, and security functionalities, thereby furnishing intelligent services on a global scale. To realize this overarching vision, the integration of a suite of disruptive new technologies into the 6G framework is imperative. Drawing from extant research and the latest advancements in pertinent domains, we identify 16 prospective key technologies for 6G, which are classified into four evolutionary trajectories, as illustrated in Figure 3.

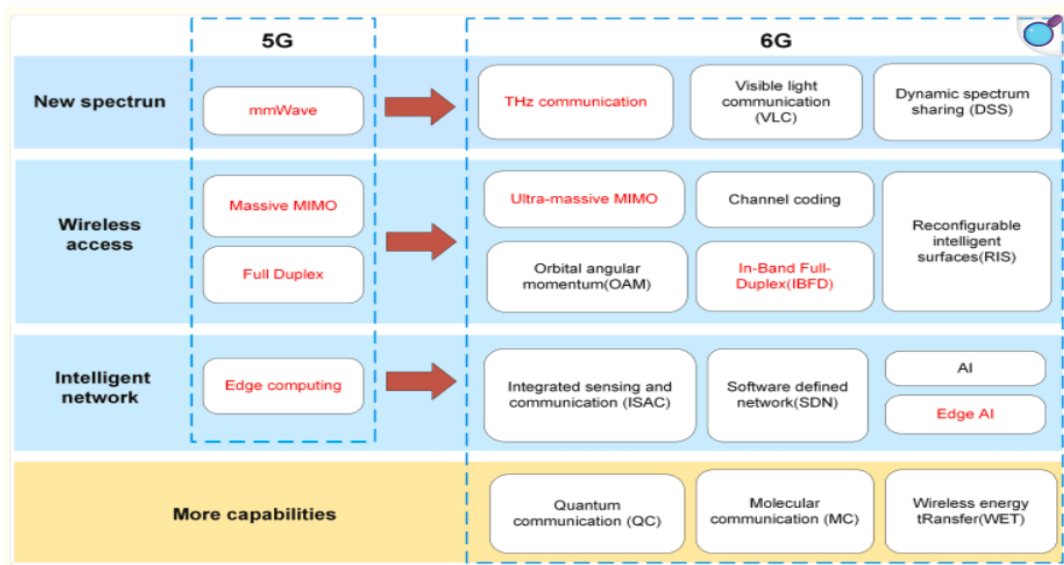


Figure3: Key technologies for 6G mobile communication network

CONCLUSION

This article provided a survey of mobile technologies. Here presented the evolution road from 1G to 6G and comparative study of 6G technology.

REFERENCES

1. Fisher, Tim (April 2022). "6G: What it is and when to expect it". Lifewire. Retrieved April 3, 2024.
2. "China sends 'world's first 6G' test satellite into orbit". BBC. Archived from the original on November 8, 2020. Retrieved November 7, 2020.
3. "6G: The Intelligent Network of Everything – A Comprehensive Vision, Survey, and Tutorial" Retrieved 12 Jul 2024.