Qualcomm

Qualcomm response to the public consultation on the Draft RSPG Report on 6G Strategic vision

Qualcomm would like to thank RSPG for the opportunity to comment on its draft report on 6G Strategic Vision. As we march toward 2030, the relentless demand for wireless data is reshaping the landscape of connectivity.

Wireless connectivity has become the backbone of global digital transformation. The proliferation of smartphones, Internet of Things (IoT) devices and connected vehicles — each supported by wireless broadband — has driven a massive surge in data consumption. It is expected that by 2030, global mobile data traffic will quadruple, reaching a staggering 465 exabytes per month, with a compound annual growth rate (CAGR) of 23%[1] from 2023. This surge is powered by key trends such as the continued proliferation of 5G, increasing demand for video including enhanced video quality, the rise of extended reality (XR), cloud gaming, and the increasing prevalence of AI-driven applications and services. Notably, AI is reshaping data flows, with global wide-area network (WAN) traffic projected to grow five to nine times from 2023 to 2033. By then, AI will account for an estimated 33% of all WAN traffic[2].

Meeting this demand requires a well-orchestrated strategy to secure new spectrum and optimize existing bands. The success of 6G, with commercial deployments expected to start around 2030, hinges on the timely availability of spectrum. Given the complexity of the spectrum allocation process, initiating activities to ensure spectrum readiness for 6G are imperative and cannot be delayed. Thus, Qualcomm welcomes RSPG proactive approach in defining a European 6G vision and in addressing spectrum challenges early and encourages RSPG to finalize the European 6G spectrum roadmap as soon as possible and no later than the end of 2026 as the race to define and deploy 6G is intensifying with an increasing number of countries and regions investing heavily in research, while standardization efforts are actively underway.

ENABLING THE NEXT GENERATION OF WIRELESS TECHNOLOGY

As the world proceeds from the present wireless technology generation to the next, the current capabilities of 5G wireless networks will be improved, and new 6G capabilities, applications and services will be added. 6G will address, at its foundational level,

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[1] GSMA. (2024). The Mobile Economy 2024. Retrieved on Dec 2, 2024 from: https://www.gsma.com/solutions-and-impact/connectivity-for-good/mobile-economy/.
[2] Nokia. (2024). Global network traffic report. Retrieved on Dec 2, 2024 from: https://onestore.nokia.com/asset/213660.

environmental sustainability concerns and incorporate technology enablers that extend the platform capability beyond connectivity. In the 6G era, capabilities such as RF sensing, Machine Learning/Artificial Intelligence ("ML/AI") and compute will merge with enhanced communication capabilities and foster ubiquitous access to use cases such as immersive multisensory devices, supporting Digital Twins and collaborative robotic applications, among other innovations. 6G also is being designed from the ground up to be more cost-efficient, allowing mobile network operators to maximize return on investment ("ROI")[3]. With a focus on reducing capital and operating expenditures, 6G will enhance network efficiencies and drive down network costs.

6G Anticipated Use Cases

Initially, 6G use cases will improve performance across various vectors including throughput (eMBB), latency and reliability (URLLC) and device density (mMTC) of 5G use cases.[4]

We anticipate the development of use cases that fall within the following categories:

1. **Next Generation Broadband**. Use cases will be improved coverage resulting in improved data rates throughout the cell addressing the needs of customers in urban, and particularly in suburban and rural areas. In addition, higher peak data rates will better serve fixed wireless access bringing higher rates and better quality, particularly for those in more rural areas where other approaches are less cost effective.
2. **Immersive Platforms and Services**. Use cases fall within two different subgroups: a. immersive and multi-sensory communications that require gigabit data rates and single digit millisecond latency, like Tactile Communications, Metaverse Collaboration, Holographic Video Conferencing, Metaverse Gaming and Education, Holographic Communication/Telepresence; and Compute and Communication Convergence, like Vehicle-UE aggregation and user-centric cloud.
3. **Real Time Control**. This class of services will push the technology boundary to deliver even lower latency and higher reliability/availability than what is available with 5G to allow for use cases like interactive, collaborative and autonomous service robots (for industrial and consumer settings).[5]

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[3] For instance, according to a report by GSMA, "20% of operators rate energy efficiency as the No.1 attribute to prioritise in 6G networks from a business standpoint." See GSMA Intelligence, The Next Generation of Operator Sustainability: Greener Edge and Open RAN at 6 (Sep. 2023).

[4] eMBB refers to Enhanced mobile Broadband; URLLC refers to ultra reliable latency communications; and mMTC refers to massive Machine Type Communications.

[5] Aside from industrial and consumer collaborative robots (also referred to as Cobots), 6G-enabled field robots would facilitate more responsive and efficient teleoperations while performing mission critical tasks such as inspections or maintenance tasks in crises and disaster scenarios, or environments deemed dangerous for humans.

4. **Spatial Perception**. These use cases will be based on the new and improved capabilities of wireless sensing (and positioning) to offer services like smart farming, environmental monitoring, and digital twins.[6]
5. **Pervasive Access**. Use cases support a very high density of devices,8 especially low complexity devices supporting public safety applications, next generation smart grid applications, asset management using zero-power tags, and wide-area IoT networks with non-terrestrial network ("NTN") communications capabilities.
6. **Sustainability**. refers to three aspects: (i) economic sustainability where the wireless ecosystem fuels sustained global growth; (ii) environmental sustainability where the system design consciously minimizes environmental impact and enables the reduction in greenhouse gas emissions in other sectors; (iii) social sustainability where more accessible networks, devices, and services promote digital equity and inclusion. e.g., for bridging the divide, multi-connectivity using UAVs, satellite (both GEOs, and LEOs) and High-Altitude Platforms (HAPs), devices with scalable affordability.

These anticipated use cases were presented and discussed in 3GPP's Stage-1 Workshop on IMT-2030 Use Cases, which took place on May 8, 2024, in Rotterdam, Netherlands. During the several regional and global research organizations, as well as market partners, operators' associations and the ITU presented 6G use cases. These use cases, along with 6G requirements and KPIs, will further be addressed in 3GPP's RAN Plenary study item discussed below.

Roadmap for Development, Standardization and Rollout

1. Pre-Standardization Industry Alignment

The industry has engaged in extensive pre-standardization collaboration where stakeholders share their vision of 6G, the anticipated use case scenarios, technical requirements and implementation considerations. Similarly, there have been numerous regional efforts on 6G technology development. In Europe where there is a strong focus on standardization leadership, the EU's Flagship Hexa-X project, along with eight 6G exploratory projects, is focusing on developing the vision for future 6G systems and developing key technology enablers. These projects are positioned to act as a bridge to the strategic European partnership, which is the joint undertaking on Smart Networks and Services (SNS). In the United States, the NextG Alliance is an initiative advancing North American wireless technology leadership through private sector-led efforts. 6G participation continues to

[6] A digital twin is the real-time digital replica of a real-world object, which connects physical systems and digital spaces. Digital twin can monitor, design, simulate, analyze, optimize and predict the behavior of physical systems. See generally, "What Is a Digital Twin? And How Can It Make Companies – and Cities – More Efficient?" Wall Street Journal (Mar. 17, 2023) at https://www.wsj.com/articles/what-is-digital-twin-making-companies-cities-moreefficient-92e551b6 8 The 5G connection density requirements is 106 devices/km2

expand globally as new entrants (e.g., India with Bharat 6G Alliance, China with China IMT-2030 PG, Japan with Beyond 5G Promotion Consortium and Korea with 6G Forum) propose their vision and requirements. This type of industry dialogue applies the commercial lenses of profit, expenses, and losses so research efforts are more focused on successes. Market considerations, which may potentially impact some of the proposals, are properly evaluated through reasoned forecasts made by individual participants taking their own business interests into account because of their opportunity to see and share their own visions for the future of 6G. Further, informal industry discussions allow tackling complex technical matters with business implications like the benefits of the next generation of connectivity, the path to migration from 5G and new services to be enabled. The industry is learning from previous transitions from one generation to the next and is resolute in ensuring a smooth, clean and better transition to 6G.

2. 3GPP Timeline

3GPP plans to define the sixth generation of wireless technology in Release 21. The efforts for global 6G standardization will begin in 2025 with a 6G Workshop, scheduled for March 10-11, 2025. The 6G Workshop will focus on proposals for the Radio Access Network (RAN), including the physical and media access control (PHY/MAC) layers, other protocol levels and system architecture aspects. Following the workshop, 3GPP will undertake study items at the RAN Plenary-level, that will address use cases, requirements and KPIs, and at the working group level, which will focus on how the requirements will be met technically and corresponding evaluation methodologies. The study items, which will result in multi-staged technical reports, are estimated to be completed by June 2027. The studies will tackle a number of complicated and sophisticated issues surrounding 6G, including the transition from 5G to 6G. The outcome of these efforts will be a Work Item. 3GPP will proceed in considering the Work Item, which will result in the 6G specifications. It is expected that the 6G specification will be frozen no earlier than March 2029, which would enable the first 6G deployments in 2030. Over the following decade, we anticipate the continued evolution of the technology, with development and release of more 6G standards as they expand into more consumer and industrial applications.

Rollout of 6G

The 6G rollout will be impacted by regulatory, technical, and business considerations. A lesson learned from 5G deployments was that new technologies are increasingly expensive to roll out broadly. As mobile operators are focusing on lowering the total cost of ownership (TCO) of their networks, the timing of 6G deployments will be tied closely to optimization of operators' capital and operational expenditures.

Reducing network operational costs, including the energy costs, will play a great role in these decisions, as will technical considerations about the migration from 5G to 6G. Choosing the right migration strategy from 5G to 6G is not merely a technical decision but a strategic one that will have an impact on the economic viability of mobile networks and operators, and the supplier ecosystem that supports their work. Hence, it is imperative that the migration strategy is well-planned to minimize disruptions, reduce deployment costs, and lower the total cost of ownership for the operators.

There is industry-wide consensus for adopting a standalone solution for 6G,[7] which will allow the new features of 6G to be deployed on Day 1. This is a preferable long-term strategy for the ecosystem's evolution and will allow for the development of a 6G standalone solution, rather than a scenario that resembles the non-standalone transition from 4G to 5G. By limiting the amount of interworking required with a legacy generation, a standalone 6G RAN and core network will be the primary design to benefit from the latest and future advances in cloud, artificial intelligence (AI) and other technology enablers to maximize the platform capabilities and revenue opportunities for new use cases and verticals. This type of migration from 5G to 6G will influence the implementation and ease of deployment of 6G features and be a differentiating factor between mobile operators that adopt the new generation.

Open RAN and 6G

Open Radio Access Network (Open RAN) provides an open and flexible RAN architecture, where different parts of the network can be sourced from different vendors and interoperate through standardized interfaces. Qualcomm has been working closely with numerous industry partners worldwide on standardizing, developing, testing, integrating, verifying, and deploying Open RAN technology, equipment, and networks. Qualcomm has showcased technological innovations with unmatched performance that can lead to the proliferation of Open RAN deployments globally[8].

5G specifications were developed through the 3GPP process, with the O-RAN Alliance building upon that foundation to define 5G Open RAN standards. The O-RAN Alliance also has a research group (Next Generation Research Group or nGRG) looking forward to 6G Open RAN, including 6G use cases that impact the Open RAN architecture, evolution of the current Open RAN architecture to 6G, future cloud-native Open RAN interfaces and APIs, network

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[7] Standalone refers to a cellular network that operates independently without reliance on any previous mobile technology generation. Contrary to a 5G non-standalone system, which use a 4G/LTE core and a 5G RAN, and similar to 5G standalone networks with the core network and the RAN built based on the 5G specifications, a 6G standalone solution would be comprised entirely of network elements developed on the 6G specifications.

[8] Qualcomm Technologies, Inc. (QTI) is at the forefront of the Open RAN movement, having developed sophisticated platforms that are integral for the advancement of 5G networks. QTI's Open RAN platforms have been widely adopted by a variety of MNOs and network equipment manufacturers, including NTT DOCOMO, Viettel, Mavenir, Fujitsu, and NEC. These engagements across diverse entities demonstrate the wide applicability and dependability of Qualcomm's Open RAN solutions and highlight their robustness and potential for broader industry adoption.

management automation, security for 6G Open RAN deployments, advanced 6G spectrum sharing, network energy savings, and the application of pervasive Native AI in the evolved Open all next generation RAN use cases. 5G Open RAN will serve as the foundation for 6G multi-vendor interoperability, by establishing the technical and operational feasibility of open and disaggregated network architectures, creating a more competitive and diverse market for RAN products and services, and accelerating the innovation and adoption of new RAN technologies and features. At this time, it is unclear how exactly the 6G Open RAN standards will be developed, but there is growing industry consensus that the responsibilities will be shared between 3GPP and the O-RAN Alliance. While the complete architecture and scope of 6G Open RAN networks are still in the early stages of research and standardization, there are several key areas that will be key components of the final design for 6G systems: a) the evolution of the "Open Fronthaul" interface between the 6G Distribution Unit (DU) and the Radio Unit (RU); b) the disaggregation of functions with clearly defined Cloud Native APIs to support advanced AI-based RAN automation (as well as to support the network functionality that will be essential to enable AI applications in the 6G timeframe); c) the evolution of "RAN Intelligence," e.g., far beyond the 5G RAN Intelligent Controller (RIC), to support much more advanced use cases, and d) evolution of security requirements to meet all the challenges in the 6G timeframe. These areas could benefit from additional funding to support early R&D, prototyping, proof-of-concept, and standardization activities that are ramping up rapidly in 3GPP and the O-RAN Alliance (and other groups).

6G Resiliency and Security

Qualcomm is steadfastly committed to 6G Network Resiliency and Security R&D, to ensure cellular systems are the most secure and resilient global scale wireless systems. 6G resiliency and security will improve upon the advancements of 5G design and further incorporate a number of security principles on the device. For example, in the area of post-quantum security, Qualcomm has been engaged in the United States in the National Institute of Standards and Technology's (NIST's) development of Post-Quantum Cryptographic algorithms and is collaborating closely with industry partners (including government customers) to ensure 6G systems are resilient against Quantum attacks that may be feasible in the lifetime of the 6G system. In addition to the new use cases 6G will enable, 6G will introduce security enhancements across the system in compliance with zero-trust architectural principles (that relate to how the different elements of the network, device and user securely interact with each other). Security enhancements in the MAC/PHY layer will improve user privacy and resiliency of wireless channels to adversarial attacks. Cloud-native security will be tightly integrated into the 6G network and considered from the early stages when the system/network is designed. Besides security, data privacy on the network and device will be ensured by technical means in compliance with domain specific policies as well as regulatory requirements. In addition, 6G will be adopting post-quantum cryptography to secure all 6G assets involving communications, data processing, and data storage. Quantum computers invalidate the computational hardness of certain mathematical problems upon which the current security algorithms were built and thereby threaten those security algorithms. To address this, 6G is expected to adopt quantum-safe algorithms, including post-quantum cryptographic algorithms and 256-bit symmetric key algorithms.

6G and Public Safety

Public safety and first responder mission critical communications will benefit greatly from the new generation of wireless connectivity with new use cases that will allow for better training, sophisticated forensics and more effective emergency services, rescue and disaster relief. 6G will support mission critical services and other National Security/Emergency Preparedness (NS/EP) services such as wireless priority service (WPS) and network restoration in the same (or better) way as 4G and 5G already do.

As discussed above, 6G should have an increased level of security, reliability and resilience on both the network and device sides than previous generations. For example, support of more reliable and resilient network timing and its provision to devices is ongoing for 5G in 3GPP which should help counter any threats or attacks on GPS, Galileo, and other GNSS systems. This trend will continue in 6G, where all improvements will build upon earlier 5G improvements.

Further, the 6G network will have greater redundancy on the network side (e.g. no single point of failure) and will have multiple access options for devices including Wi-Fi and satellite access. While some of these improvements can be network operator-specific (e.g. use of multiple redundant backhaul alternatives), others can be defined in 6G standards that network operators and device vendors must support. The adoption of sidelink signaling, which will increase network coverage and enable signal penetration deep inside buildings, is an example of what can be expected. Other examples include the continued development of non-terrestrial networks (satellites, high altitude platform stations), and improvements on vehicle mounted relays and distributed base stations, which will improve public safety use cases.

THE R&D ROAD TO 6G

For over 30 years, Western companies have been the driving force behind the development and standardization of cellular standards, from 2G through to 5G, and are now well positioned to lead in 6G. Qualcomm's commitment to wireless R&D has enabled us to invent many of the foundational technologies at the heart of 3G, 4G, and 5G wireless products and networks. Since our founding in 1985, Qualcomm has invested over $95 billion in R&D to develop foundational and groundbreaking wireless technologies that have created the wireless ecosystem. Technological leadership in standards is determined by the quality of technological contributions, not the total number of contributions, participants, or chairmanships. Qualcomm is at the forefront of wireless R&D. Our continuing re-investment in new R&D will enable us to continue to make foundational technology breakthroughs in 6G and beyond and lead in the development of the 6G specifications. For well over the past decade, Qualcomm has been researching AI-native communications technologies, scalable and resilient network architectures, air interface innovations, the meaningful merging of physical, digital and virtual worlds, and expanding uses in new frequency bands. Each of these long-term research vectors is fueling the development and adoption of 6G. The 6G R&D areas Qualcomm is focused on are detailed below:

6G Network Architecture

Qualcomm foresees the continuation of the trend goingfrom traditional hosting of services within the mobile network to shift towards IP-based services that will allow the network to leverage the robustness and scalability of the Internet. Mobile network operators can provide these IP-based services as well as over-the-top providers. Our research into the 6G network architecture has focused on simplifying the network to accelerate the introduction and operation of new services. This effort has led to a 3-part approach to addressing key core network functionalities in future architectures:

Relocate

We propose to adopt a user plane-first design approach for 6G where we relocate any service that is only using the network as a transport to be hosted in the user plane.[9] By adopting a user plane-first approach, operators can benefit from the scale and developer ecosystem for Internet services and protocols, while leveraging the advantages of new cloud-based deployments, eliminating the need for additional hardware. Additionally, a user plane-first approach is "G-agnostic" which means that services work seamlessly across different generations of cellular networks, i.e., the operator will not be required to upgrade the services that do not manage basic connectivity or enable data services for a new G, while it also enables backporting these services to previous generations of mobile networks or cross-port them to other access technologies like Wi-Fi, fiber or cable.

Reuse

6G will reuse some of the functionality initially introduced in 5G. Examples include the external interfaces/APIs, such as Data exposure (NEF) and IP functions (UPF) that operators

[9] The user plane, also known as the data plane, is a component of a telecommunications network that carries user information, such as messages, web browsing, or file downloads. It is responsible for forwarding packets from one interface to another, based on logic created by the control plane. The user plane applies actions to the packets based on rules programmed into routing tables.

use to expose information/services to third parties. These are common for 5G and 6G for service and data interworking and should be backward compatible in the 6G timeframe.

Replace

To evolve with cloud platforms, Qualcomm believes that NAS protocols and the RAN interfaces should be replaced in 6G with new solutions. A new protocol will allow for more flexible and independent evolution of functions for the introduction of new verticals. Additionally, certain interfaces should be replaced with a service-based architecture aligned to core network to benefit from cloud functionality

Radio Interface

Our ongoing research into the 6G radio interface innovations will improve the efficiency through a combination of factors and techniques such as reduced signaling overhead, optimized coding, modulation and MIMO.[10] Even though spectral efficiency is the most important area of improvement, we are designing 6G to improve other areas like cost effecting scaling to larger bandwidth and more antennas, and to enhance coverage. The massive MIMO techniques developed for 5G will be further improved through better channel state feedback and channel reciprocity mechanisms, resulting in robust, spectrally efficient Giga-MIMO networks with higher throughput at each cell and also better user experience through enabling larger number of single user and multiuser MIMO layers.[11]

Spectral efficiency, uplink coverage, latency and energy efficiency will be further improved using sub-band full duplex techniques. The enabling technology we call "Giga-MIMO", an end-to-end system design that has a much denser antenna array (e.g., 1024 antenna elements at 7 GHz) in the base station, is comparable in size to the 5G massive MIMO antenna system in 3 GHz spectrum, as well as a more complex device baseband and radio frequency (RF) design. These improvements will enable efficient use of newly allocated spectrum while also ensuring 6G deployments on existing spectrum, including the narrower bandwidths available in sub-6 GHz bands, are more efficient than existing 4G and 5G systems.

[10] Spectral efficiency refers to how efficiently the allocated spectrum/channel is used for communication. There are two components to spectral efficiency. First, the fraction of the spectrum occupied by the waveform used which is tied into the guard band, and second, how many bits/sec/Hz can be carried in the said spectrum and how it can be improved using better modulation, coding and MIMO techniques.

[11] Qualcomm has developed a Giga-MIMO antenna, a key innovation for wide area mobile communications with a new design for base stations and devices. Just like 5G introduced Massive-MIMO to expand into higher bands in sub-7GHz, Qualcomm developed Giga MIMO which has a large number of antenna elements (over a thousand antenna elements) with the same aperture, and a 3-4 times wavelength reduction. As a result, Giga MIMO can expand macro network coverage in the upper mid-band frequencies, by allowing for tight control of very narrow beams in upper midband that in the presence of incumbent systems can lead to new and more efficient coexistence approaches. However, specific sharing mechanisms will depend on the target bands and incumbent systems.

Artificial Intelligence (AI)/Machine Learning (ML)

6G will natively integrate AI/ML in its design and functionality. AI will be used to optimize communication between the network and the user equipment and for intelligent RAN/network management such as energy efficiency and network optimization. An "AI-Native" approach involves the integration of AI/ML design principles from the outset, enabling a mobile wireless experience that seamlessly incorporates AI and machine learning enhancements. The design allows the system to rapidly adapt to specific deployment environments, resulting in fundamental performance gains over the previous generation of non-adaptive wireless systems. ML methods will be embedded across all layers and protocols of the device and network infrastructure, both for training the system with relevant data and utilizing the inference to adapt dynamically to varying signal and network conditions. We expect that this "AI-Native" design - both the ML models, and the data management of training data - will be incorporated in the 6G specifications. While several functionalities such as beam management, channel state feedback and positioning are already being explored in 5G Advanced in preparation for 6G, there are many other functionalities of operating a 6G network such as scheduler, resource management, energy management, traffic and loading mapping to cells, interference measurement and management which will be enhanced by AI/ML. For example, the scheduler will be able to learn the requirements of the traffic profile and tailor resource allocation to meet latency requirements for a delay sensitive application or optimize power if the application is delay tolerant. Similarly, depending on the time of the day, network planning would know user density in each cell and plan for load distribution pro-actively to enable the best user and network performance, especially in optimizing energy savings. The framework envisioned will support hyperlocal models which are highly optimized for specific deployments and geographical regions.

Wireless Sensing

6G networks will incorporate wireless sensing, which will lead to a radar-like functionality built into every wireless node. With Giga MIMO antenna arrays and large available bandwidths, wireless networks will be able to sense the environment at a very fine resolution in both time and space. High resolution RF sensing will be an important component in enabling the vision of a merged physical, digital, and virtual world in the 6G era and will enable a number of new use cases like environmental monitoring and activity detection. Security and privacy will be built into the sensing functionality, similar to functionalities such as communications and positioning offered by the cellular networks. Compliance with regulation and user awareness will be ensured while limiting exposure of sensing results to authorized entities only through the support for encryption, integrity protection, and data privacy.

User Equipment (UE)

From the UE perspective, 6G will continue with the trend 5G set in pushing the envelope of user equipment form factors and capabilities in terms of data rates, antennas supported, battery life and compute power available. 6G will enable at least eight antennas with a corresponding eight MIMO layers of reception and at least four layers of transmission in many scenarios and form factors in upper mid-band (6 to 15 GHz). The peak data rates will be higher, and this will be achieved through a combination of improved spectrum usage and optimized data processing algorithms and AI on the user equipment. With further expansion of use cases such as eXtended Reality (XR), additional form factors for user equipment will be enabled that will be demanding and challenging in terms of weight, required performance level, battery life, and heat dissipation. There will be a wide variety of device use cases, form factors, and modern envelopes that use low power and involve less complexity.

IoT

IoT will play an increasingly important role in the 6G ecosystem as the physical/digital/virtual divide is bridged through data collected from distributed sensors and trackers, with applications ranging across consumer, retail, and industrial use cases. IoT requirements vary widely due to constraints from the underlying use cases including power, cost, form factor, battery life, density and infrastructure support, and 6G will scale to support IoT device needs efficiently. IoT devices are expected to be deployed for longer time durations than typical consumer devices, imposing requirements on both the network and the device to maintain compatibility over longer lifecycles. On the network side, 6G will be designed to ensure that deployed IoT device base will not hinder or delay the network migration from 5G to 6G. This will be achieved through efficient Multi-RAT Spectrum Sharing (MRSS) techniques, waveform compatibility, and network architecture. The main goal is to remove the need for operators to maintain multiple networks to support mobile broadband and IoT use cases, thus reducing deployment as well as operating costs. 6G will also ensure that lower bands, which are inherently more suited for IoT deployments, will operate much more efficiently with close to 50% improvement in spectral efficiency. On the device side, 6G will bring reduced cost and complexity for IoT devices, leveraging the broader eco-system for mobile broadband devices through a shared network and common design. 6G will also integrate the paradigm of battery-less devices using energy harvesting techniques to communicate with the network. 5G is currently studying such techniques that are expected to be an integral part of 6G IoT. 6G Ambient IoT built using energy harvesting techniques will drive down the cost and form factors to a point that will be suitable to provide continuous coverage and track the location and state of individual products in retail and industry. Such requirements can be met today only under certain conditions (e.g. chokepoints in distribution) and 6G will expand those applications to much wider areas.

Energy Efficiency

To minimize power consumption and maximize energy efficiency, the industry will first incorporate energy-efficient features available from the latest releases of 5G and consider new innovative approaches for environmentally sustainable 6G. While additional capabilities of the next generation networks tend to increase the energy consumption compared to previous mobile generations, R&D is exploring innovative approaches to pave the way for an environmentally sustainable 6G by considering new, innovative solutions that will in fact minimize energy consumption. Some of these includes Innovative Operational Network, Computing and Device technologies, like:

Intelligent Power Saving Modes.[12]

This solution is the starting point to be able to turn networks on and off at a short time scale and adapt effectively to traffic patterns. These modes will be further enhanced by AI/ML capabilities providing more accurate actual and predictive traffic load information to be readily available in the network in near real-time/real time, allowing for faster and more efficient adaptation of network resources in the time, frequency, spatial and power domains.[13]

Advancement in Power Amplifier:

More than 73% of the power consumed by the network is consumed in the Radio Access Network (RAN), especially the Power Amplifiers.[14] There are some promising R&D developments that include enhanced pre-distortion and post-distortion techniques and enhanced impairment cancellation techniques to provide more efficient power consumption.

Near-Zero Energy (NZE) or Energy Harvesting Devices:

These devices are powered using electrical energy converted from ambient energy sources such as solar, thermal, wind, light or even RF and are power-efficient, lightweight, low-cost and operating without a battery. They are low-cost and environmentally friendly and are envisioned to cater to the 6G IoT market and support a range of different use cases.

Passive Network Infrastructure:

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[12] These modes involve the powering off of network elements (in the Radio Access Network (RAN), Core Network, UEs, and Data Centers) due to unused resources and powering on only when needed.

[13] In addition, the ability to power on/off components in the network efficiently requires that the network components are designed in a modular fashion ensuring that the adaptation of the resources closely matches the traffic patterns on the network. It is important to note that the powering off/on of network components due to the traffic load incurs latency which may impact the responsive of the network to user applications. Therefore, this latency needs to be managed so the user experience is not adversely impacted.

[14] Power Amplifiers are used during wireless signal transmission and the main issue has been identified as the operation of PA in regimes that are power inefficient.

R&D efforts focus on Reconfigurable Intelligent Surfaces[15] for dynamic RF signal propagation control for 6G networks, By reusing RF signals and eliminating the circuitry for RF generation or the need for power amplifiers, reduces the cost of network elements and lend itself to the environmentally friendly solution.

Advancements in cloud and distributed computing:

Given the explosive growth of data from one mobile generation to the next, the processing and storage requirements for the network are growing. Advancements in computing technologies, such as edge computing that involves moving the computing and processing resources from the centralized cloud closer to the data source, and virtualization of network functions and disaggregation of the network infrastructure, which started with 5G, will prove useful for maximizing network efficiency and improve efficient utilization of the ubiquitous computing infrastructure expected in the 6G era. These advances in computing are expected to be leveraged in supporting the processing and storage demands of enhanced communication technologies and emerging capabilities such as AI/ML, and sensing.

End-to-End Energy Assessment and observability:

In the 6G era, the power consumption reporting, assessments, and energy efficiency solutions are expected to be readily available for each component in the network, devices and data centers. The assessment and implementation of energy efficient mechanisms are expected to be coordinated wholistically (i.e., in an end-to-end fashion), to facilitate maximization of the energy efficiency across the entire network and devices, and ensuring that power consumption savings in one component does not lead to power consumption increases in other components.[16]

SPECTRUM POLICY TO ENABLE 6G LAUNCH

The emergence of 6G opens the door to transformative opportunities across all spectrum bands — low, mid and high. Qualcomm's vision is to drive innovations that unlock new spectrum while enhancing the operational efficiency of existing bands. This dual approach creates cost-effective scaling of traffic capacity, even as new use cases emerge. 6G will use wider bandwidths in the upper mid-band spectrum range (e.g., from 6-8.5 GHz) to enable high-performance applications like immersive extended reality (XR) and generative AI, while

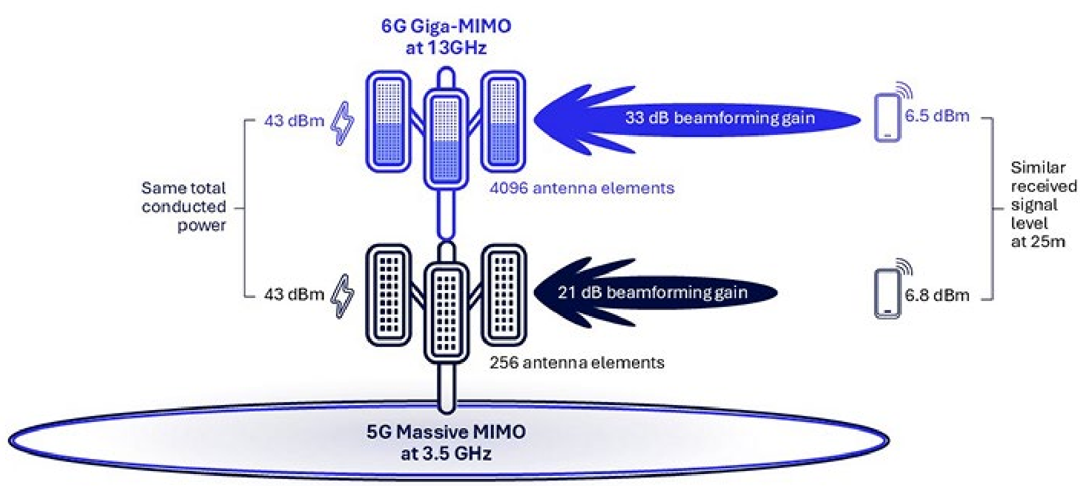
[15] Reconfigurable Intelligent Surfaces (RIS) comprise of large, thin meta-surface of metallic and dielectric material which use existing RF signals rather than actively generating RF signals and dynamically controls the RF signal propagation to improve propagation in desirable directions improving network features such as coverage, providing localization information, etc.

[16] To achieve this, accurate models for assessing the power consumption of each network elements (i.e., RAN, core network and cloud) under different conditions (e.g., network load and constraints) will be addressed, as well as cohesive metrics to efficiently track the power consumption and energy efficiency across the different network components and devices and assessing the impact of the innovative energy efficiency strategies across the network.

enhancing efficiency in low and mid-band spectrum bands (below 6 GHz) to boost coverage and capacity in these important wide area coverage bands.

Securing spectrum for 6G is a decade-long journey that is already underway across the globe. Frequencies between 6 GHz and 15 GHz — known as the upper mid-band — have been identified as prime candidates for 6G use. The International Telecommunication Union (ITU)'s World Radiocommunication Conference 2023 (WRC-23) have initiated studies to identify bands within this range for 6G. For instance, one of the most impactful agenda items for WRC-27 involves the study of several frequency bands, including 4.4-4.8 GHz, 7.125-8.4 GHz and 14.8-15.35 GHz, for potential International Mobile Telecommunications (IMT) use. In addition, many countries throughout the world are planning to deploy IMT services in the upper 6 GHz band (6.425-7.125 GHz).

In the U.S., the National Spectrum Strategy (NSS) has pinpointed the 7.125–8.4 GHz band for wireless broadband studies. These efforts reflect a growing recognition of the upper mid-band's potential to deliver both wide-area coverage and high capacity, particularly when paired with next-generation technologies like Qualcomm Giga-MIMO. Giga-MIMO leverages advanced antenna systems on both the base station and device to achieve coverage comparable to today's 5G massive MIMO in the lower mid-band spectrum, further enhancing the feasibility of the upper mid-band utilization for 6G.

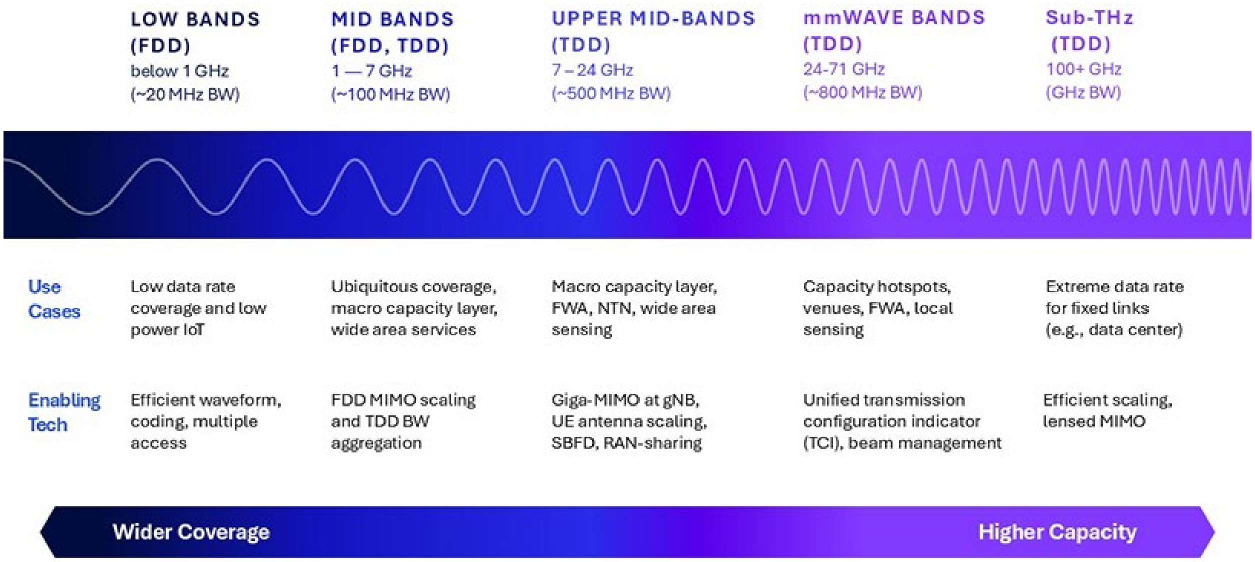


Giga-MIMO: Meeting the capacity demands of the decade to come.

6G also represents an opportunity to improve the use of existing bands. By focusing on air interface design advancements in foundational technologies such as waveforms, coding, modulating, MIMO, data and control channels, and multi-band carrier aggregation, 6G will enable transformative upgrades for both existing and new bands:

- Low-Band spectrum (<1 GHz): Designed for lower data rates, wide-area coverage and power efficiency, advancements in waveforms, coding/modulation designs and multiple access technologies will enhance low power IoT applications.
- Mid-Band spectrum (1–6 GHz): As a macro capacity layer, mid-band innovations such as MIMO dimension scaling for FDD and bandwidth aggregation for TDD will optimize coverage, latency and spectral efficiency to better support wide-area services.
- Upper Mid-Band spectrum (6–24 GHz): As a macro capacity layer, the upper mid-band enabled by Giga-MIMO will not only optimize spectral efficiency and support wide-area coverage services, but it will also be complemented by innovations such as sub-band full duplex (SBFD), further enhancing overall efficiency.
- mmWave spectrum (24–71 GHz): Innovations like fast AI-driven beam management and Giga-MIMO will enhance capacity in dense environments, efficiently enabling multi-gigabit connectivity in venues, transportation depots, shopping malls and dense urban areas, and supporting fixed wireless access (FWA). In addition, 6G integrated sensing and communication (ISAC) will enable new sensing use cases for local area coverage.
- Sub-THz spectrum (100+ GHz): Targeted at fixed links requiring extreme data rates, advancements like lensed MIMO will unlock use cases such as fronthaul and data center communications.

By driving these innovations, Qualcomm is setting the stage for enhanced wireless efficiency, helping to enable 6G to deliver on its promise of improved capacity, coverage and performance.



As pointed out before, the success of 6G in Europe, with commercial deployments expected to start around 2030, hinges on the timely availability of spectrum. Given the complexity of the spectrum allocation process, initiating activities to ensure spectrum readiness for 6G are imperative and cannot be delayed. Thus, Qualcomm encourage RSPG to finalize the European 6G spectrum roadmap as soon as possible and no later than the end of 2026.

This roadmap should identify which frequency bands should be made available for the launch and future development of 6G. Qualcomm would like to highlight the following:

Sub-1GHz Spectrum

To ensure ubiquitous connectivity and avoid increasing the digital gap between urban and rural areas, Qualcomm suggests considering sub-1GHz spectrum (470-694 MHz) as a candidate band for 6G. This spectrum is vital for providing coverage in sparsely populated and hard-to-reach areas. In addition of harmonizing the 470-694 MHz band, Qualcomm considers the developments in 3GPP band n105. This band, which includes UL 663-698 MHz and DL 617-652 MHz, has seen a robust ecosystem emerge in North America and is now being considered for introduction in regions like the Middle East, following a new primary mobile allocation from WRC-23. Qualcomm recommends that any harmonization efforts should consider the potential future use of the 663-698 MHz range for mobile uplink.

Additionally, the utilization of spectrum below 617 MHz requires a broader discussion beyond CEPT, involving ITU Region 1, to address both ecosystem development and coordination challenges. This comprehensive approach ensures that harmonization efforts are aligned with global trends and technological advancements, facilitating a more efficient and effective use of the 470-694 MHz band across the European Union.

6425-7125 MHz and 7125 -8400 MHz bands

The upper 6GHz (6425-7125 MHz) is uniquely capable of supporting the channel sizes, coverage, and capacity needs for 6G, and the band is essential to enabling 6G deployments in Europe in the 2029-2030 timeframe. Europe should ensure that the whole 700 MHz are made available for 6G deployments. Longer term, 6G would need more spectrum than that made available in the upper 6GHz band. Thus, initial 6G deployments could start in Europe in the upper 6GHz spectrum but at the same time it would be important to evaluate the potential for additional spectrum in the 7125 – 8400 MHz range for longer term needs. These two bands should be addressed in European 6G Roadmap.

We anticipate cost-effective macro-layer deployments in these two bands by optimizing the re-use of the existing C-band grid. As previously outlined, the evolution of the radio interface will enhance coverage in both downlink (DL) and uplink (UL) directions, thereby enabling 6G use cases for both indoor and outdoor environments. To achieve this objective, it is crucial to permit full-power macro base station deployments.

At the same time, Qualcomm acknowledges the demand for mid band spectrum for unlicensed operations. In fact, Qualcomm is actively supporting ongoing efforts to explore sharing opportunities between licensed IMT and unlicensed RLANs in the upper 6 GHz band and in particular in the United Kingdom (UK) working closely with Ofcom and the UK Department for Science, Innovation and Technology (DSIT).

In April 2023, DSIT released its Wireless Infrastructure Strategy and related Spectrum Statement that highlighted the importance of spectrum sharing. DSIT expects sharing will be a key feature of future wireless networks, including 6G networks, and that sharing will help realize many of the benefits of advanced wireless, including novel use cases. As part of this work, DSIT is funding several spectrum sharing studies between RLAN and IMT operations to assess sharing approaches not possible under current licensing conditions. Qualcomm and its partners in the UK were awarded funding to study RLAN/IMT co-existence in the upper 6 GHz band via test beds.

The objective of this technically challenging work effort is to provide UK regulators with an assessment of the costs and benefits of the sharing solutions, i.e., implementation cost and performance impact from an interference perspective versus performance improvements through sharing, and the regulatory mechanisms that may help achieve the country's desired goals.

Considering the importance of the upper 6GHz to Europe's 6G leadership in achieving deployment in the 2030 timeframe, it is Qualcomm's position that any potential co-channel sharing with unlicensed operations, should not materially impact full power IMT deployments in the whole 700 MHz. Qualcomm also believes that any potential solution would necessitate adequate standardization to define requirements and associated conformance assessment.

Local and Vertical Use Cases

Qualcomm agrees that any additional spectrum considerations for local usage should be assessed once deployments in the recently harmonized 3.8-4.2 GHz range mature. Vertical use cases can also be addressed by public networks, and it is premature to conclude that the spectrum need for local and vertical use will increase significantly.

mmWave and Sub-THz Spectrum

Deployments in the mmWave spectrum are expected to continue, complementing spectrum below 8.4 GHz in high-density areas, such as fiber-like fixed wireless access, smart factories, stadiums, etc. However, Qualcomm does not see the need to highlight mmWave in the 6G roadmap at this stage. Sub-THz spectrum is interesting from a research perspective but should not be part of the 6G roadmap currently as well.

Conclusion

Qualcomm appreciates the RSPG's efforts to outline a European vision for 6G. We urge the RSPG to take decisive steps toward:

- Finalizing the European 6G spectrum roadmap as soon as possible and no later than the end of 2026
- Prioritizing the whole upper 6GHz band for full power macro base station deployments to secure Europe's leadership in 6G.
- Including 7125-8400 MHz band in the 6G roadmap.
- Providing regulatory clarity to drive investments in 6G research, infrastructure, and technologies.

Qualcomm remains committed to collaborating with the RSPG, regulators, and industry partners, offering technical expertise and research insights to ensure Europe remains at the forefront of technological innovation and connectivity.