The path to 6G

6G is expected to accelerate the mobile AI-powered era

RADCOM

WHITEPAPER

6G is expected to accelerate the mobile AI-powered era that is just beginning. Analysts expect a vast increase in data usage over the next five years. At the same time, it is imperative for operators to lower operating costs and constantly improve customer experience in increasingly complex networks.

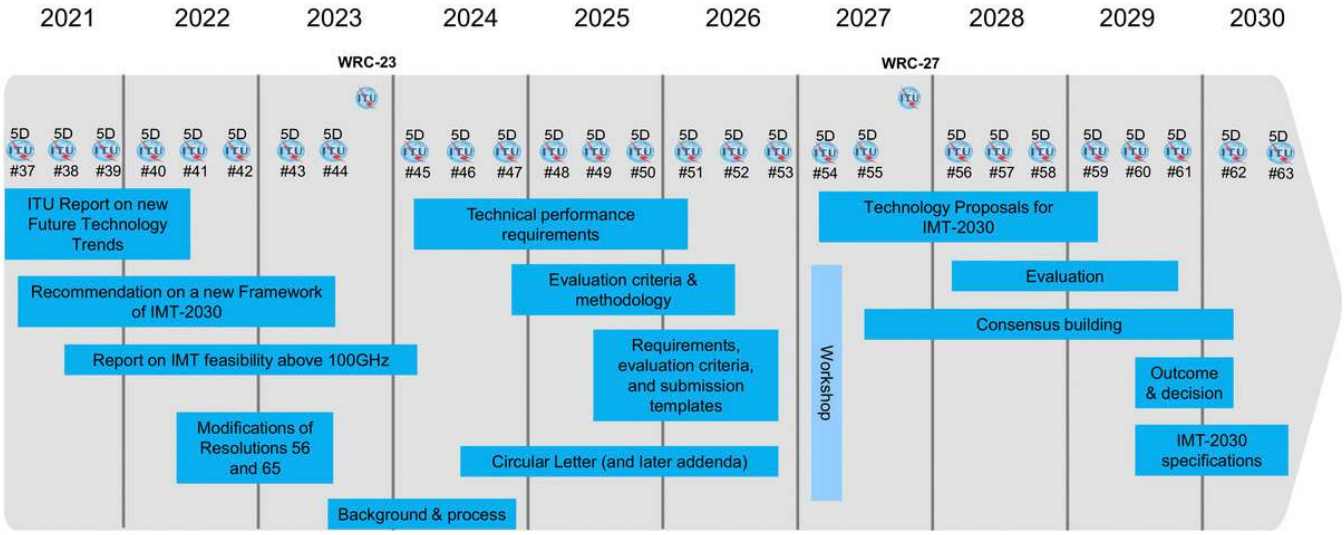
6G will offer even greater capacities, faster speeds, and system throughput than 5G, and by an order of magnitude. If the move to 5G Advanced takes us to around 20Gbps, with 6G, we can expect speeds of about 100GBps, and some anticipate reaching 1TBps.

However, it will also demand higher levels of observability, flexibility, and automation. Observability will be critical to end-user experience, network usage, and granular network management in a more complex infrastructure. Observability will also play an important role in 6G with AI capabilities integrated into use cases such as optimising network performance, detecting security threats, planning capacity, fault isolation and troubleshooting, and more.

This white paper looks at the main pillars of 6G networks. It will discuss some of the capabilities intended to augment future mobile communications as well as key performance indicators. In particular, it urges a rethink of resilience that will prioritise adaptation and recovery as operators move to adopt 6G in an AI-enabled world.

WHAT IS 6G?

In December 2023, the International Telecommunication Union (ITU) published the framework for developing standards and radio interfaces for 6G as part of its International Mobile Telecommunications strategy (IMT-2030) – see the timeline below. The proposed radio interface technology will make greater use of the distributed RAN and terahertz (THz) spectrum to increase capacity, lower latency, and use spectrum much more efficiently via a number of mechanisms.



Note 1: Meeting 5D#59 will additionally organize a workshop involving the Proponents and registered IEGs to support the evaluation process
Note 2: While not expected to change, details may be adjusted if warranted. Content of deliverables to be defined by responsible WP 5D groups

Source: ITU https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2030/Pages/default.aspx

The 3rd Generation Partnership Project (3GPP), a collaboration between telecom standards organisations, works closely with ITU-Radiocommunications Sector Working Party (IT-UR WP) 5D to translate IMT requirements into detailed technical specifications and standards. This working party is responsible for the overall radio system aspects of the terrestrial component of IMT. Organisations all over the world are working on various aspects of 6G technology and sharing their research – see below.

IT TAKES A GLOBAL COMMUNITY TO RAISE A STANDARD

There are many parties around the world working on various aspects of 6G. They include:

- **The University of Oulu in Finland with the government-backed, Finnish 6G Flagship initiative;**
- **The European Union's Hexa-X consortium led by Nokia;**
- **Osaka University in Japan is working with Adelaide University in Australia and in testing have achieved speeds of 11Gbps;**
- **China's Ministry of Industry and Information Technology;**
- **The US' Federal Communications Commission made 6G spectrum available in 2020 to universities and industry;**
- **South Korea's Electronics and Telecommunications Research Institute is researching the THz frequency band for 6G;**
- **ETSI's Industry Specification Group (ISG) on Multiple Access Techniques (MAT).**

***This list is not intended to be exhaustive.**

6G'S KEY CHARACTERISTICS

Just as 5G networks can use higher frequencies than 4G, giving them a greater capacity over shorter distances, 6G can go higher still. 5G's high-frequency use is called millimeter wave or mmWave, while 6G will be designed to run on sub-millimeter waves less than 1mm in length. This enables faster sampling and, therefore, greater transmission speed and throughput.

6G's latency is expected to be 1 microsecond, which is 1,000 times faster than 1-millisecond communications – 5G aims to achieve latency of low single-digit milliseconds. By comparison, the typical latency for a 4G network is between 30 and 50 milliseconds. Hence, 6G is expected to facilitate applications that involve imaging, presence technology, and location awareness, which range from production lines to public safety and far beyond.

1000x

How much faster 6G's 1 microsecond is compared to 1 millisecond, which is beyond 5G's capabilities

As T-Mobile for Business explains, "Humans can perceive a lag as short as 13 [milliseconds] for visual stimuli. For a voice call, a sub-50 [milliseconds] lag makes the call feel natural; communication becomes untenable when you get up around 150 [milliseconds]. For other 5G low-latency applications – like when you need actual physical, haptic feedback – a 50 [millisecond] lag is an eternity."

Coupled with this super low latency, 6G will be able to select frequencies to determine relative electromagnetic absorption rates. Why does this matter? TechTarget explains, "6G wireless sensing solutions will selectively use different frequencies to measure absorption and adjust frequencies accordingly. This method is possible because atoms and molecules emit and absorb electromagnetic radiation at characteristic frequencies, and the emission and absorption frequencies are the same for any given substance."

This means 6G could be used in industrial settings or mining, as it could 'sense' dangerous levels of chemicals that are routinely used. It could also be used for public safety regarding pollution levels and safeguarding critical and valuable assets.

Regarding transmission speed, 5G's theoretical upper limit is 10Gbps, with peaks of up to 20Gbps with the move to 5G Advanced. 6G is expected to deliver speeds of about 100Gbps and has achieved this in lab conditions; some even anticipate speeds reaching 1TBps.

In another boost to 6G's ultra-efficient use of spectrum, its access points will be able to serve multiple clients simultaneously because it is based on orthogonal frequency-division multiple access tech. It supports multiple subcarriers within one communications channel, which helps prevent fading and interference.

Finally, AI, combined with 6G's communications and computational infrastructure, will figure out the best place for computing to be carried out. 6G will make automated decisions about where data is stored, processed, and distributed. In other words, the mobile 'edge' will be built into the fabric of the infrastructure rather than added as the need arises, like in 5G.

THE IMPETUS FOR 6G

How difficult it is to reach any destination is largely dictated by the starting point. Many in the industry question why we are thinking about 6G when 5G has 'failed' to fulfill its predicted potential. One of the reasons 5G has not delivered new services and revenues is that its deployment is massively lagging where we thought it would be at this point, particularly deployments of new cloud-native, core technology, 5G SA. Most 5G deployed so far is of the non-standalone variety – 5G in the RAN runs on top of 4G infrastructure.

The delay in SA's deployment is due to various reasons. They include fallout from the pandemic and the adverse economic conditions since, particularly the soaring price of energy, plus geopolitical tensions. But there is a technological element, too: operators have generally found the shift to cloud-native daunting.

As David Martin, Senior Analyst and Telco Cloud Lead at STL Partners, said, ***"I think operators have been sitting on these questions for the last two or three years, not just SA, but what do we do about public cloud? And do we go for a fully multi-cloud model? It all hangs together; you can't really take one in isolation from the bigger picture."***

Also, 5G was hijacked by hype, leading to unrealistic expectations – back in 2016, we were expecting a world dominated by self-driving vehicles, AR/VR/XR (which temporarily morphed into Metaverse mania in 2020), remote medical care, especially surgery, Industry 4.0 and smart cities. The hype made 5G feel like a technology looking for a purpose rather than a technology invented from necessity.

BORN OF NECESSITY

But 5G (and 6G) are born of necessity. Telecoms is a low-growth business; S&P Global Ratings predicts operators' revenues will increase by only 1-2% this year. But data volumes keep rising; even without those applications we expected 5G to kick start. In late January 2025, DE-CIX, a leading global internet exchange operator, reported that worldwide traffic volumes hit another record high. Traffic throughput has doubled since 2020, increasing by 15% in 2024 to reach 68 Exabytes (see below).

HOW MUCH IS 68 EXABYTES?

The transmission speed of data is specified in terabits per second (Tbps).

1

TERABIT PER SECOND

is 10^3 Gbps,

106 Mbps,

109 kbps,

or 1012 bps,

that is, 1,000,000,000,000 bps.

8

TERABITS

= 1 Terabyte (TB),

1,000 TB = 1 Petabyte (PB),

and 1,000 PB = 1 Exabyte (EB)

68

EXABYTES

is the amount of data that streaming a football match which lasted 2 million years in high definition would require.

Source: DE-CIX, January 2025

As Vodafone's Scott Petty coolly pointed out in 2018, 5G's primary attraction is that it is about four times more "spectrally efficient" than 4G at carrying data. In an industry with little revenue growth, lowering operating costs is essential to improve margins and sustain the business. "We need to find a way to service customers more cost-effectively," explained Petty, who has progressed from Vodafone UK's CTO back then to Vodafone Group's CTO now.

Then there is AI generally, and Generative or GenAI especially, which were not factored into the evolution of mobile technologies until November 2022 when ChatGPT from OpenAI burst into the public consciousness.

"As the use of artificial intelligence intensifies – particularly with the advancement of generative AI models – it becomes the catalyst for a data deluge," wrote Adam Wright, Research Manager at IDC's Global DataSphere in May 2024. ***"But that deluge will be staggered over the next five years and beyond. AI's transformative potential is undeniable; however, the lag between its expansion and the subsequent upsurge in data generation will serve as a critical pause – a period where systems will adapt, infrastructure will evolve, and business and consumer trust in and use of the technology will mature,"*** he added.

6G services are expected to launch commercially in 2030-2032.

There is an additional critical factor to take into account, too. In November 2024, Moody's Ratings moved telecoms into the Very High-Risk category in its annual cyber heat map for the first time. The ratings agency said that, like other high-risk industries (airlines and power generation projects), telecoms are "highly digitized and play a crucial role in the functioning of society and the economy". Another factor that contributed to higher cyber risk scores is "below-average cyber risk mitigation practices," Moody's added.

RETHINKING RESILIENCE

This is a huge wake-up call regarding resilience in 6G. Professor Mehdi Bennis is Head of the Intelligent Connectivity and Networks/Systems Group (ICON) at the University of Oulu and IEEE Fellow. In his opinion, resilience is "a quality that's ill-defined today, partly because telecom networks hadn't previously been able to predictably and reliably handle adversity...But the age of pervasive AI has changed that equation. So it's important that resiliency not only be recognized as a 6G priority – but also that benchmarks and metrics be put forward to measure it."

Bennis continues, "In the race to prioritize higher data rates and lower latencies, telecom is not fully prioritizing what should also be a push toward networks that can better accommodate adversity and better adapt to unforeseen challenges."

6G RESILIENCE

must be rooted in real-time adaption and recovery

He notes that so far, resilience in telecoms is typically seen to mean reliability (that is, about performance such as 99% reliability, meaning, on average, one packet out of 100 is lost within a pre-defined timeframe) or robustness (preparedness for the network's worst-case scenario). In his view, neither properly covers consecutive packets lost over extended periods or unforeseen disturbances to the network.

Bennis explains, "Resiliency should be defined as the recognition of the anticipation of unanticipated events. A resilient network would require the system to adapt, recover, and withstand various stressors – whether known or unknown, such as node failures, misinformation, adversarial attacks, network outages, and malicious agents injecting false information."

He stresses resilience should be rooted in real-time adaptation and recovery. The good news is that we already have technologies that support adaptation and recovery options, such as assurance, which draws on observability. They will play a key role in next-generation networks as they are vendor-agnostic and can transition operators to proactive network management, allowing them to review, verify, and predict anomalies. This includes providing device and service data across thousands of users and devices at a granular level.

EXPANDING THE ROLE OF AUTOMATION

A modern, cloud-native assurance solution should include a closed-loop Network Data Analytics Function (NWDAF), a 5G network function defined by the 3GPP to drive automation by extending the role of closed loops. The NWDAF protocol collects data from across the network, from the RAN to the core, applying real-time analytics to detect issues in real time. Then it automatically provides information to optimise network operations and user experience without manual intervention.

The 5G standard provides frameworks, architectures, and interfaces like 3GPP's NWDAF, service-based architecture (SBA), management, and orchestration functions. It also includes guidelines on data monitoring for some functions like network slicing. How data analytics are implemented is not specified, it is left to individual operators and vendors, and executed with varying degrees of success.

NWDAF's success depends on having a good data strategy in place so that data analytics can enable service differentiation: the extracted data can drive GenAI models or machine learning models and/or support applications from IoT to smart cities, autonomous vehicles, and many other use cases to meet customers' demands.

Conventional service assurance and network analytics are network-centric, relying on data that is not real time and only drawn from some network functions because network data is typically siloed. In this scenario, operators infer customers' experience rather than have direct, real-time insight. This incomplete data cannot be correlated with data from subscribers' network sessions and lacks sufficient detail. This limited visibility hampers identifying root causes and accurate, rapid troubleshooting.

SERVICE ASSURANCE IN THE AGE OF AI

Service assurance in the age of AI needs granular, real-time data at subscriber, service and session levels that can be broken down into specific components for particular purposes, as required. This modern approach provides a granular, precise, and comprehensive analysis of the many aspects of the network's performance, users' behavior, and service quality.

Granular data fed into AI-powered solutions can raise anomaly detection and assurance to the next level. As the model is trained over time, it can predict issues so operators can take a proactive and pre-emptive, rather than reactive, stance to avoid network degradation and disruption to customers.

These attributes help one operator's service stand out from its competitors and provide an unprecedented level of observability. This will become increasingly important to operators' customers (and maybe the customers' customers, depending on the nature of the business) as well as to operators themselves as customers order, configure, and activate services they want through Network-as-a-Service and as the network API-enabled ecosystem and market develop.

SUMMARY

6G will be essential to meet growing data volumes and reduce operating costs, mainly through more efficient use of spectrum and more, better automation. This is despite networks becoming increasingly complex and the challenges of leveraging AI everywhere effectively.

A solid data strategy that makes good quality data accessible as required remains fundamental to achieving resilient infrastructure, service assurance and differentiation, and a sustainable business in every sense. The other essential step to success for those who deploy 6G is to be crystal clear about the business outcomes they strive to achieve.