
Qualcomm
6G TECHNOLOGY & SPECTRUM NEEDS
Our vision and upcoming innovations to power the next era of wireless connectivity
@QCOMResearch
Snapdragon and Qualcomm branded products are products of Qualcomm Technologies, Inc. and/or its subsidiaries.

Today's agenda

OUR PRESENTERS

John Kuzin

Senior Vice President,
Spectrum Policy & Regulatory Counsel
Qualcomm Incorporated

Tingfang Ji

Vice President, Engineering
Qualcomm Technologies, Inc.

1. Mobile data demands continue to fuel the need for more licensed spectrum
2. Wireless ecosystem is preparing today for new 6G technologies
3. Spectrum innovations will form the foundation of 6G advancements, providing enhancements across all bands
4. Our wireless research is enabling enhanced spectrum efficiencies and support for new bands
5. Questions?

Shaping the digital future

Powering the mobile revolution

Redefining inter-connected processing

Enabling intelligent computing everywhere

Intelligent computing everywhere

Unrivaled connectivity

High-performance, low-power compute

Leading edge AI

Growing mobile data demands continue fueling the need for more licensed spectrum

GLOBAL DATA CONSUMPTION

Unstoppable growth

Continued mobile data consumption

Global mobile data usage predicted to grow **4x** by 2030

Key drivers fueling mobile traffic increase:

- Broad 5G use
- Enhancements in streaming video quality
- The rise of XR
- Cloud gaming

AI is bringing new data traffic for mobile

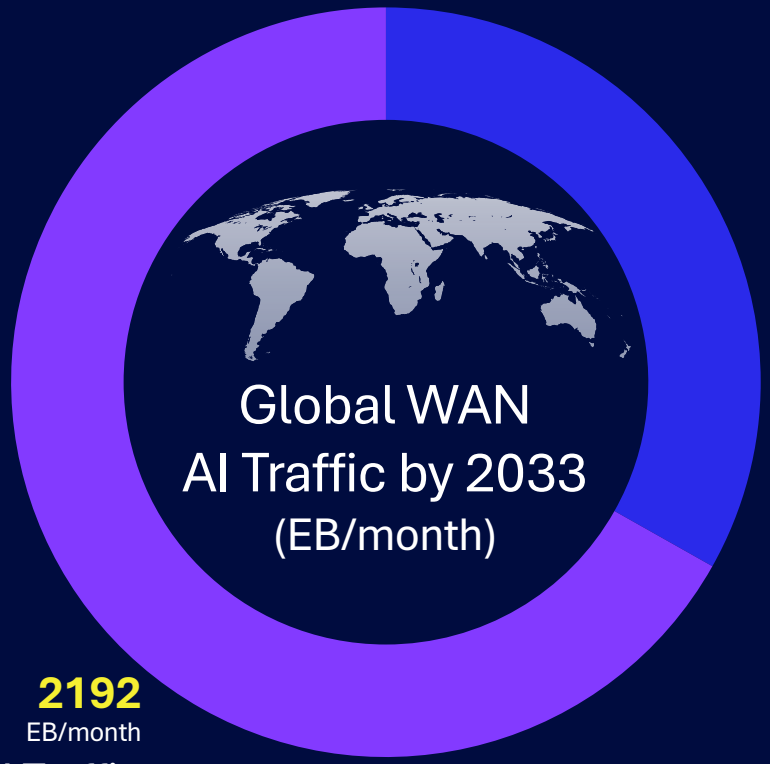
AI poised to transform global wide-area network (WAN) traffic with consumer AI traffic dominating

Global WAN traffic projected to grow **5x** to **9x** from 2023 to 2033, with AI accounting for **33%** of all traffic

Sources: GSMA The Mobile Economy 2024, Nokia Bell Labs Global Network Traffic Report 2024

Additional spectrum will be needed to address surging AI traffic

AI is poised to transform global wide-area network (WAN) traffic with consumer AI traffic dominating



1088
EB/month
AI Traffic

Global WAN traffic is projected to grow 5X to 9X from 2023 to 2033

AI traffic → 33% of global WAN traffic
1088 EB/month – CAGR of 24% from 2023 to 2033

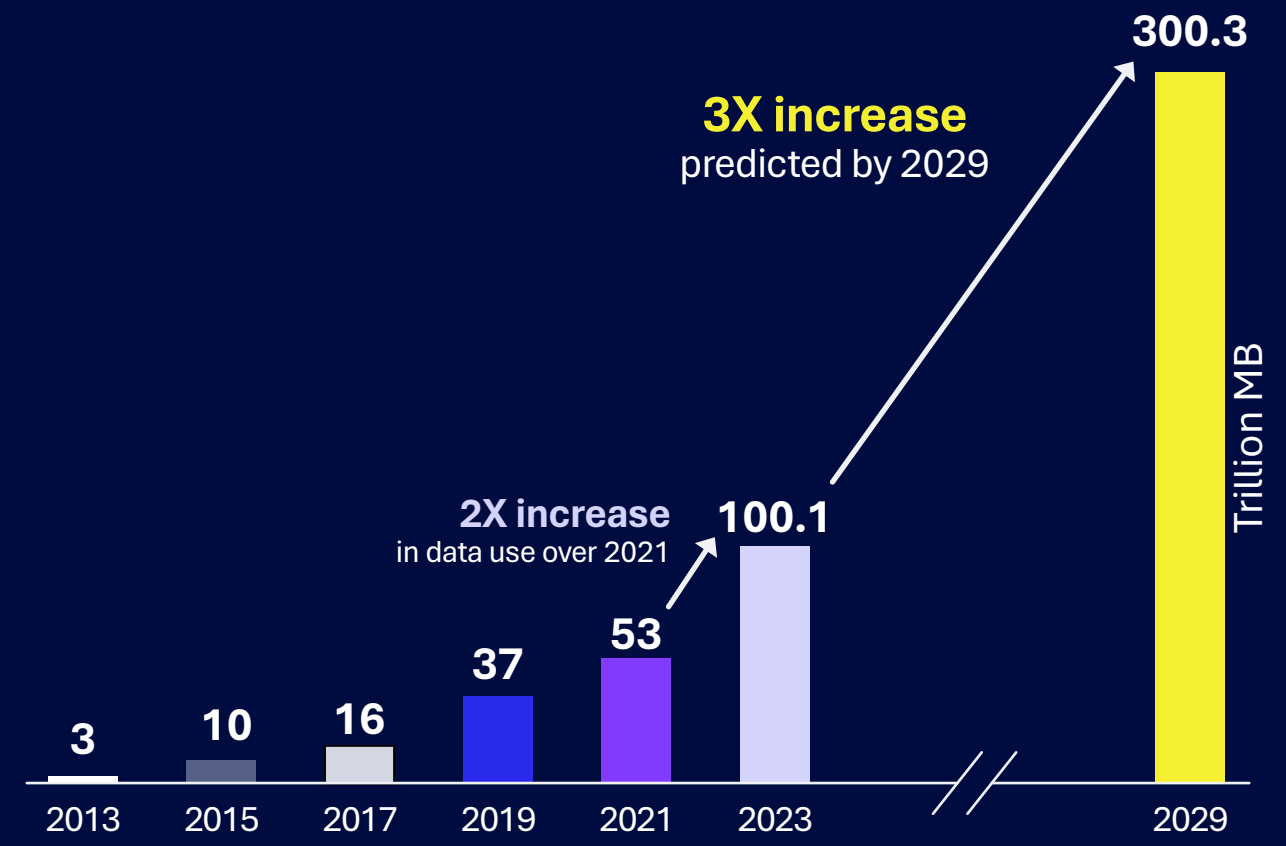
Consumer AI traffic
1006 EB/month – CAGR: 23%

Enterprise AI traffic
81 EB/month – CAGR: 57%

To meet the soaring demands of both consumer and enterprise AI applications, communication service providers and hyperscalers have to invest boldly in high-capacity, low-latency, and resilient network infrastructure

Sources: Nokia Bell Labs Global Network Traffic Report 2024

Booming US mobile data traffic



Source: CTIA Annual Survey 2024

US wireless data demand will

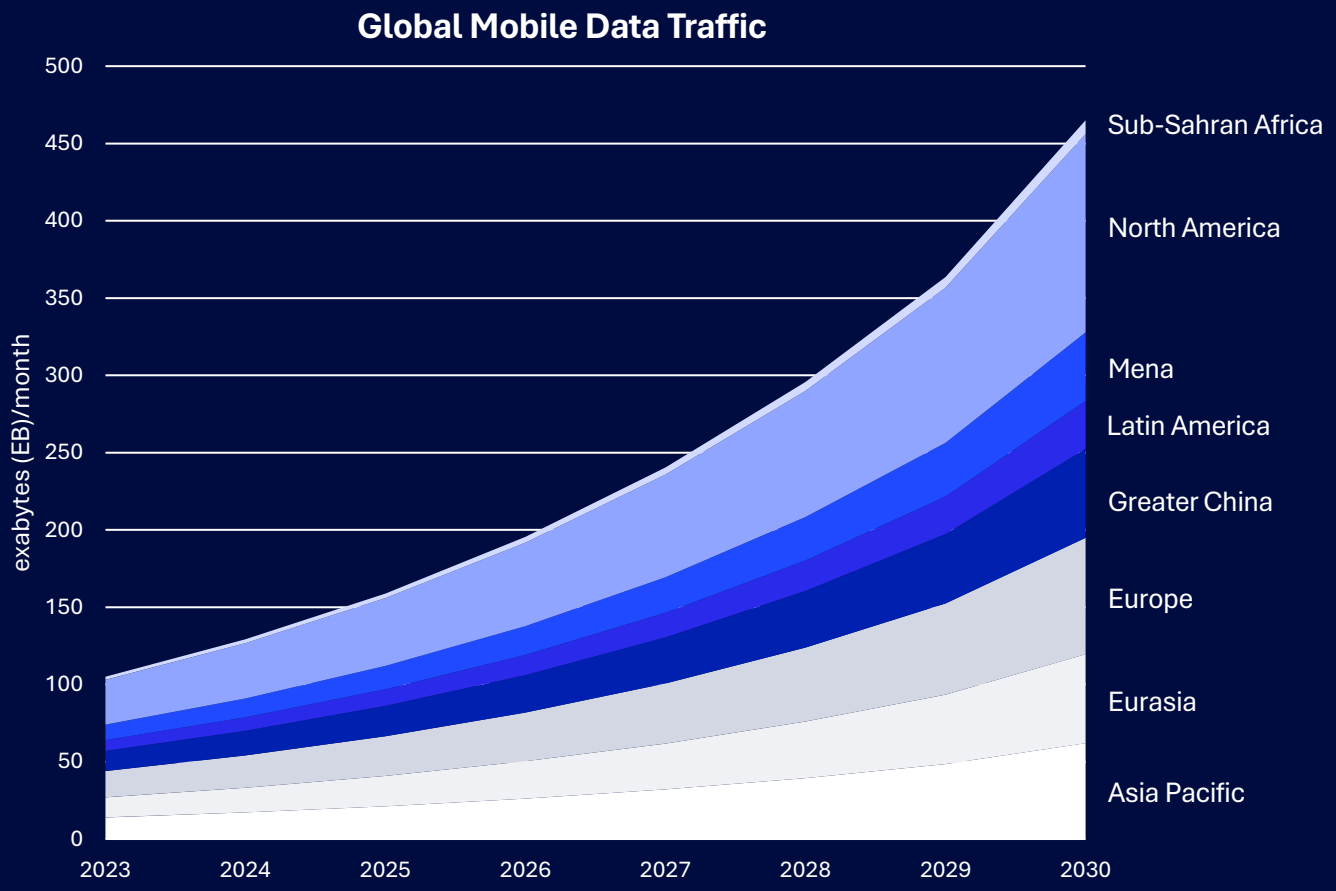
triple by 2029

More wireless data consumed in 2023 than 2010 to 2018 combined

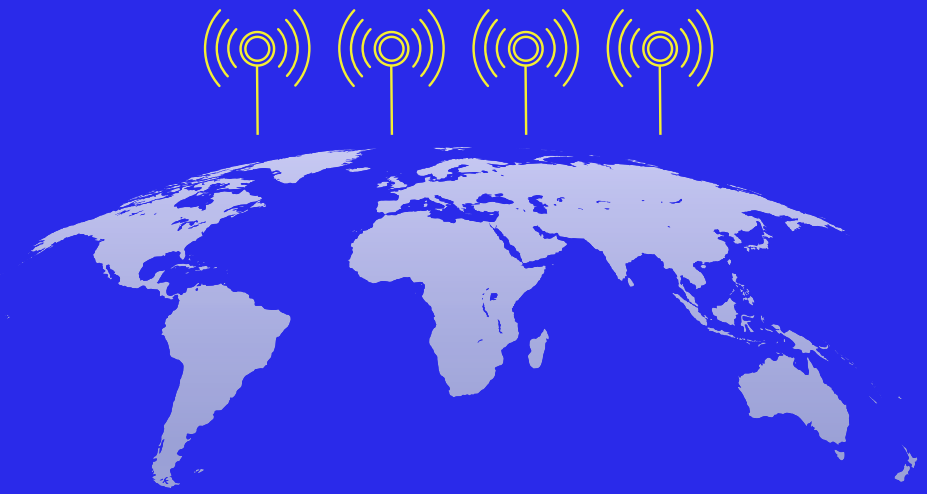
Equivalent to every household streaming 'House of the Dragon' Season 1 daily

5G's rising role in daily life — from mobile and fixed broadband to connected healthcare — is driving wireless data demand

Surging global mobile data usage – **A trend we can't ignore**



Source: GSMA The Mobile Economy 2024



Global mobile data usage will **quadruple by 2030**

Mobile data traffic is projected to grow at a 23% CAGR from 2023 to 2030, reaching over 465 exabytes monthly by 2030

Key drivers for mobile traffic increase:

- Broad 5G adoption & use
- Enhancements in streaming video quality
- The rise of XR eye-ware
- Cloud gaming
- AI-powered application growth

Today's spectrum allocations are enabling MNOs to support growth in the 5G era but it cannot satisfy surging demands

5G (& Wi-Fi) Bands

- Licensed
- Unlicensed / shared
- Under study/proposed rules/waiting for auction

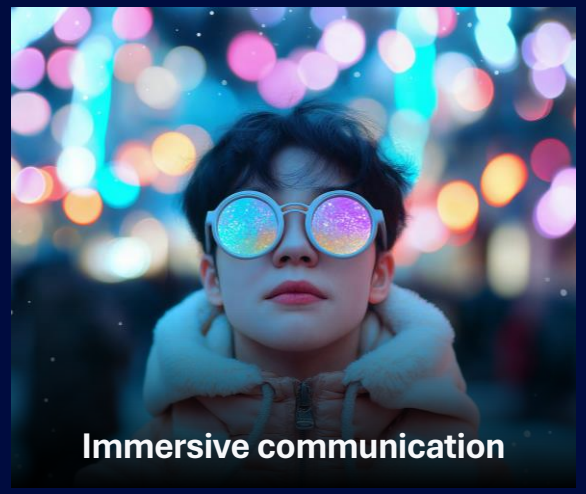
	<1GHz	3GHz	4GHz	5GHz	6GHz	24-30GHz	37-50GHz	60GHz	>95GHz	
	600MHz (2x35MHz) 900MHz (2x3MHz) 2.5/2.6GHz (B41/n41)	3.1-3.45GHz 3.45-3.55GHz 3.55-3.7GHz 3.7-3.98GHz	4.94-4.99GHz	5.9–7.1GHz		24.25-24.45GHz 24.75-25.25GHz 27.5-28.35GHz	37-37.6GHz 37.6-40GHz 42-42.5GHz 47.2-48.2GHz	57-71GHz	>95GHz	
	600MHz (2x35MHz)	3.45-3.65 GHz 3.65-3.9GHz		5.9–7.1GHz		26.5-28.35GHz	37-37.6GHz 37.6-40GHz	57-71GHz	>95GHz	
	700MHz (2x30 MHz)	3.4–3.8GHz		5.9–6.4GHz		24.5-27.5GHz		57-66GHz		
	700MHz (2x30 MHz)	3.4–3.8GHz		5.9–6.4GHz		24.25-27.5 GHz	40.5-43.5 GHz	57-66GHz		
	700MHz (2x30 MHz)	3.4–3.8GHz		5.9–6.4GHz		24.25-27.5 GHz		57-66GHz		
	700MHz (2x30 MHz)	3.46–3.8GHz		5.9–6.4GHz		24.25-27.5 GHz		57-66GHz		
	700MHz (2x30 MHz)	3.6–3.8GHz		5.9–6.4GHz		24.25-27.5 GHz		57-66GHz		
	700/800MHz 900MHz 2GHz (n1) 2.5/2.6GHz (B41/n41)	3.3–3.6GHz	4.8–5GHz			24.75-27.5GHz	37-43.5GHz			
	700/800MHz 2.3-2.39GHz	3.4–3.7GHz 3.7-4.0GHz	4.72–4.82GHz	5.9–7.1GHz		25.7-26.5GHz 26.5-28.9GHz 28.9-29.5GHz	37GHz	57-64GHz		
	700/800MHz 2.3 GHz	3.6–4.1GHz	4.5–4.9GHz	5.9–6.4GHz		27-29.5GHz		57-66GHz		
	600MHz (2x40 MHz) 700MHz (2x30 MHz)	3.3–3.67GHz				24.25-27.5GHz				
	2.3 GHz	3.4–3.7GHz 3.7-4.0GHz		5.9–6.4GHz		24.25-29.5GHz	39GHz	57-66GHz		

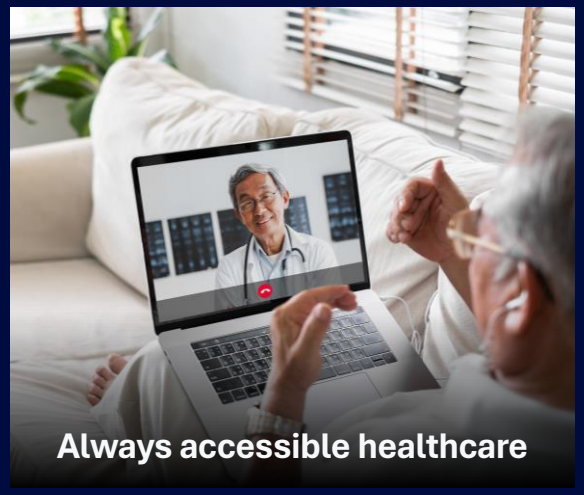
Source: GSA

Wireless stakeholders are actively working to open new 6G spectrum bands

Future use cases and performance needs demand greater capacity

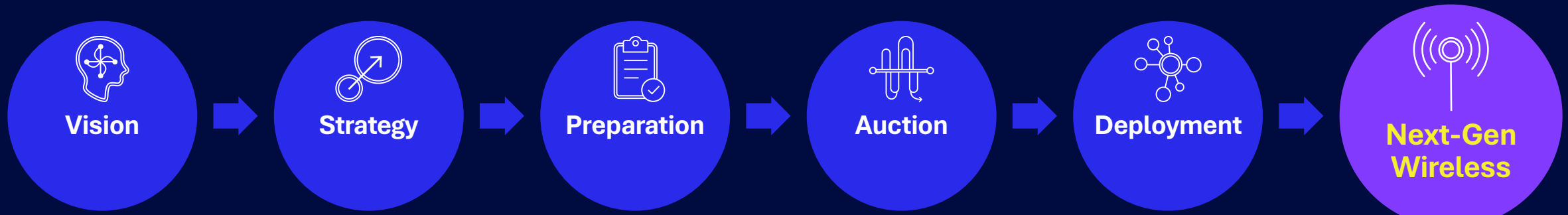
6G will need fresh spectrum assets





Introducing new bands for global connectivity takes time

Spectrum is the key ingredient to unlocking wireless advancements



Requiring new spectrum to fuel next-gen wireless use cases with improved coverage and capacity

Identifying new bands and technologies to support capacity demand and growth

Ensuring targeted bands for new deployments can be cleared or efficiently & economically shared

Allocating spectrum to service providers so it's ready for deployment

Delivering on the vision to enable advanced connectivity and intelligent compute everywhere

Spectrum planning cycle: ~8-10 years

Qualcomm began working to open 6G spectrum bands in 2021

Why the path to new spectrum for 6G takes time

Technology Innovations

Advancements are continuous but early alignment of targeted spectrum helps to secure focused financial and human resource investments

Regulatory Coordination

Governments plan, gather inputs, assess options, and complete studies to inform spectrum policy decisions and efficient allocations

Technology Standards

New technologies take time to mature and become a part of the global technology standard through a consensus-driven process (e.g., 3GPP)

Preparation for WRC-27

Spectrum harmonization is complex and doesn't happen overnight, we need thorough planning to ensuring a successful transition to 6G

Global Leadership

New spectrum can bring significant competitive advantages to fuel economic growths and sustainability initiatives

Outcome from WRC-23

Creates the conditions for a more connected and technologically advanced future

Setting the stage for WRC-27

Outlined the WRC-27 agenda, encompassing the evaluation of extra spectrum bands for IMT to support next-gen mobile connectivity in the 2030s

New spectrum allocations

Allocated new low-band (< 1GHz) and mid-band (3.5 GHz and 6 GHz) spectrum, crucial for mobile sector innovation and digital ambitions globally

3.5 GHz band harmonization

Achieved final harmonization across EMEA, marking a significant advancement for 5G technology

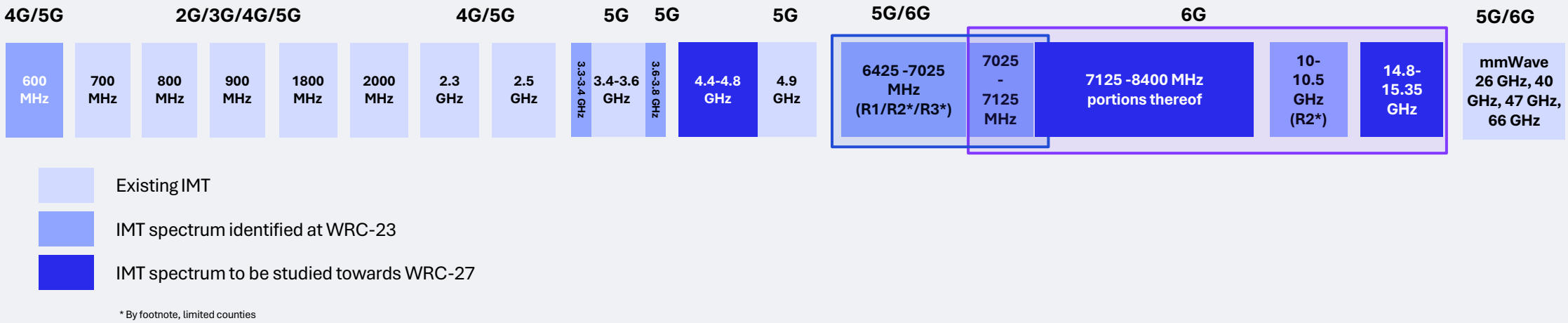
6 GHz band for IMT

Identified 6.425 - 7.125 GHz for IMT in all ITU regions, supporting the expansion of mobile capacity for future networks

Low-band spectrum for digital equality

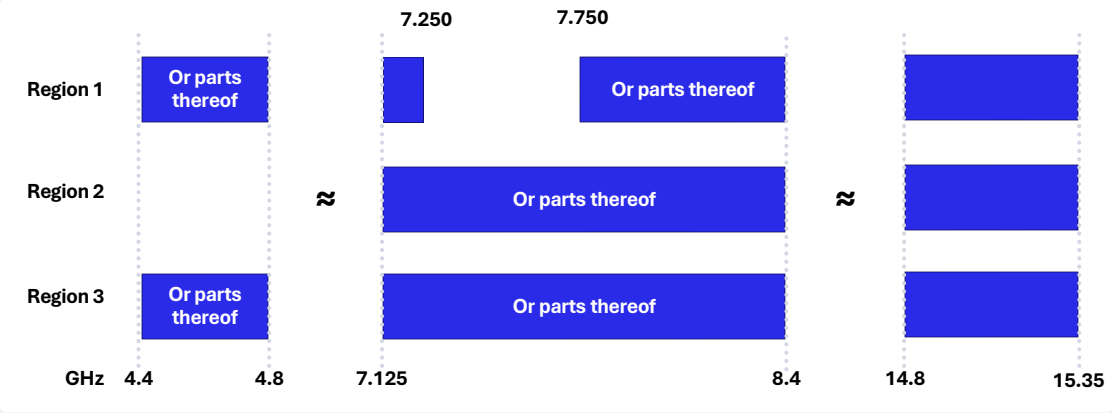
Allocated the 470-694 MHz band, aiming to improve internet connectivity, especially in rural areas

Setting the stage for WRC-27



* By footnote, limited counties

ITU-R will study new candidate bands for IMT-2030/6G usage with decisions to be made at WRC-27



To support the usage scenarios defined in the IMT-2030 framework, i.e., ITU-R M.2160 Recommendation, there is a need to study **mid-band spectrum** with **more contiguous bandwidth**

Region 1: Europe, Middle East and Africa; Region 2: Americas; Region 3: Asia Pacific

US 6G spectrum: Creating a pipeline including the upper mid-band and modernizing utilization

US National Spectrum Strategy (NSS) bands under study

Published on November 13, 2023

Spectrum identified for in-depth study

- **3.1 – 3.45 GHz:** expanded shared federal/non-federal uses
- **5.03 – 5.091 GHz:** federal/non-federal UAS operations
- **7.125 – 8.4 GHz:** federal use for mobile broadband
- **18.1 – 18.6 GHz:** federal/non-federal satellite operations
- **37.0 – 37.6 GHz:** shared access

FCC's Notice of Proposed Rulemaking (NRPM) on upper 12 GHz

Published on July 10, 2023

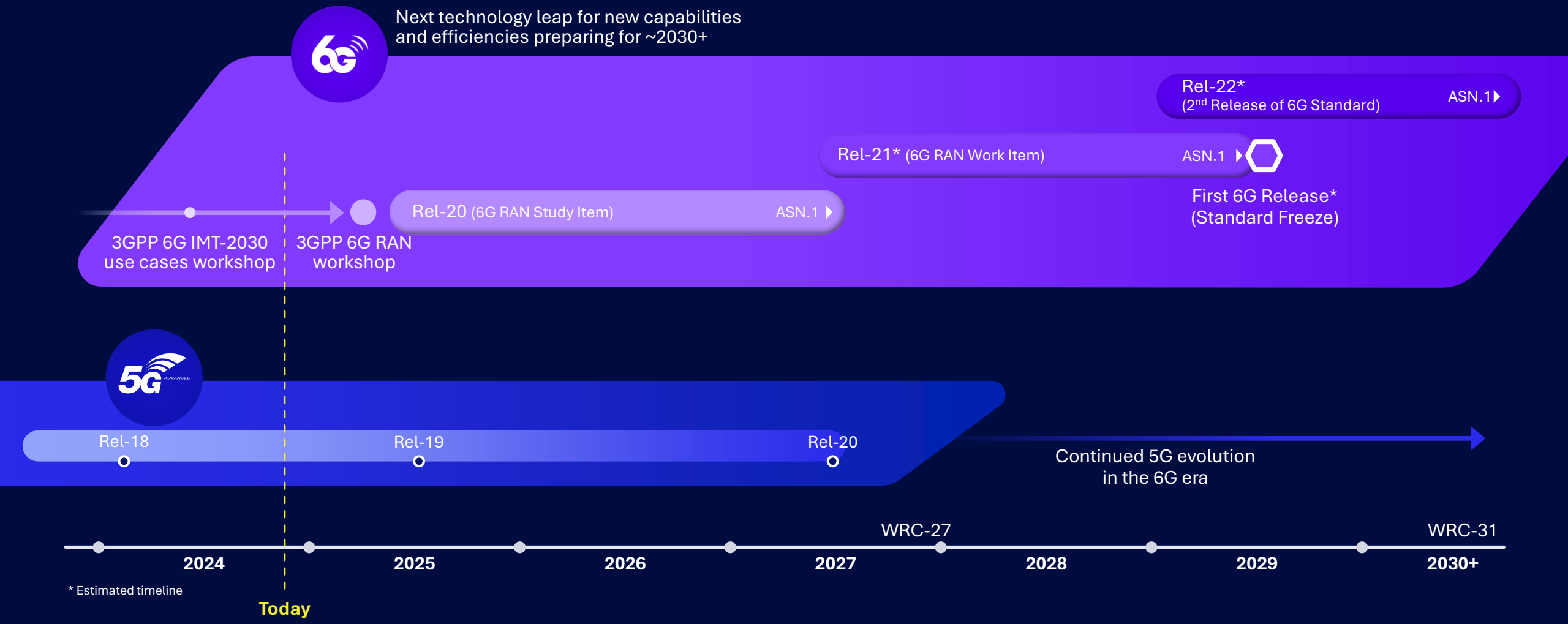
Seeks to repurpose some or all the **12.7 – 13.25 GHz** band for mobile broadband

Encourages more efficient and intensive use of the band, considering spectrum sharing methodologies

Includes measures to protect incumbent services

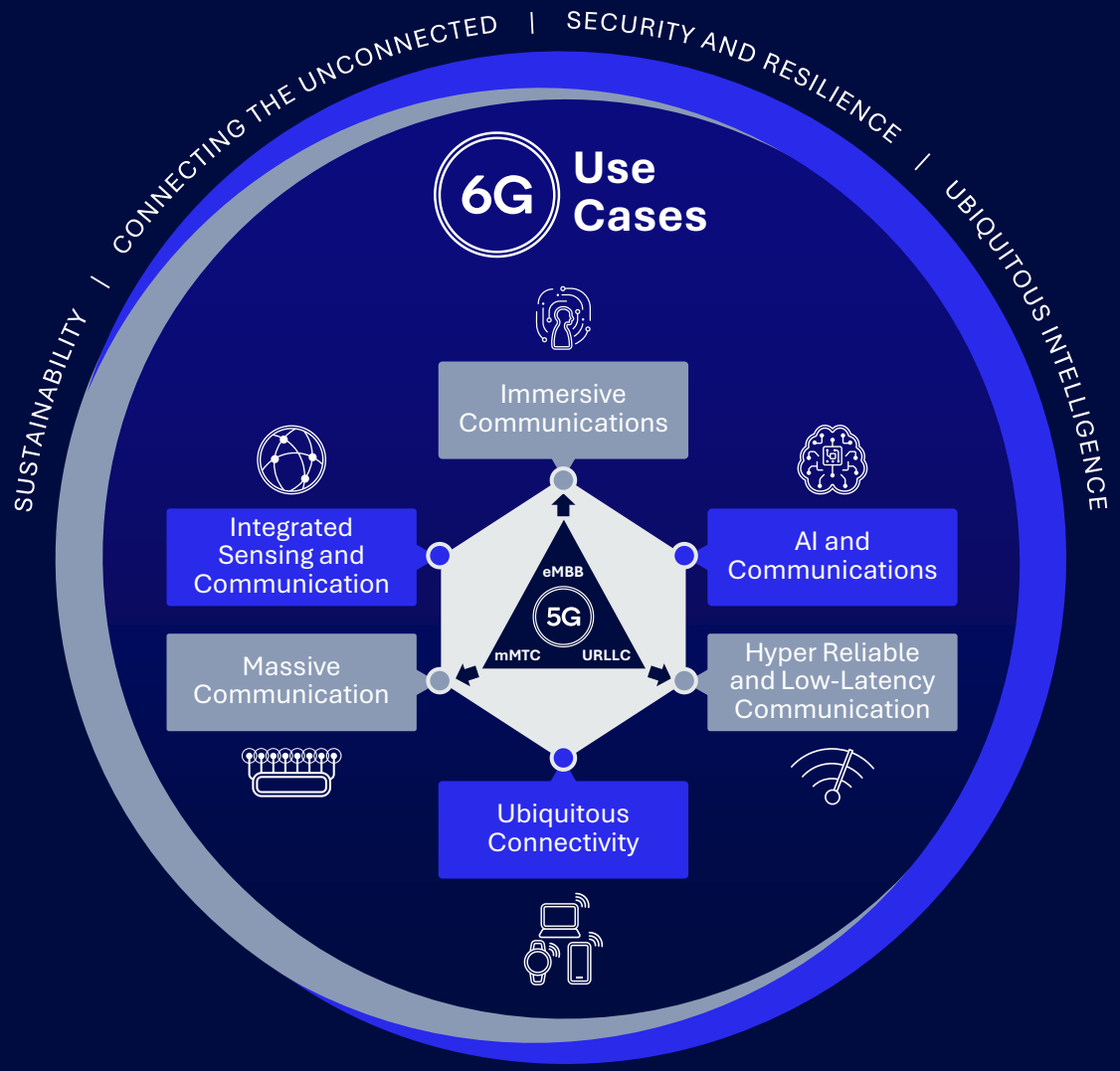
Spectrum innovations will form the foundation of 6G advancements

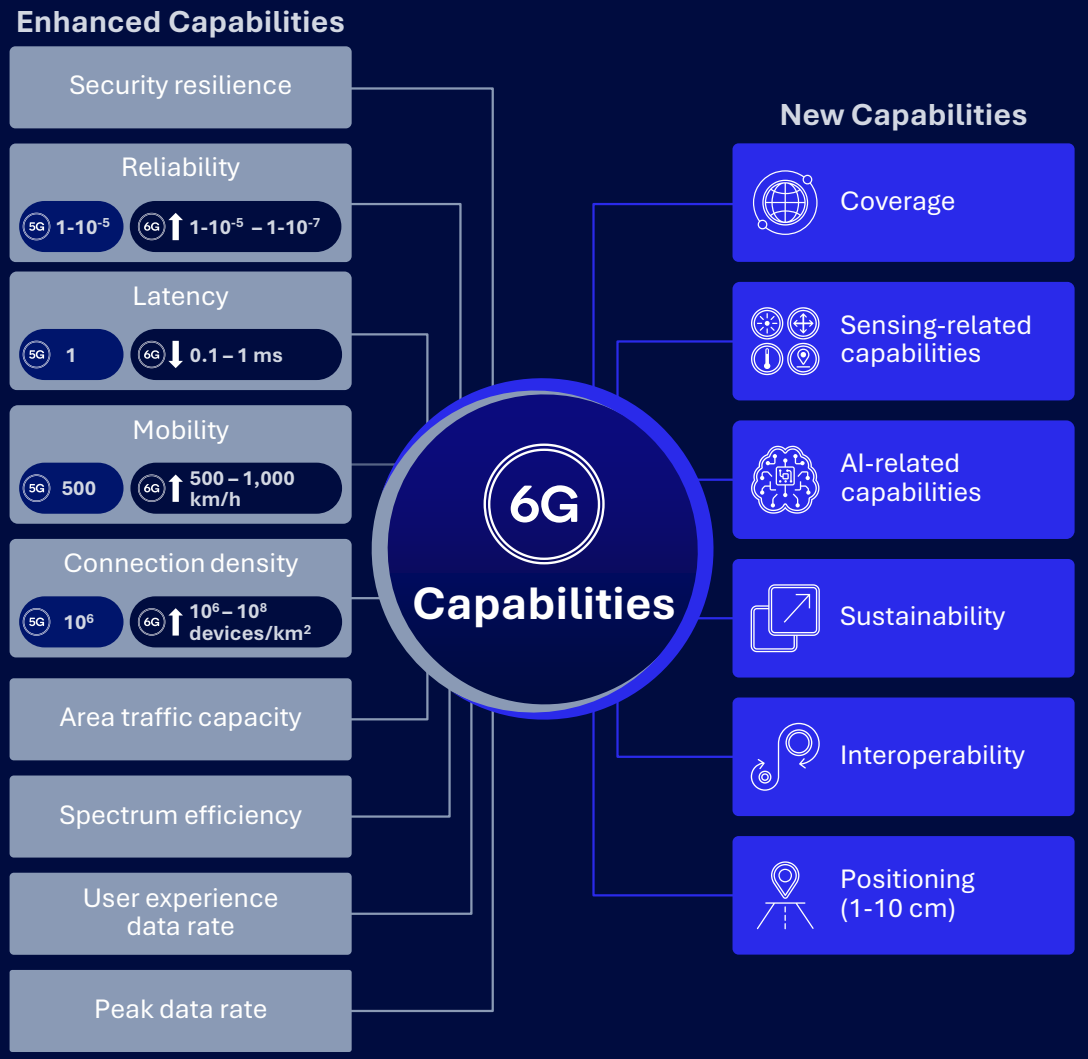
DELIVERING ENHANCEMENTS ACROSS ALL BANDS



Driving the 6G technology evolution

6G vision from ITU-R — Usage scenarios and capabilities

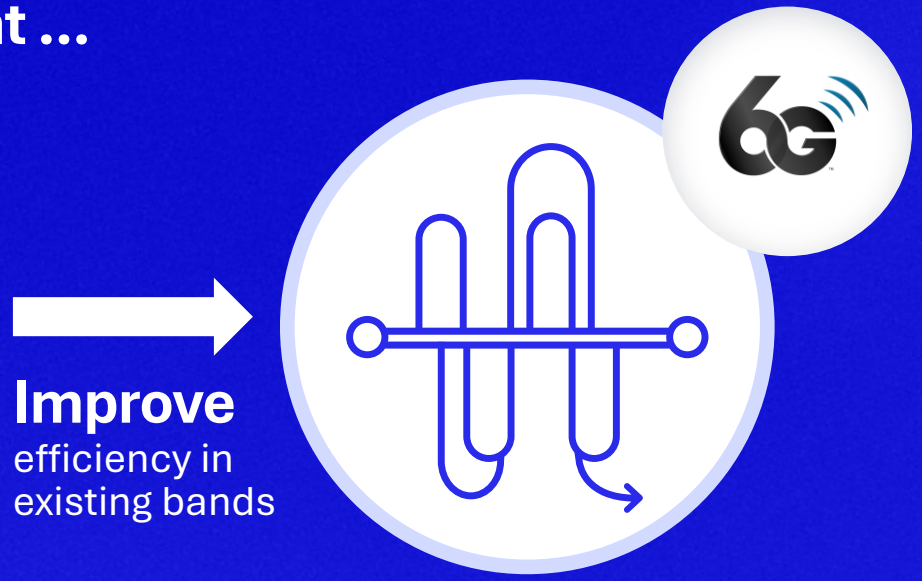




Source: ITU-R's IMT towards 2030 and beyond (https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2030/Pages/default.aspx)

Our vision for 6G spectrum is to deliver …

Innovations that …



Improve
efficiency in existing bands

Unlock
new spectrum

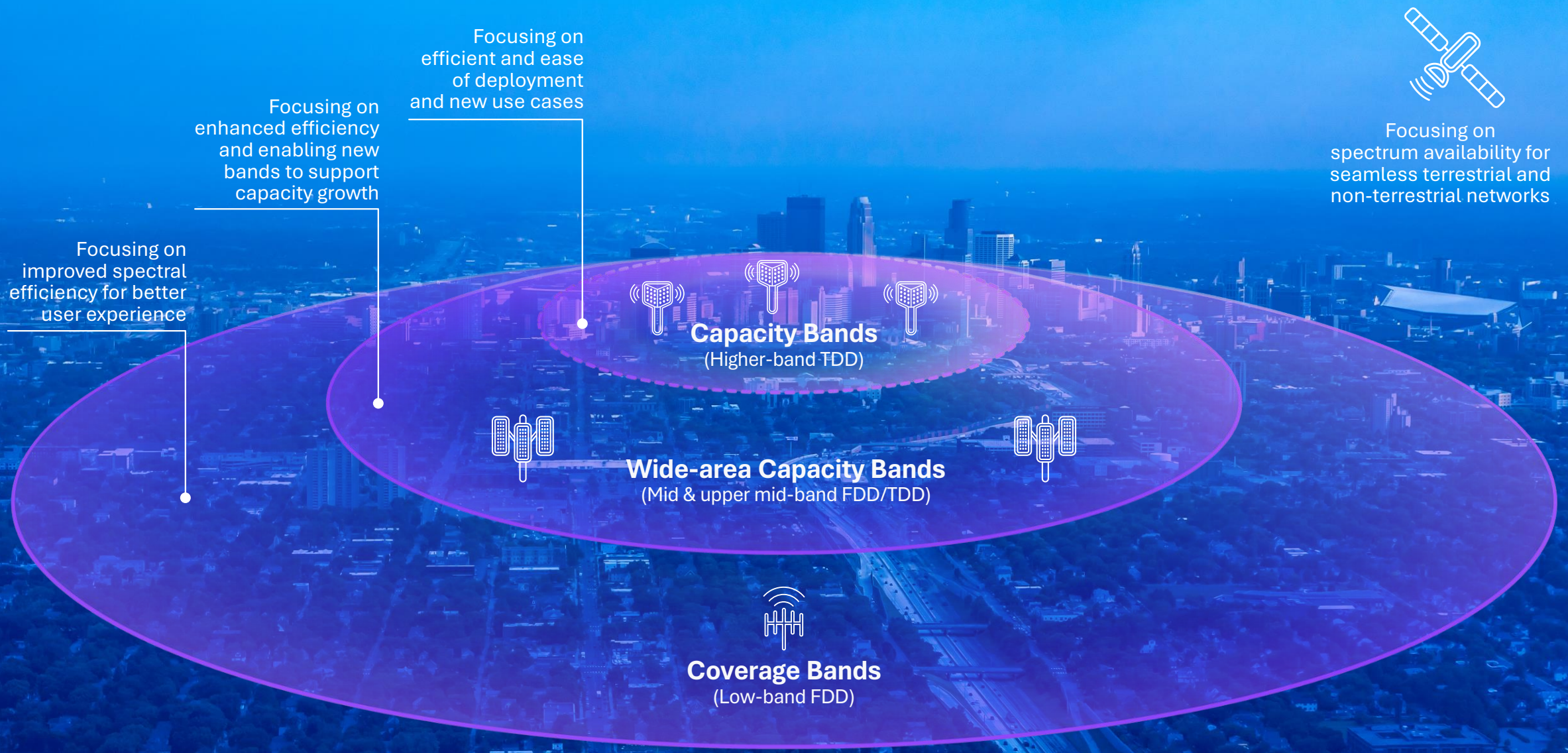
Fostering sustained growth and allowing new services to truly take off…

6G is set to prioritize cost-efficient traffic scaling, which necessitates additional capacity even without accounting for new use cases (e.g., smartphones)

New spectrum with wider- bandwidth to enable new high-performance use cases (e.g., immersive communication and consumer Gen-AI traffic)

Improve capacity in existing coverage spectrum bands (e.g., low-band FDD/TDD)

6G will bring innovation opportunities for all spectrum bands



6G will leverage all spectrum bands to serve diverse use cases and deployments

	LOW BANDS (FDD) below 1 GHz (~20 MHz BW)	**MID BANDS (FDD, TDD)** 1 — 7 GHz (~100 MHz BW)	**UPPER MID-BANDS (TDD)** 7 – 24 GHz (~500 MHz BW)	**mmWAVE BANDS (TDD)** 24-71 GHz (~800 MHz BW)	**SUB-THZ (TDD)** 100+ GHz (GHz BW)
Use Cases	Deep wide-area coverage and low power IoT	Wide area coverage layer & macro capacity layer, wide area location services	Macro capacity layer for 6G data, FWA, NTN, wide area sensing	Capacity hotspots, venues, dense urban outdoor, FWA, local sensing	Extreme data rate for fixed links (e.g., data center communications), sensing
Enabling Tech	Efficient waveform, coding, multiple access	FDD MIMO scaling and TDD BW aggregation	Giga-MIMO at gNB, UE antenna scaling, SBFD, RAN-sharing	Unified transmission configuration indicator (TCI), beam management	Efficient scaling, lensed MIMO

Wider Coverage → **Higher Capacity**

6G presents an opportunity to bring significant upgrade to lower band spectrum

Targeting low/mid-FDD[1] coverage bands to enhance wide-area user experience

Guard band reduction

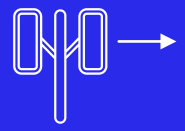
Higher bandwidth occupancy for 6G FDD bands

Modulation, coding, and MIMO mapping

Evolved 5G coding, modulation to 6G LDPC [2] code, constellation shaping, MIMO mapping

Reference and feedback signals

Combine best of 4G/5G reference signal designs (LTE CRS[3] & NR DMRS[4]), enhanced HARQ[5] design



Downlink MIMO

New CSF[6] design (e.g., empowered by AI/ML) to achieve accurate beamforming in 6G FDD

Uplink waveform

Advanced DFT-S[7] with MIMO to yield gain over 5G NR single-layer DFT-S uplink

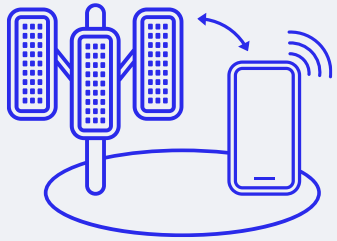
Uplink antenna / Tx power management

Advanced antenna/power management accounting for UL/DL imbalance, and MPE[8]

Targeting **>50% gain** from the above features without cell RF equipment upgrade

1 Frequency division duplex; 2 Low density parity check; 3 Cell-specific reference signal; 4 Demodulation reference signal; 5 Hybrid ARQ; 6 Channel state feedback; 7 Discrete Fourier transform-spread; 8 Maximum permissible exposure

6G will continue to enhance midband spectrum performance and efficiency



Further improving sub-7 GHz TDD wide-area system design

Spectral efficiency and capacity improvement

Through e.g., modulation, coding, MIMO mapping, interleaving, new data & control channel, reference signaling, beamforming, coherent UL MIMO

Coverage extension

Through e.g., native control & data bundling, lean broadcast signaling, low PAPR waveform, enhanced cell-edge beamforming, advanced duplexing, flexible CA

Energy efficient design

Through e.g., lean initial access, new designs of always-on signaling, enhanced bandwidth, antenna adaptation framework, low-power WUS, wideband operation

Complexity optimization

Through e.g., area-efficient modulation, coding, memory-efficient MIMO mapping, wideband TDD-native design, MIMO CA adaptation for TDD, integrated HARQ/ARQ process for high memory efficiency

1 Additional gain expected with antenna increase in network and device

New Uplink Design

Native control and data bundling

Low overhead, DMRS bundling for Eb/N0 improvement

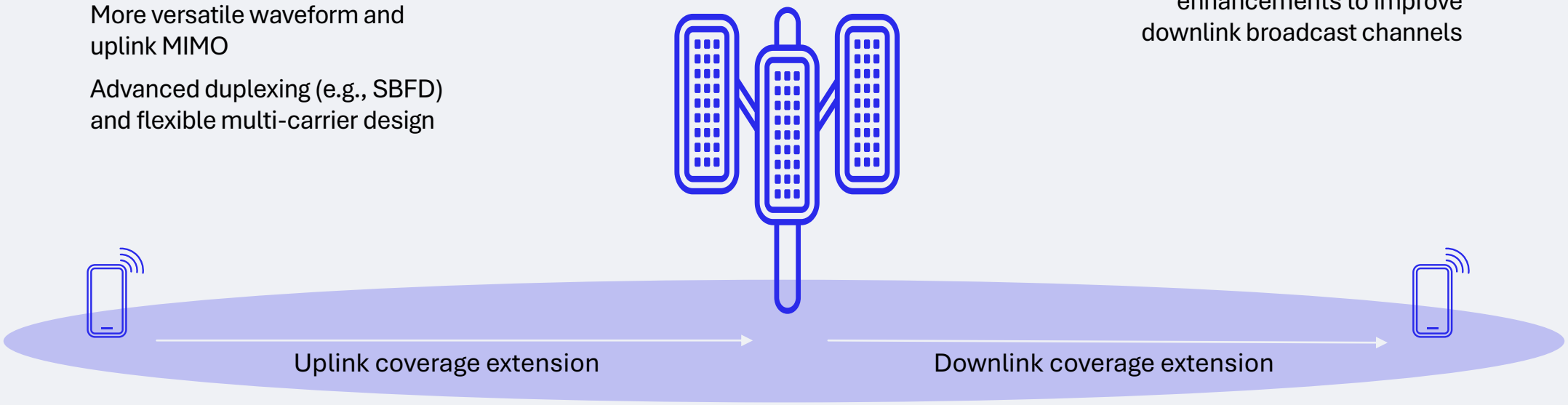
More versatile waveform and uplink MIMO

Advanced duplexing (e.g., SBFD) and flexible multi-carrier design

New Downlink Design

Expanded cell-edge reciprocity-based beamforming

Systematic design enhancements to improve downlink broadcast channels



6G will deliver enhanced coverage across all bands right from the start

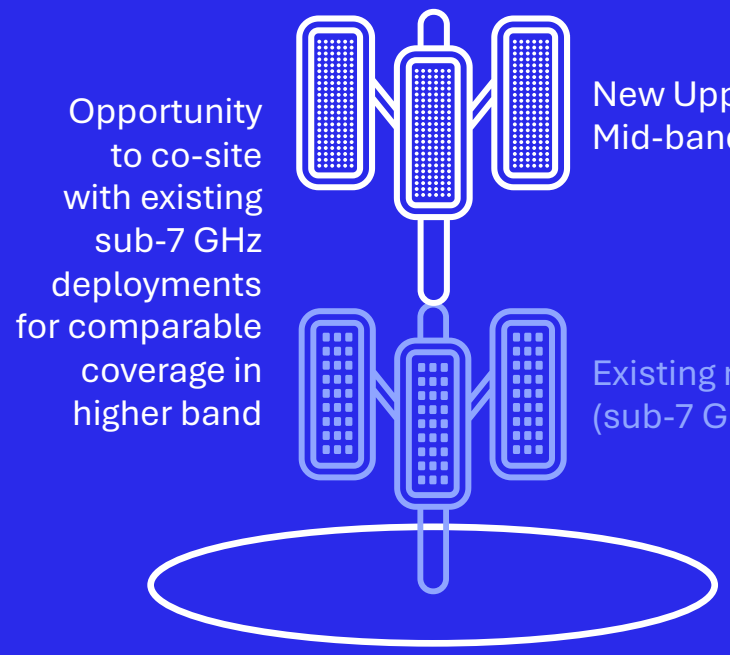
Substantial coverage gains with new 6G design based on link and system-level evaluations

Enabling upper-midband (7-15 GHz) to meet wide-area capacity demand

Delivering new capacity for wide-area broadband (e.g., smartphones, smart cities, automotive, verticals)

Fueling scalable boundless XR user support in wide area through wider bandwidth availability

Supporting high-resolution wireless sensing for new use cases (e.g., environmental monitoring, activity detection)

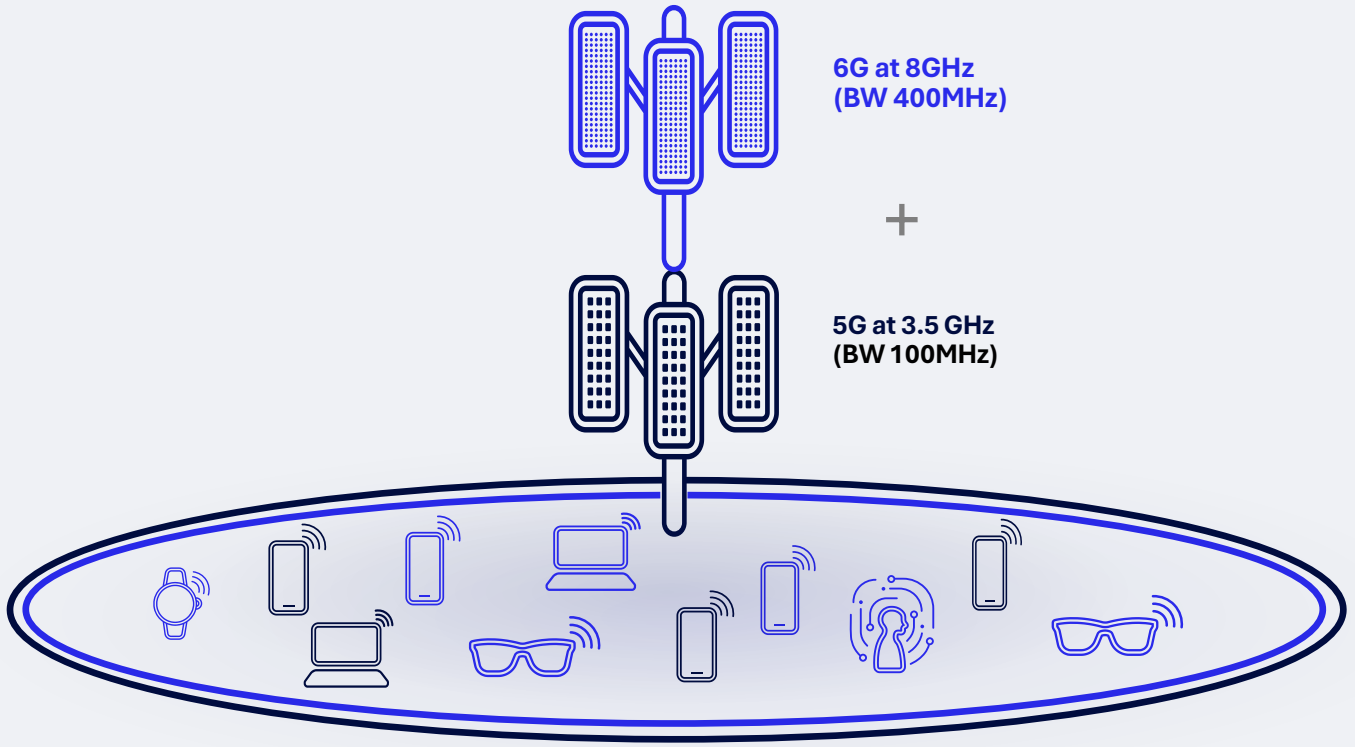


6G Giga-MIMO can open up ~500 MHz wide-area bandwidth with comparable coverage as 5G massive MIMO in sub-7 GHz

New upper mid-band spectrum will increase system capacity

Supporting more users per area and increased throughput

5G at 3.5 GHz
(BW 100MHz)



Supports **5x** the network load while maintaining at least 100 Mbps for the bottom 10% users

Provides **3x** faster average user data speeds[1]

1 Without baseband gain

Qualcomm

Giga-MIMO

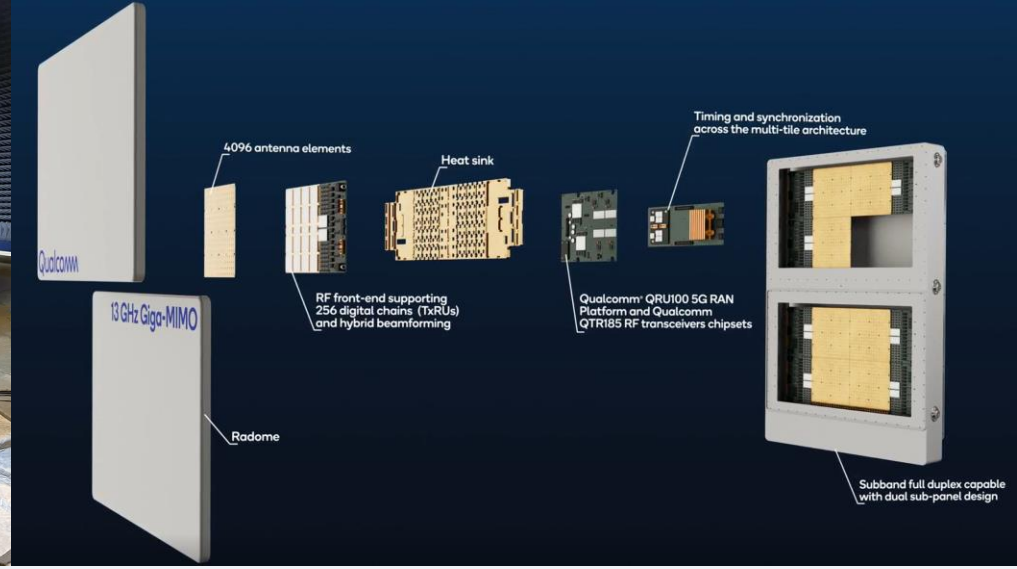
Meeting the capacity demands of the decade to come

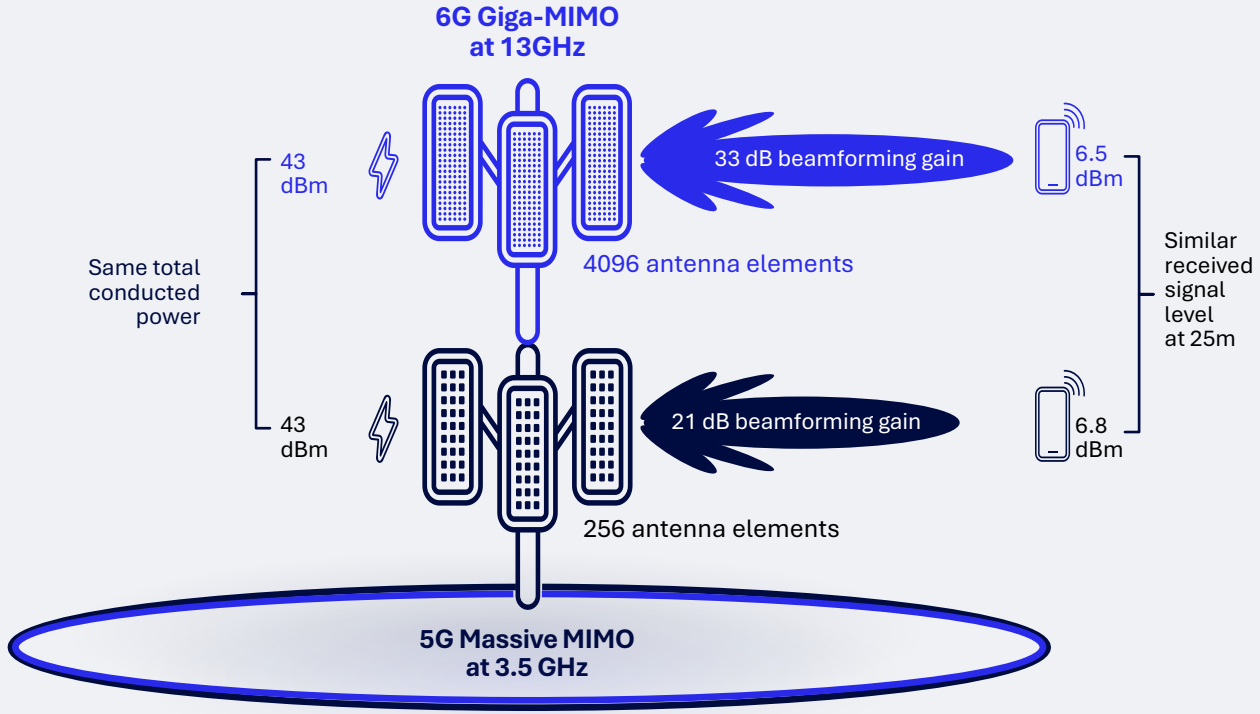
End-to-end system design operating in the 13 GHz band with 500 MHz+ bandwidth

Comparable size as 5G massive MIMO with 4096 antenna elements and 256 digital chains

Hybrid beamforming and subband full duplex capable

Over-the-air testing at our advanced antenna range in San Diego, CA



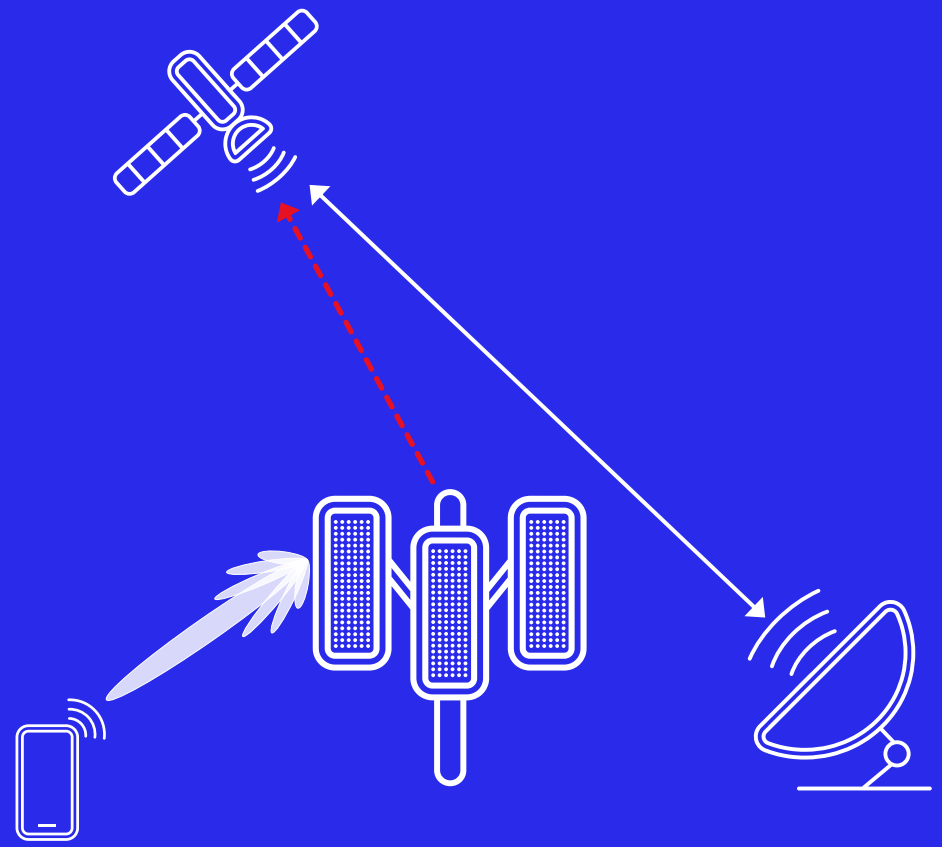


Giga-MIMO improves coexistence with other systems

Compared to previous generations, we expect 6G design to account for sharing with non 3GPP systems, i.e., implementing a “sharing by design” approach

Giga-MIMO allows tight control of very narrow beams in upper midbands that in the presence of incumbent systems can lead to new and more efficient coexistence approaches

Specific sharing mechanisms will depend on the target bands and incumbent systems



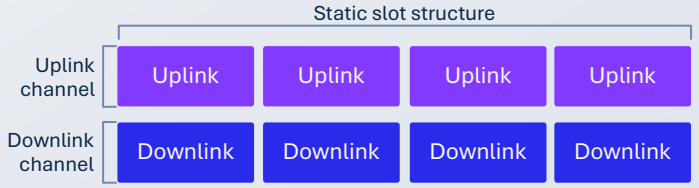
Flexible new 6G air interface design with native support for spectrum sharing

Evolving towards a full duplex wireless system

Better **coverage**, lower **latency,** and flexible **spectrum** sharing

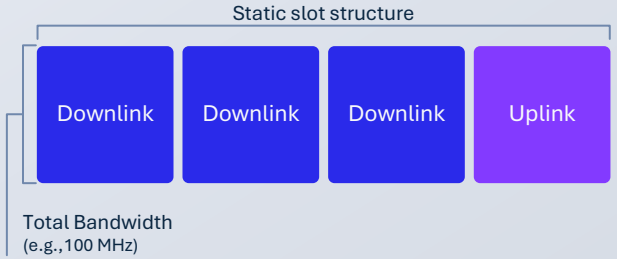
FDD

Transmit and receive using the same time slot in different frequency channels



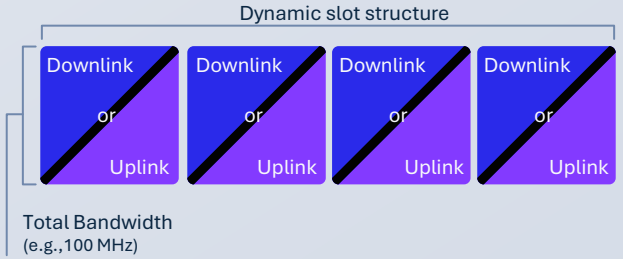
Static TDD

Transmit and receive using the same frequency channel in different time slots



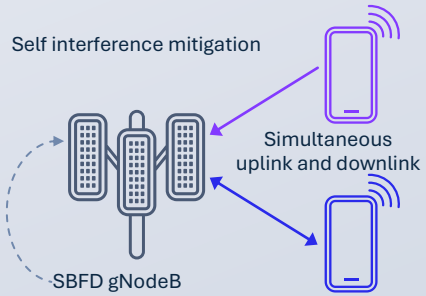
Dynamic TDD

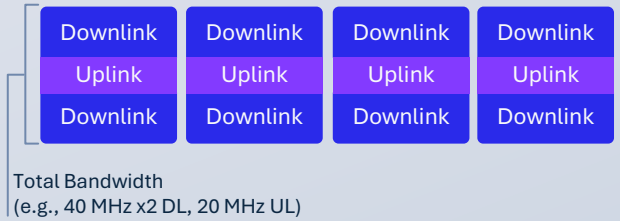
Transmit and receive can be configured dynamically for all time slots in the same frequency channel



Subband full duplex

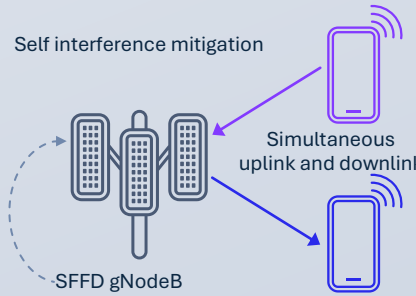
Frequency aligned to avoid inter-site interference; Frequency separation + interference cancellation to avoid self-interference

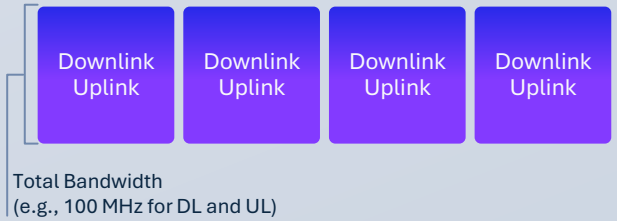




Single frequency full duplex

Interference cancellation to avoid self-interference





Coverage

Innovations to overcome significant path loss in mmWave bands

Beam management

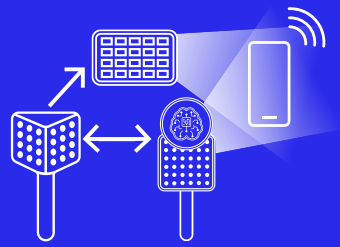
Innovations to beam pairing, tracking and recovery

Device size / power

Innovations to optimize mmWave design for smartphone form factor

Robustness

Innovations to overcome blockage from hand, body, walls, foliage, etc.



Topology enhancement

Innovations to efficiently scale and densify the network

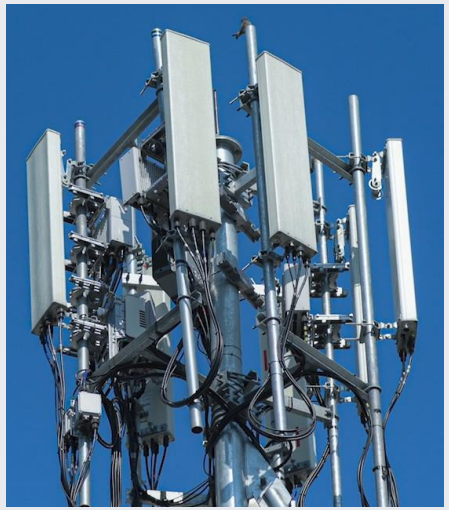
Continue to enhance and expand the role of mmWave — Building on 5G and 5G Advanced

6G targets to further improve coverage, robustness and power efficiency via enhanced beamforming, beam-tracking, and topology

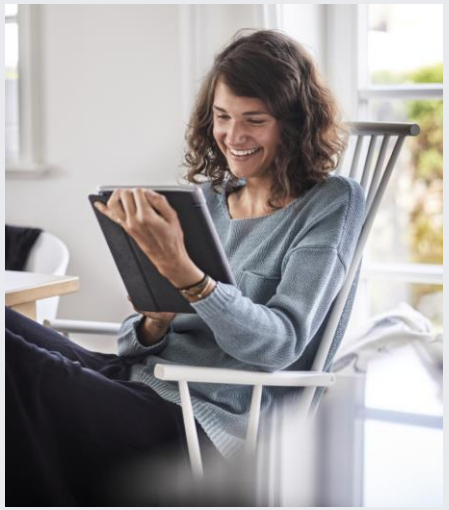
Complementing communications and beyond with sub-Terahertz

Building on our mmWave experience to address key system challenges at higher band spectrum

WIRELESS DATA CENTER

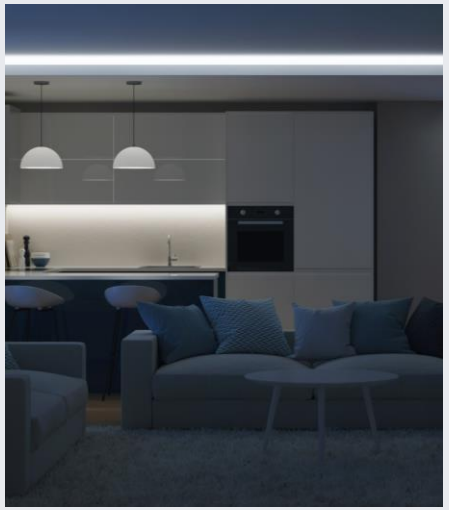


WIRELESS FRONTHAUL



WIRELESS FIBER TO THE HOME

ULTRA-PRECISE POSITIONING



RADIO FREQUENCY SENSING

Use case feasibility

Evaluating diverse use cases, form factor requirements and how sub-THz can deliver effective solutions

System design

Building early prototypes to overcome implementation challenges (i.e., device formfactor, power consumption, etc.)

Propagation loss

Using intelligent beamforming to overcome path loss, penetration loss, foliage loss, and others

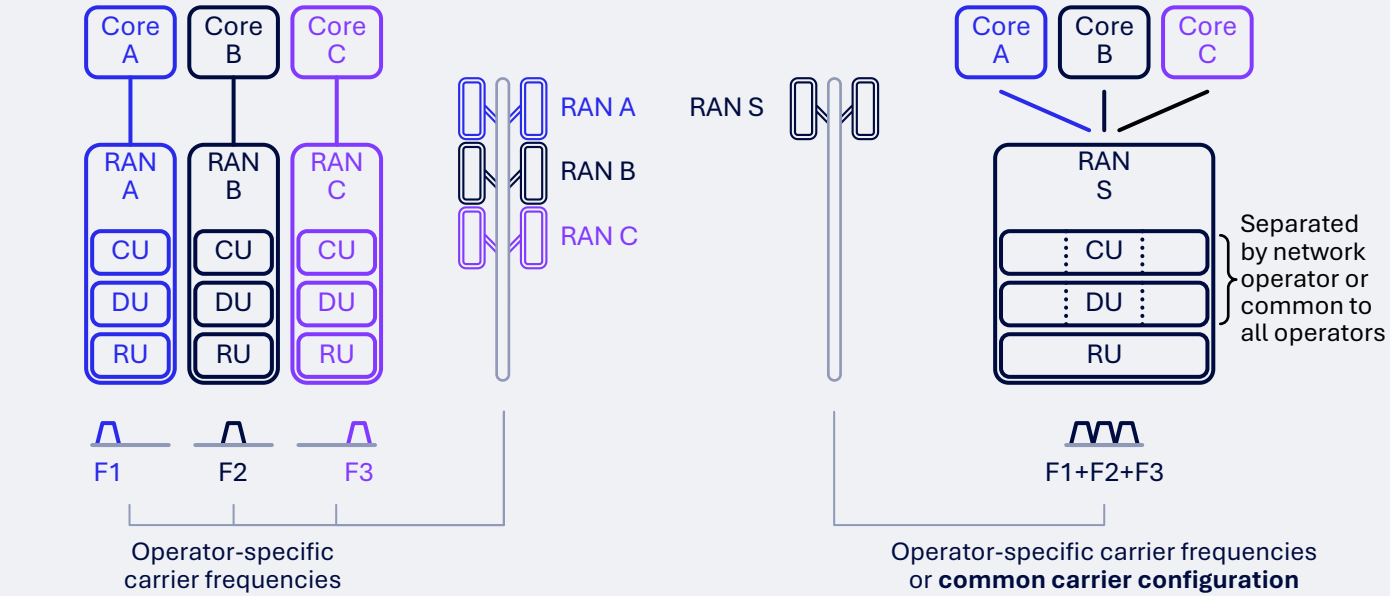
Reduce TCO and accelerate rollouts with advanced RAN sharing

Share some or all RAN components to reduce CAPEX and OPEX

Differentiate network services and user experiences with separate core networks

Continue with operator-specific spectrum or combine spectrum resources for joint scheduling over a common wide carrier (~ 500 MHz BW)

Reduce antenna tower loading and tower lease costs with fewer antennas by using the common carrier configuration



Independent networks → **RAN sharing**

Other TCO reduction technologies:

AI-based network automation for continuous operational optimization

Non-terrestrial networks for energy- and cost-efficient rural coverage

Green networks with energy-saving operational modes for lower OPEX

Examples of commercial RAN sharing:

4G/5G regional RAN sharing in Europe, Japan and Latin America

5G national RAN sharing in China

Qualcomm

Our wireless research is leading the transformation of future wireless systems

Key longer-term research vectors

Enabling the path towards 6G

AI-native E2E communications

Data-driven communication and network design, with joint training, model sharing and distributed inference across networks and devices

Scalable network architecture

Disaggregation and virtualization at the connected intelligent edge, use of advanced topologies to address growing demand

Expanding into new spectrum bands

Expanding to THz, wide-area expansion to higher bands, new spectrum sharing paradigm, dynamic coordination with environmental awareness

Air interface innovations

Evolution of duplexing schemes, Giga-MIMO, mmWave evolution, reconfigurable intelligent surfaces, non-terrestrial communications, waveform/ coding for MHz to THz, system energy efficiency

Merging of worlds

Physical, digital, virtual, immersive interactions taking human augmentation to next level via ubiquitous, low-power joint communication and sensing

Communications resiliency

Multifaceted trust and configurable security, post quantum security, robust networks tolerant to failures and attacks

Qualcomm Driving Technology Innovation on the Path to 6G

Foundational Wireless Innovations

5G Advanced

Advanced mmWave Deployment

Multi-user MIMO, enhanced mobility, WAB, IS, RIS, simple repeater, NCR

Wireless AI Interoperability

Cross-node channel feedback
Nokia collab.

AI-enabled Beam Management

Device-side spatial-domain beam prediction

6G

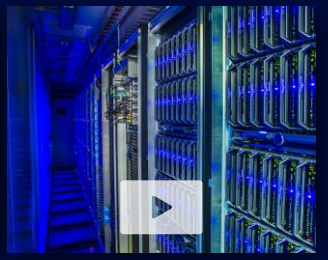
Giga-MIMO System Enabling Upper Midband

World's First Giga-MIMO antenna prototype operating at 13 GHz

Digital Twin Network

Precise network coverage validation, mobility, capacity planning

On the Path to Sub-THz



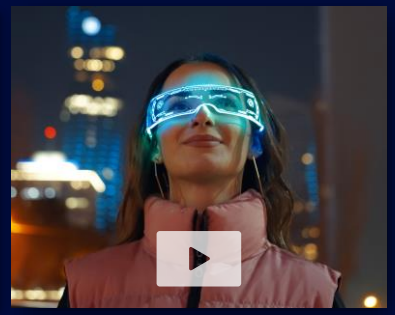
Single-to-multi-point, data center comm., multi-object sensing

5G Beyond Mobile Broadband

Advanced Automotive Connectivity

Large-scale VRU alerts OTA
Coverage prediction

Boundless eXtended Reality (XR)



Boundless AR over 5G/Wi-Fi
Hololight collab.

Wide-area IoT RedCap Evolution

Capacity simulation
Low-power wakeup signal

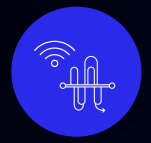
5G from Space (5G NTN)

TN-NTN, NTN-NTN mobility
Ericsson, Keysight collab.

5G Broadcast Readiness

Commercial readiness
Rohde & Schwarz collab.

6G Spectrum Innovations



Wireless data consumption growth continues to fuel the need for more spectrum

Wireless ecosystem is starting to prepare for 6G spectrum needs today

Spectrum innovations will form the foundation of 6G advancements, bringing enhancements across all bands

Our wireless research is enabling enhanced spectrum efficiencies and new bands for future systems

Thank you

Follow us on:

For more information, visit us at qualcomm.com & qualcomm.com/blog

APPENDIX

5G Global spectrum alignment and harmonization

Crucial to facilitate the future of wireless connectivity

5G operates in all spectrum types / bands

Spectrum is the lifeblood of wireless communications

Licensed spectrum

Exclusive use

Mobile industry's top priority

Shared spectrum

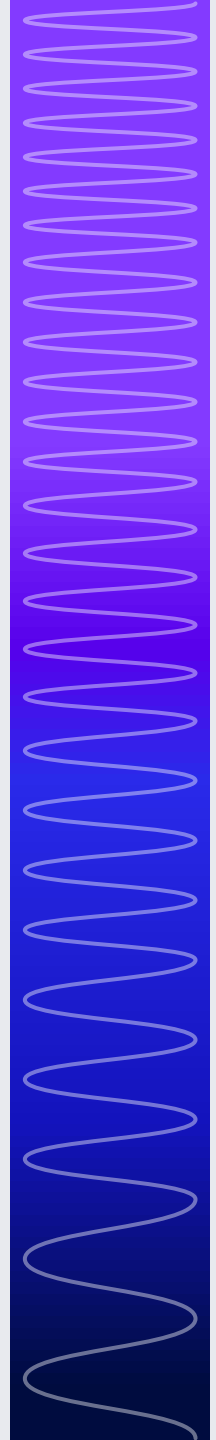
Existing and new paradigms

e.g., 3.8-4.2 GHz UK, 3.5 GHz & 37-37.6 GHz USA

Unlicensed spectrum

Shared use

e.g., 5 GHz / 6 GHz / 60 GHz global



HIGH BANDS
ABOVE 24 GHz (mmWAVE)

MID BANDS
1 GHz — 7 GHz

LOW BANDS
BELOW 1 GHz

Today's spectrum allocation is enabling increased data consumption and growth in the 5G era

5G (& Wi-Fi) Bands

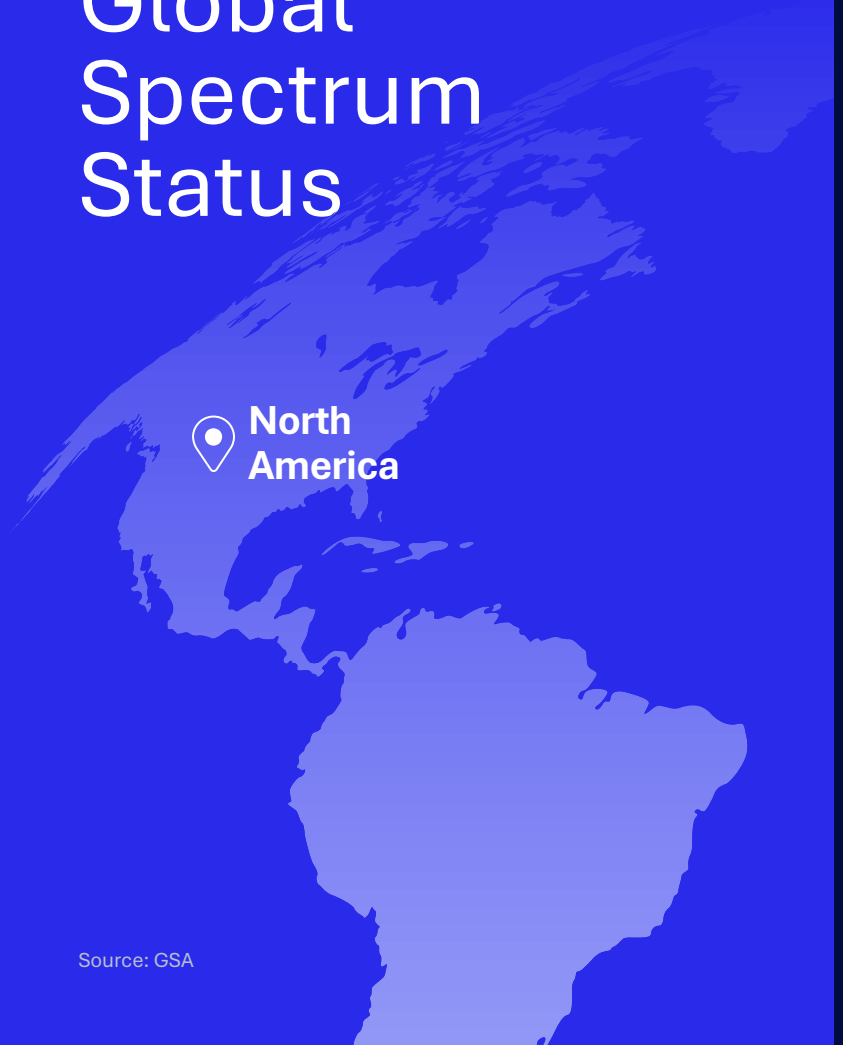
- Licensed
- Unlicensed / shared
- Under study/proposed rules/waiting for auction

	<1GHz	3GHz	4GHz	5GHz	6GHz	24-30GHz	37-50GHz	60GHz	>95GHz	
	600MHz (2x35MHz) 900MHz (2x3MHz) 2.5/2.6GHz (B41/n41)	3.1-3.45GHz 3.45-3.55GHz 3.55-3.7GHz 3.7-3.98GHz	4.94-4.99GHz	5.9–7.1GHz		24.25-24.45GHz 24.75-25.25GHz 27.5-28.35GHz	37-37.6GHz 37.6-40GHz 42-42.5GHz 47.2-48.2GHz	57-71GHz	>95GHz	
	600MHz (2x35MHz)	3.45-3.65 GHz 3.65-3.9GHz		5.9–7.1GHz		26.5-28.35GHz	37-37.6GHz 37.6-40GHz	57-71GHz	>95GHz	
	700MHz (2x30 MHz)	3.4–3.8GHz		5.9–6.4GHz		24.5-27.5GHz		57-66GHz		
	700MHz (2x30 MHz)	3.4–3.8GHz		5.9–6.4GHz		24.25-27.5 GHz	40.5-43.5 GHz	57-66GHz		
	700MHz (2x30 MHz)	3.4–3.8GHz		5.9–6.4GHz		24.25-27.5 GHz		57-66GHz		
	700MHz (2x30 MHz)	3.46–3.8GHz		5.9–6.4GHz		24.25-27.5 GHz		57-66GHz		
	700MHz (2x30 MHz)	3.6–3.8GHz		5.9–6.4GHz		24.25-27.5 GHz		57-66GHz		
	700/800MHz 900MHz 2GHz (n1) 2.5/2.6GHz (B41/n41)	3.3–3.6GHz	4.8–5GHz			24.75-27.5GHz	37-43.5GHz			
	700/800MHz 2.3-2.39GHz	3.4–3.7GHz 3.7-4.0GHz	4.72–4.82GHz	5.9–7.1GHz		25.7-26.5GHz 26.5-28.9GHz 28.9-29.5GHz	37GHz	57-64GHz		
	700/800MHz 2.3 GHz	3.6–4.1GHz	4.5–4.9GHz	5.9–6.4GHz		27-29.5GHz		57-66GHz		
	600MHz (2x40 MHz) 700MHz (2x30 MHz)	3.3–3.67GHz				24.25-27.5GHz				
	2.3 GHz	3.4–3.7GHz 3.7-4.0GHz		5.9–6.4GHz		24.25-29.5GHz	39GHz	57-66GHz		

Source: GSA

RECENT HIGHLIGHTS

5G Global Spectrum Status



Source: GSA

UNITED STATES

- Multiple bands in commercial deployment from all major mobile operators, e.g., 600 MHz, 2.5/2.6 GHz, 3.5 GHz, 28 GHz, as well as other existing bands using DSS
- 4.9 GHz band targeted for public safety use with non-commercial secondary use
- 5.9 GHz band for automotive safety – waiver granted by FCC to permit initial C-V2X deployments
- 6 GHz band (5.9-7.1 GHz) for unlicensed operations (e.g., Wi-Fi and 5G NR-U)
- 5030 MHz band (5030-5091 MHz) for UAS operations
- Lower 37 GHz band - advanced spectrum sharing possibilities

CANADA

- Multiple bands in commercial deployment from major mobile operators, such as 600 MHz, 3.5 GHz, and other mobile bands using DSS
- Looking to open 3.9 GHz band and 26, 28, and 38 GHz bands for exclusive use and for non competitive local (NCL) licensing
- Above 95 GHz bands opened by ISED for unlicensed operations

RECENT HIGHLIGHTS

5G Global Spectrum Status

Source: GSA

ARGENTINA

- 5G auction held on October 2024. Claro (100 MHz), Telecom (100 MHz) and Movistar (50 MHz) obtained spectrum in the 3.3-3.6 GHz band

BRAZIL

- Assigned 3.3-3.7 GHz and 26 GHz. Reserved 3.7-3.8 GHz for local networks
- Considering and consulting on 4.8-5.0 GHz band

BOLIVIA

- ATT announced spectrum assignment by Q1 2025. It will likely include 100 MHz in the 3.5 GHz band

COLOMBIA

- 5G auction held in Q3 2023. Four 80MHz blocks assigned in the 3.3-3.7 GHz band
- Remaining spectrum will be auctioned on a regional basis

COSTA RICA

- 5G auction for the 3.5 and 26 GHz bands scheduled for January 2025

CHILE

- Assigned 3.3-3.4 GHz, 3.6-3.65 GHz, and 26 GHz for 5G in Q1 2021
- Second 5G tender to assign 50 MHz in 3.4-3.6 GHz concluded in June 2024
- 3.75-3.8 GHz range reserved for local networks

MEXICO

- Assigned 3.4-3.45 and 3.45-3.55 GHz for 5G
- Evaluating 3.3-3.4 GHz and 26 GHz. Working to recover the 3.3-3.35 GHz band

PERU

- MTC is working to refarm and assign the 3.3-3.7 GHz band during Q1 2025

PARAGUAY

- Draft of 5G auction rules published in Dec 2024
- Auction for 3.3-3.7 GHz, expected for Q1 2025

URUGUAY

- Assigned 27.5-28.25 GHz for 5G (via temporary assignments)
- Auction finalized in Q2 2023. Claro, Movistar and Anel obtained 100 MHz block each in the 3.3-3.6 GHz band

RECENT HIGHLIGHTS

5G Global Spectrum Status

Source: GSA

U.K.
- Assigned 3.4-3.8, 3.8-4.2 for private networks
- 26 GHz, 40 GHz auction expected in 1H 2025

ITALY
- Assigned 3.4-3.8 GHz
- Assigned 26 GHz

FRANCE
- Assigned 3.4-3.8 GHz
- Test licenses for 26 GHz band

SPAIN
- Assigned 3.4-3.8 GHz
- Assigned 26 GHz - including dedicated spectrum for private networks (24.25-24.7 GHz)

SWEDEN
- Assigned 3.4-3.8 GHz – including dedicated spectrum for private networks (37.20-38 GHz)
- Local licensing in 24.25-25.1 GHz

GERMANY
- Assigned 3.4-3.7 GHz, 3.7-3.8 GHz for private networks
- 26 GHz licenses issued on demand on a local basis

FINLAND
- Assigned 3.4-3.8 GHz
- Assigned 26 GHz – including dedicated spectrum for private networks (24.25-25.1 GHz)

GREECE
- Assigned 3.4-3.8 GHz
- Assigned 26 GHz

SLOVENIA
- Assigned 3.4-3.8 GHz
- Assigned 26 GHz band

CROATIA
- Assigned 3.4-3.8 GHz
- Assigned 26 GHz band

ROMANIA
- Assigned 3.4-3.8 GHz

ESTONIA
- Assigned 3.4-3.8 GHz
- Assigned 26 GHz

CZECH REP.
- Assigned 3.5-3.8 GHz, local license 3.4-3.5GHz

DENMARK
- Assigned 3.4-3.8 GHz
- Assigned 26 GHz, 24.25-24.65 for private networks

RECENT HIGHLIGHTS

5G Global Spectrum Status

Source: GSA

MAINLAND CHINA

- Assigned 700MHz, 3.4-3.6 GHz, 4.8-5.0 GHz for 5G
- Allocated 3.3-3.4 GHz for shared indoor use
- Refarming 800/900 MHz 2G/4G band for 5G
- Identify IMT service in 6.425-7.125 GHZ, 24.75-27.5 GHz and 37-43.5GHz (portion thereof)

HONG KONG

- Assigned 3.3-3.6 and 4.84-4.92 GHz
- Allocated 400 MHz per operator in 26/28 GHz, with 400 MHz reserved for local licensing
- 2.5-2.6 GHz planned for 5G re-allocation

TAIWAN

- Assigned 3.3-3.57 GHz for 5G
- Assigned 27.9–29.2 GHz, and 29.3–29.5 GHz
- 4.8-4.9 GHz allocated for local private network licenses

JAPAN

- Allocated 3.6-4.1 GHz, 4.5-4.6 GHz, and 27-28.2, 29.1-29.5 GHz to 4 operators
- Allocated 4.6-4.9 GHz and 28.2-29.1 GHz for local licensing
- 4.9-5.0 GHz to be allocated
- 25.25-27 GHz, and 37-43.5 GHz will be studied

SOUTH KOREA

- Allocated 3.4-3.7 GHz and 26.5-28.9 GHz
- Considering 3.7- 4.0 GHz band
- MSIT plans to allocate additional 5G spectrum

AUSTRALIA

- Assigned 3.4-3.7 GHz
- 3.7-4.2 GHz, 4.4-4.5 GHz, 4.8-5.0 GHz under on-going consultation
- 26 GHz mmWave band for local licensing and wide-area allocation

NEW ZEALAND

- Assigned 3.4-3.59 GHz and 3.59-3.8 GHz
- 26/28 GHz mmWave under consideration

RECENT HIGHLIGHTS

5G Global Spectrum Status

Source: GSA

INDIA

- Assigned spectrum across all bands for 5G, including 700 MHz, 3.4-3.67 MHz and 26 GHz to 4 operators
- 800, 900 MHz,1.8, 2.1, 2.3, and 2.5 GHz bands currently used for 4G, but expected to become 5G bands

SINGAPORE

- Assigned mid-band 3.45-3.65 GHz to two operators with 100 MHz each
- Assigned mmWave in 26.25-29.5 GHz for 4 operators with 800 MHz each

MALAYSIA

- Assigned 700 MHz, 3.5 GHz and 28 GHz bands to a wholesale operator

THAILAND

- Assigned 700 MHz and 2.5 GHz TDD spectrum for 5G
- Assigned 26 GHz spectrum to 4 operators
- Considering 3.3-3.7 GHz
- Considering 4.5-4.9 GHz foo private networks

INDONESIA

- Assigned 2.3 GHz TDD band for 5G
- Conducted 5G SA trials in 700 MHz and 26 GHz
- Plan to release 700 MHz, 2,6 GHz, 3.4-3.6 GHz and 26 GHz for 5G

PHILIPPINES

- Assigned 3.3-3.5 GHz in mid-band
- Considering 26 GHz band

VIETNAM

- Assigned 2.5 GHz and 3.7-3.9 GHz bands
- Planning to auction 700 MHz and 900 MHz

Global snapshot of spectrum optimized for industrial IoT / vertical / private network use

Local licensing or sharing

USA	3.5 GHz CBRS, shared licenses 37 - 37.6 GHz shared spectrum/local licenses, under study
GERMANY	3.7 – 3.8 GHz 24.25 - 27.5 GHz, local licenses
U.K.	3.8 - 4.2 GHz 1781.7-1785/1876.7-1880 MHz 2390 – 2400 MHz 24.25 - 26.5 GHz, local licenses
SWEDEN	1780-1785/1875-1880 MHz 3720 - 3800 MHz 24.5 – 25.1 GHz
FINLAND	2300 – 2320 MHz Sub-licensing of 3.4 – 3.8 GHz 24.5 – 25.1 GHz
NORWAY	Sub-licensing of 3.4-3.8 GHz 3.8-4.2 GHz local licenses 24.5 – 25.1 GHz under allocation
NETHERLANDS	3410 – 3450 MHz for local industrial use 3750 – 3800 MHz available with restrictions 2.3 – 2.4 GHz (licensed shared access online booking system) Local private service to migrate to 3400-3450 MHz or 3750-3800 MHz by 2026
FRANCE	2575 – 2615 MHz 26.5 – 27.5 GHz (test licenses)
CZECH REP.	3.4 - 3.6 GHz, 2*20 MHz, Allocated in 2020 with a leasing option
POLAND	3.4 – 4.2 GHz local licenses
BRAZIL	703 – 708 / 758 – 763 MHz (Infrastructure segment) 1487 – 1517 MHz, 2390-2400 MHz, 2485 – 2495 MHz 3.7 – 3.8 GHz 27.5 – 27.9 GHz
CHILE	2300 - 2325 MHz (already has requests from ports and mining sectors) 3.75 – 3.8 GHz
NEW ZEALAND	Licenses in 2575 – 2620 MHz may be assigned for localized use
AUSTRALIA	1755-1785 MHz in remote areas 1920-1980 MHz in remote areas 3.7 – 4.0 GHz for local area licensing 24.25 - 27.5 GHz and 27.5 – 29.5 GHz for local licensing
CHINA	Issued the first local 5G trial license in 5925-6125 MHz and 24.75-25.15 GHz to COMAC
SINGAPORE	Each operator has acquired 800 MHz of 26/28 GHz spectrum to deploy local networks
HONG KONG	24.25 - 28.35 GHz (400 MHz) available for local licenses
JAPAN	2,575 - 2,595 MHz and 1,888.5 – 1,916.6 MHz (NSA anchor) 4.6 - 4.9 GHz (4.6 - 4.8 GHz indoor only, 4.8 - 4.9 GHz outdoor possible) & 28.2 - 29.1 GHz (Outdoor use; total 250 MHz 28.2 – 28.45 MHz) Uplink heavy TDD config. using semi-sync allowed in sub-6 & 28 GHz
SOUTH KOREA	4.72 – 4.82 GHz and 28.9 - 29.5 GHz for 5G specialized local applications
TAIWAN	4.8 – 4.9 GHz for 5G local private and enterprise licenses

Source: GSA, MFA