GSMA

VISION 2040

Spectrum for the future of mobile connectivity

The GSMA is a global organisation unifying the mobile ecosystem to discover, develop and deliver innovation foundational to positive business environments and societal change. Our vision is to unlock the full power of connectivity so that people, industry and society thrive. Representing mobile operators and organisations across the mobile ecosystem and adjacent industries, the GSMA delivers for its members across three broad pillars: Connectivity for Good, Industry Services and Solutions, and Outreach. This activity includes advancing policy, tackling today's biggest societal challenges, underpinning the technology and interoperability that make mobile work, and providing the world's largest platform to convene the mobile ecosystem at the MWC and M360 series of events.

We invite you to find out more at gsma.com

GSMA Intelligence is the definitive source of global mobile operator data, analysis and forecasts, and publisher of authoritative industry reports and research. Our data covers every operator group, network and MVNO in every country worldwide — from Afghanistan to Zimbabwe. It is the most accurate and complete set of industry metrics available, comprising tens of millions of individual data points, updated daily.

GSMA Intelligence is relied on by leading operators, vendors, regulators, financial institutions and third-party industry players, to support strategic decision-making and long-term investment planning. The data is used as an industry reference point and is frequently cited by the media and by the industry itself.

Our team of analysts and experts produce regular thought-leading research reports across a range of industry topics.

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FOREWORD

A SHARED VISION: THE ROAD TO 6G

At the GSMA, we see every generation of mobile technology as part of a continuous evolution, one that connects more people, strengthens digital economies and helps widen access to connectivity. Today, the industry is developing the standards and spectrum that will shape mobile through the 2030s, a period that we expect to be defined as the 6G era.

6G will not arrive through a single breakthrough. Instead, it will provide capacity for new applications while supporting the development of services emerging today. New concepts such as embedding AI or augmented reality into our everyday lives will depend on sustainable and harmonised spectrum solutions. Our task is to ensure that these advances remain accessible and affordable. Careful planning is essential to ensure that 6G is not just available everywhere, but available to everyone.

Industry and government alignment can support a shared vision for 6G that delivers national digital ambitions – from economic growth to environmental goals. The spectrum choices we make together in the coming years will determine how effectively 6G delivers value. Harmonising spectrum is a long-term process, and the work undertaken today will shape outcomes throughout the 2030s. We must understand future requirements while remaining pragmatic and flexible as today's new applications turn into tomorrow's digital imperatives.

Through our research arm, GSMA Intelligence, we have drawn on our global MNO data and our unique relationship across the operator and vendor communities to generate insights on spectrum needs in the period 2035-2040, when we expect 6G to be at its peak. This rigorous modelling is designed to help policymakers and industry stakeholders define the future requirements of mobile.

The GSMA remains committed to working with governments, regulators and industry partners to ensure that 6G is built on principles of inclusivity, efficiency and innovation. Understanding the requirements of spectrum will provide important guidance on our journey.

Together, we can ensure the next generation of connectivity builds on the strengths of the past and brings the benefits of 6G to everyone, everywhere.

Vivek Badrinath
Director General
GSMA

EXECUTIVE SUMMARY

1

Cities with over 50% of the world's urban population will be capacity-constrained by 2030 if mid-band spectrum remains at today's levels.

2

A global average of 2-3 GHz of total mid-band spectrum will be required in urban areas by 2035-2040; higher-demand countries will need 2.5-4 GHz in this period.

3

A harmonised spectrum roadmap that delivers the total mid-band spectrum requirements should be developed to enable operators to meet these capacity demands from 2030.

4

Regulators should seek to assign spectrum in 3.8-4.2 GHz and upper 6 GHz to mobile by around 2030 to meet demand and consider 4.4-4.99 GHz and 7-8 GHz beyond that.

2035-2040

2-3 GHZ
Global average

2.5-4 GHZ
Higher-demand countries

2 GHz needed by 2030

50%
Cities with over 50% of the world's urban population will be capacity-constrained by 2030 if mid-band spectrum remains at today's levels

Driven by applications

- Extended reality
- Generative AI video

Driven by needs

- Capacity
- Latency

6G penetration

2035
2.1 BILLION
connections

24%
market penetration

2040
5 BILLION
connections

54%
market penetration

Spectrum needs driven by high-demand locations

83%
of traffic is from **5%** of geographic area

Dense urban needs are

9x GREATER
than other urban

650x GREATER
than rural

The mobile industry, alongside government and regulatory experts, is laying the long-term foundations for the deployment of 6G networks in the 2030s. Understanding future spectrum requirements has become critical for operators, the wider mobile industry, regulators and policymakers.

The GSMA's Vision 2040 study on spectrum needs during the peak 6G era of 2035–2040 provides a comprehensive assessment of mid-band spectrum needs for mobile networks. It is designed to support policymakers in developing the long-term spectrum roadmap needed to ensure seamless evolution into the networks of the 2030s. The World Radiocommunication Conference 2027 (WRC-27) will seek to harmonise spectrum that will be brought into use in this period, to complement existing evolution bands such as 6 GHz.

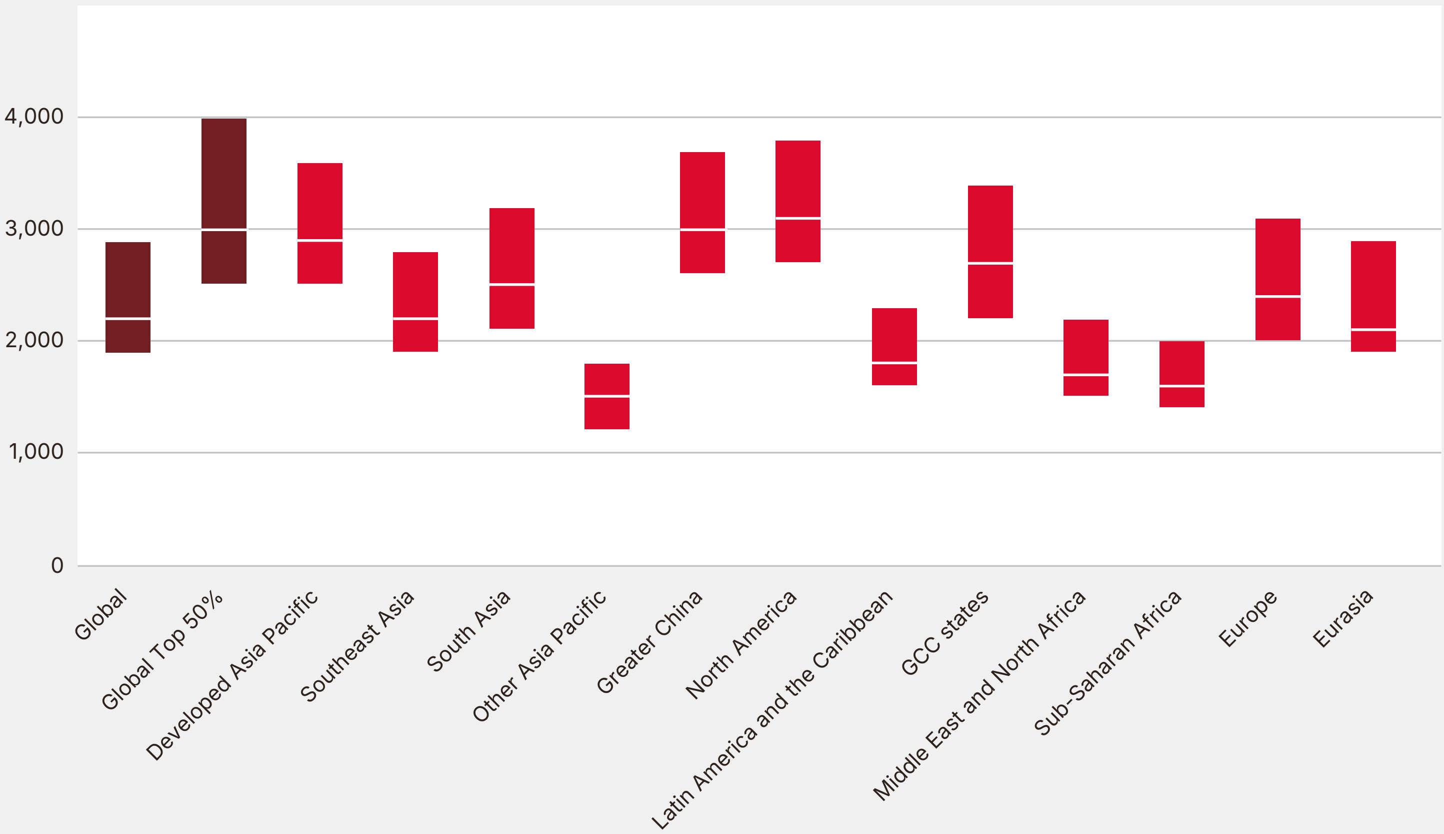
The analysis considers a range of traffic demand scenarios to 2040, encompassing existing mobile use cases such as video streaming, social media and gaming. It then considers new and emerging 6G-era use cases such as extended reality (XR), integrated sensing and communication (ISAC) and autonomous vehicles. Forecasts between mobile, IoT and fixed wireless access (FWA) traffic are distinguished, while granular geospatial data is used to identify the urban locations where peak-hour traffic demand (and therefore spectrum needs) will be at its greatest. Evolution of network capacity is also modelled. This takes into account network densification, spectrum availability, improvements in spectral efficiencies, multi-RAT spectrum sharing (MRSS) and the proportion of capacity met by low bands, mid-bands and mmWave bands.

Mobile network capacity is expected to increase as operators utilise their existing spectrum more efficiently, deploying AI-RAN and 6G technologies as well as densifying their networks where possible. However, this is not enough to meet the expected growth in demand, which necessitates a requirement for more spectrum.

Considering this evolution of demand and network capacity in dense urban areas, and reflecting the uncertainty involved in making long-term forecasts, we estimate an average of 2–3 GHz of mid-band spectrum (frequency bands between 1 GHz and 10 GHz) will be required in the 2035–2040 period to meet demand in high-population density locations around the world. In higher-demand countries (representing the top 50% of countries globally) spectrum needs will be 2.5–4 GHz in that period. Figure i presents the mid-band spectrum-needs range globally and by region.

Considering existing IMT allocations, where in most countries around 1 GHz of mid-band spectrum is identified for mobile, this means that an additional mid-band requirement of 1–3 GHz is needed.

Figure i
Total mid-band spectrum needs in 2035–2040 (MHz)



Source: GSMA Intelligence

Note: The box represents the 25th percentile, median and 75th percentile of spectrum needs estimates based on our scenario analysis. Results are based on a weighted average, which takes a population-weighted average of spectrum needs (i.e. giving more weight to countries with larger dense urban populations).

With such mid-band spectrum needs in 2035–2040, the practical implication is that 2–3 GHz of mid-band spectrum must be allocated, assigned and operational well in advance of 2035, with higher-demand countries requiring 2.5–4 GHz, to ensure networks can handle expected traffic.

Network congestion will start several years before reaching the point where mid-band spectrum needs occur, and more than 50% of dense urban populations globally will live in areas with network congestion in 2030 (when 6G deployments may begin) if only 1 GHz of mid-band spectrum is available for mobile use. Delays in availability could therefore lead to network congestion in high-demand areas, reducing service quality and negatively impacting user experience, as mobile operators need sufficient lead time to deploy and optimise the spectrum effectively. Having 2 GHz of mid-band spectrum by 2030 is therefore critical.

MAIN FINDINGS

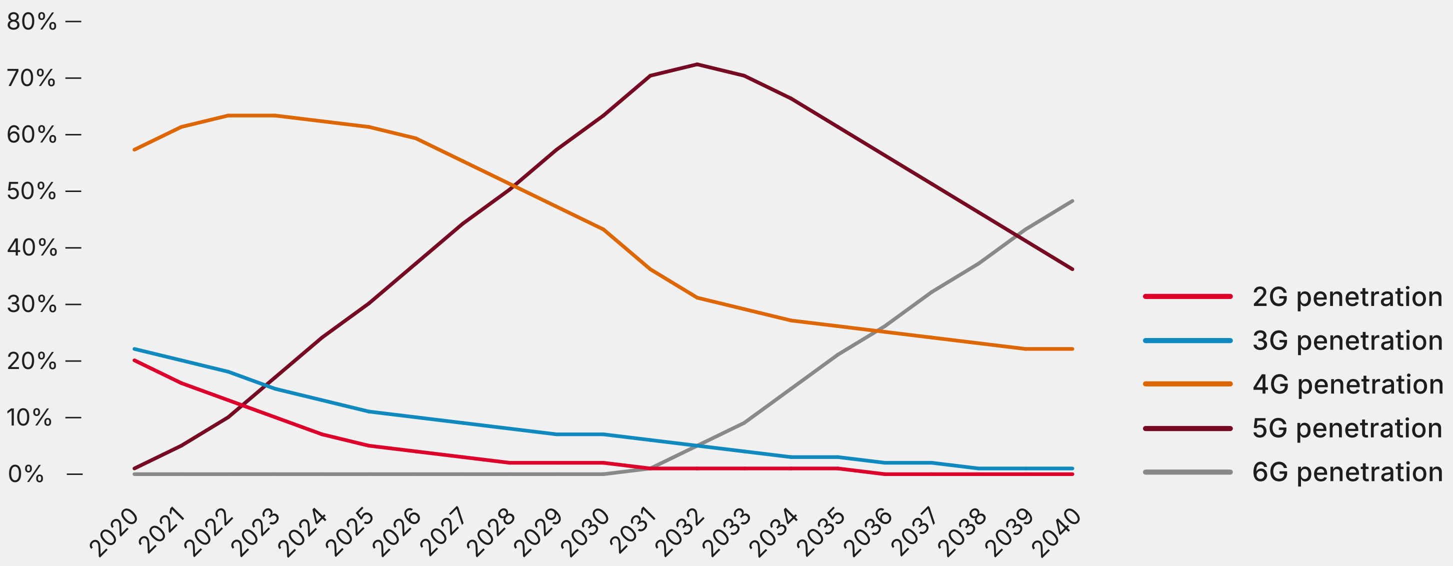
Continued growth

Demand for mobile network capacity is expected to continue growing by 15–20% in the next five years (2025–2030), with more users migrating to 5G and utilising higher-speed networks. Beyond that, demand will continue growing with more 'power' users, as currently 10% of mobile users generate 60–70% of total network traffic. Based on the lowest, most conservative demand growth scenario, global mobile traffic could increase by 10% per year during 2030–2040, reaching 1,700 EB/month by 2040 (around 140 GB per mobile connection per month).

The impact of 6G

6G is expected to be deployed from 2030, with large initial rollouts likely to occur in countries/regions such as China, Japan, South Korea, the US, the GCC states, Europe, Vietnam and India. The number of 6G connections could reach more than 5 billion by 2040, representing approximately half of all mobile connections globally. The technology is expected to enable new and emerging use cases that could increase demand further in the 2030–2040 period, with much heavier uplink requirements. This includes XR, image- and video-driven generative AI (genAI) and potentially holographic communication. The highest demand growth scenario shows global mobile network traffic increasing by more than 20% per year after 2030, reaching almost 4,000 EB/month by 2040 (around 360 GB per mobile connection per month).

Figure ii
Market penetration by technology, 2020–2040



Source: GSMA Intelligence

High-demand locations drive spectrum requirements

Spectrum needs are fundamentally driven by traffic demand in the most congested locations during peak hours. Analysis shows that very dense urban traffic per square kilometre is typically 9× greater than in other urban areas and almost 700× greater than in rural areas. A sample of 10 countries showed that 83% of mobile traffic was in urban areas, which comprised only around 5% of the total geographic area. These high-density areas will eventually become congested even with modest long-term annual traffic growth, necessitating additional spectrum resources.

Spectrum will not just be driven by downlink and uplink requirements

Many emerging AI use cases and others enabled by 6G, such as immersive communication, will require ultra-low latencies of 10 ms or below, necessitating wider channels to reduce transmission delay and avoid network congestion. Use cases requiring high-resolution sensing, particularly in outdoor environments, such as traffic management and environmental monitoring, will also require wider bandwidth and larger channels to achieve the fine-grained spatial and temporal accuracy.

IMPLICATIONS FOR SPECTRUM POLICY

There are several important implications for policy and regulation. Each generation of mobile technology has required additional spectrum to meet increasing performance requirements and accommodate growing demand. With 6G on the horizon, the industry faces the challenge of identifying requirements well in advance to enable proper network planning and regulatory preparation.

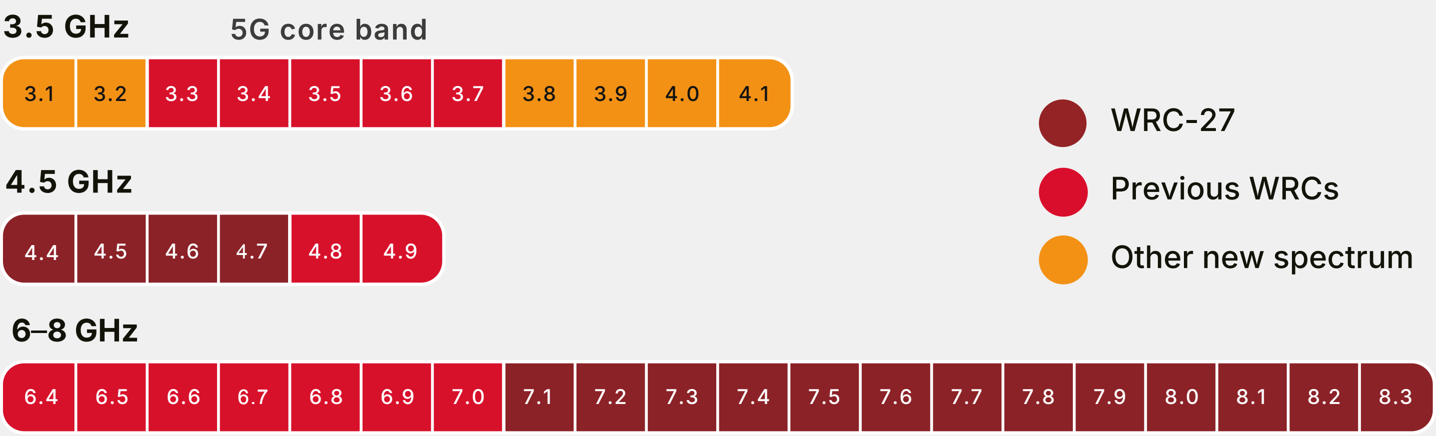
Given that 2 GHz of mid-band spectrum is required to be available by 2030 onwards and 2-3 GHz (in all countries) or 2.5-4 GHz (in higher demand countries) may be required in the 2035–2040 period to cope with the additional traffic demand, governments and regulators need to assess how best to plan for this. The upper 6 GHz band, which has already been widely harmonised and provides capacity for multiple channels of over 200 MHz, is being considered as the next expansion band for mobile evolution in the widest number of countries.

Building on existing spectrum, including recent spectrum identifications at WRC-23, and also looking ahead to WRC-27 discussion items, the primary mid-bands currently under consideration for additional mobile spectrum are from within the:

1. 3.8–4.2 GHz range, which could provide an additional 200–400 MHz of mid-band spectrum
2. 4.4–4.99 GHz range, which could provide an additional 400–600 MHz
3. upper 6 GHz range (6.425–7.125 GHz), which could provide an additional 700 MHz
4. the 7.125–8.4 GHz range, which could provide an additional 600–1275 MHz.

Given that many countries have currently allocated or assigned around 1 GHz of mid-band spectrum, use of the upper 3.5 GHz band in conjunction with the 6 GHz band offers a potential solution to provide immediate spectrum requirements by 2030. Beyond that, 4.5 GHz and 7–8 GHz are needed as a solution to the longer-term requirements. However, as each of these bands have incumbent use, regulators and policymakers need to plan for increased mobile spectrum requirements now, considering the lead times required for international harmonisation, equipment development and network deployment.

Figure iii
Evolution of mobile bands



Source: GSMA

REGIONAL BREAKDOWN

DEVELOPED ASIA PACIFIC

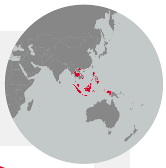
Total mid-band spectrum needs:

Average: **2.5-3.6 GHz**

Top 50%*: **2.7-4.0 GHz**

- 2040 traffic per connection: **235-620** GB/month
- 2040 6G connections: **250 MILLION** (124% penetration)
- 2040 5G connections: **50 MILLION** (23% penetration)

SOUTHEAST ASIA



Total mid-band spectrum needs:

Average: **1.9-2.8 GHz**

Top 50%*: **2.3-3.8 GHz**

- 2040 traffic per connection: **95-255** GB/month
- 2040 6G connections: **340 MILLION** (45% penetration)
- 2040 5G connections: **530 MILLION** (70% penetration)

SOUTH ASIA

Total mid-band spectrum needs:

Average: **2.1-3.2 GHz**

Top 50%*: **2.4-3.7 GHz**

- 2040 traffic per connection: **115-290** GB/month
- 2040 6G connections: **760 MILLION** (34% penetration)
- 2040 5G connections: **460 MILLION** (20% penetration)

OTHER ASIA PACIFIC

Total mid-band spectrum needs:

Average: **1.2-1.8 GHz**

Top 50%*: **1.3-2.3 GHz**

- 2040 traffic per connection: **70-170** GB/month
- 2040 6G connections: **4 MILLION** (7% penetration)
- 2040 5G connections: **13 MILLION** (26% penetration)

* Spectrum needs for the top 50% of population with the highest urban demand and spectrum needs

REGIONAL BREAKDOWN

GREATER CHINA

Total mid-band spectrum needs:

Average: **2.6-3.7 GHz**

- 2040 traffic per connection: **240-640** GB/month
- 2040 6G connections: **1,600 MILLION** (116% penetration)
- 2040 5G connections: **300 MILLION** (21% penetration)

NORTH AMERICA

Total mid-band spectrum needs:

Average: **2.7-3.8 GHz**

- 2040 traffic per connection: **240-575** GB/month
- 2040 6G connections: **440 MILLION** (107% penetration)
- 2040 5G connections: **70 MILLION** (18% penetration)

LATIN AMERICA AND THE CARIBBEAN

Total mid-band spectrum needs:

Average: **1.6-2.3 GHz**

Top 50%*: **2.1-3.0 GHz**

- 2040 traffic per connection: **85-235** GB/month
- 2040 6G connections: **340 MILLION** (46% penetration)
- 2040 5G connections: **320 MILLION** (44% penetration)

GCC STATES

Total mid-band spectrum needs:

Average: **2.2-3.4 GHz**

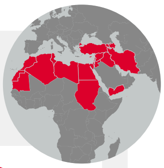
Top 50%*: **2.2-3.4 GHz**

- 2040 traffic per connection: **245-655** GB/month
- 2040 6G connections: **100 MILLION** (135% penetration)
- 2040 5G connections: **20 MILLION** (26% penetration)

* Spectrum needs for the top 50% of population with the highest urban demand and spectrum needs

REGIONAL BREAKDOWN

MIDDLE EAST AND NORTH AFRICA



Total mid-band spectrum needs:

Average: **1.5-2.2 GHz**

Top 50%*: **2.0-3.1 GHz**

- 2040 traffic per connection: **90-215** GB/month
- 2040 6G connections: **240 MILLION** (33% penetration)
- 2040 5G connections: **320 MILLION** (45% penetration)

SUB-SAHARAN AFRICA

Total mid-band spectrum needs:

Average: **1.4-2.0 GHz**

Top 50%*: **1.9-2.9 GHz**

- 2040 traffic per connection: **30-70** GB/month
- 2040 6G connections: **240 MILLION** (14% penetration)
- 2040 5G connections: **820 MILLION** (46% penetration)

EUROPE

Total mid-band spectrum needs:

Average: **2.0-3.1 GHz**

Top 50%*: **2.5-3.9 GHz**

- 2040 traffic per connection: **225-590** GB/month
- 2040 6G connections: **550 MILLION** (96% penetration)
- 2040 5G connections: **170 MILLION** (30% penetration)

EURASIA

Total mid-band spectrum needs:

Average: **1.9-2.9 GHz**

Top 50%*: **1.9-3.1 GHz**

- 2040 traffic per connection: **115-345** GB/month
- 2040 6G connections: **110 MILLION** (42% penetration)
- 2040 5G connections: **220 MILLION** (84% penetration)

* Spectrum needs for the top 50% of population with the highest urban demand and spectrum needs

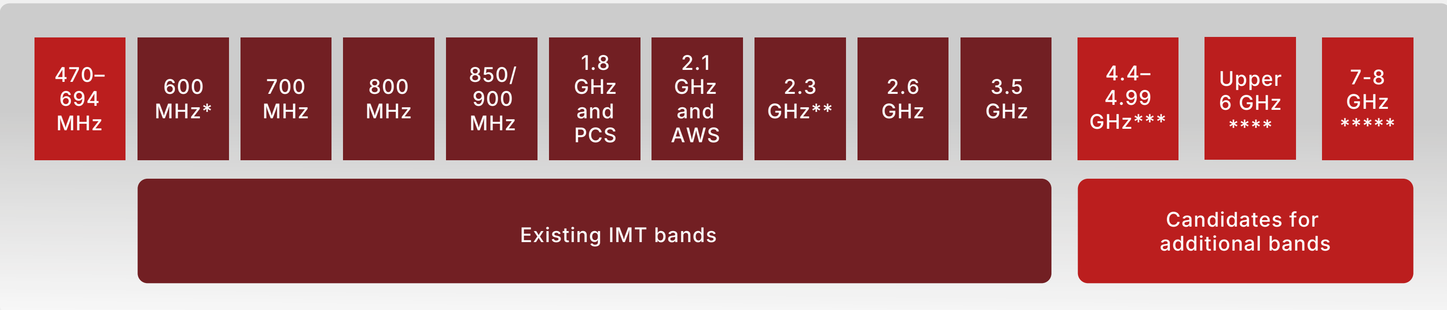
1. INTRODUCTION

THE CONTINUING EVOLUTION OF MOBILE SPECTRUM REQUIREMENTS

The mobile telecommunications industry has consistently required additional spectrum with each successive generation of technology. Following the deployment of 2G on 850 and 900 MHz bands, as well as 1.8 GHz and PCS bands, 3G technologies were deployed during the 2000s in the 2.1 GHz band.[1] 4G technologies were initially deployed during the 2010s in the 800 MHz and 2.6 GHz bands, while the primary band for to deploy 5G since 2019 has been the 3.5 GHz range. This pattern is partly due to the need to operate and maintain legacy technologies, which can limit the full reuse of existing bands for new technologies. However, it primarily reflects growing performance requirements and the capacity demands that drive each new generation forward. As the mobile industry looks ahead to 6G, which is expected to be deployed from around 2030, there is a need to identify potential new spectrum requirements so that operators can plan investments and governments can develop long-term spectrum roadmaps.

The existing IMT spectrum portfolio spans low bands (below 1 GHz), mid-bands (1–7 GHz) and millimetre wave (mmWave) allocations above 24 GHz. Figure 1 presents an overview of current and potential IMT bands, excluding mmWave bands. Recent World Radiocommunication Conference (WRC) decisions have identified additional mid-band spectrum in the upper 6 GHz range (6.425–7.125 GHz) for mobile use, with further studies planned for the 4–5 GHz range (4.4–4.8 GHz) and 7–8 GHz range (7.125–8.4 GHz) towards WRC-27. The 6.425–8.4 GHz range represents the primary candidate bands for addressing future additional mobile mid-band spectrum needs. These frequencies can support the wide channels that may become necessary for advanced 6G applications while maintaining reasonable propagation characteristics for both indoor and outdoor coverage. However, determining the precise spectrum requirements in this range requires careful analysis of expected demand growth and network capability evolution.

Figure 1:
Summary of current and potential IMT bands (excluding mmWave bands)



* IMT in the Middle East for 600 MHz and footnote in some African countries. Already an IMT band in Region 2. Still to be implemented in Regions 1 and Region 3.

** 2.3 GHz is not available in many countries in Regions 1 and 2.

*** A small number of markets have already assigned spectrum in the 4.4–4.98 GHz range, for example Japan and Hong Kong.

**** Some markets have already assigned the upper 6 GHz band (6.425–7.125 GHz), for example China, UAE, India and Brazil.

***** Includes the 7.125–8.4 GHz range.

Source: GSMA Intelligence

1 There were some exceptions. For example, in North America 3G was deployed in 850 MHz and PCS bands initially until the AWS band became available.

THE NEED FOR LONG-TERM SPECTRUM PLANNING

Mobile network deployment and spectrum harmonisation operate on extended timescales that necessitate long-term planning. Equipment development, standardisation processes and regulatory coordination can take many years to complete. For operators to be ready to deploy 6G networks commercially by 2030, the underlying spectrum framework should be established well in advance. However, such a forward-looking approach also requires robust analysis of future demand and network capacity scenarios. While predicting technology adoption and usage patterns over a horizon of 10–15 years involves inherent uncertainty, a structured analytical approach can provide the evidence necessary for informed spectrum policy decisions.

It is in this context that this study provides a comprehensive assessment of mobile spectrum needs for the 2035–2040 period, focusing on mid-band requirements in the 1–10 GHz range. The analysis employs a methodology that combines traffic-based demand forecasting with detailed network modelling to estimate capacity requirements in high-demand locations. The assessment considers multiple scenarios to reflect the uncertainty inherent in long-term forecasting, examining different growth trajectories for traffic demand, technology adoption rates and network capabilities.

2. MOBILE IN THE 6G ERA

MAIN FINDINGS

1. 6G is expected to be deployed from 2030, with large initial rollouts likely to occur in countries/regions such as China, Japan, South Korea, the US, the GCC states, Europe, Vietnam and India. 6G connections could reach more than 5 billion by 2040, representing approximately half of all mobile connections globally. While 6G connections penetration will reach (or exceed) 100% in the leading countries and regions, it is likely to lag behind in many low- and middle-income regions. This means that 4G and especially 5G will remain important in the next decade too, respectively accounting for around 2 billion and 3 billion connections globally by 2040.

2. Growth in mobile traffic is expected to be driven by existing use cases, including video and gaming, as well as new and emerging use cases that will be enhanced by 6G, such as extended reality (XR) and network sensing. Global mobile traffic is forecast to reach 1,700–3,900 EB/month by 2040 (1 EB = 1 billion gigabytes), with traffic per connection reaching 140–360 GB/month. Annualised growth rates in global traffic could range between 10% and 25%, with AI driving higher uplink and latency requirements.

3. Even if new use cases remain niche with limited take-up and current video applications remain the predominant traffic driver, demand will continue to grow as more users migrate to 5G and utilise higher-speed networks. In markets where 5G connections accounted for at least 30% of mobile broadband connections in 2024, data usage was 2.5× greater than in markets where 5G accounted for less than 10% of mobile broadband connections.

4. Beyond that, demand will continue growing with more 'power' users, especially as younger generations that are more frequent and intense users of mobile get older and drive a power use boom: what is considered a power user today will be normal behaviour by 2040. Currently, 10% of mobile users generate 60–70% of total network traffic, but the consumption rates of these power users could become the norm in the future.

5. Aside from downlink and uplink demand, spectrum needs in the 6G era will also be driven by latency, reliability and sensing requirements. Many use cases for 6G, such as network-assisted mobility, digital twins and immersive communication, will require latencies of 10 ms or below, and achieving this requires wider channels to reduce transmission delay and avoid congestion.

6. Understanding how mobile traffic is distributed geographically is fundamental to a spectrum-needs assessment because requirements are ultimately determined by demand in the most congested locations during peak usage periods:

7. A sample of 10 countries showed that 83% of mobile traffic was in urban areas, which comprised only around 5% of the total geographic area.

8. Very dense urban traffic per square kilometre is typically 9× greater than in other urban areas and almost 700× greater than in rural areas.

IMPACT OF 6G DEVELOPMENT

6G development is underway and the first deployments are expected by around 2030. While 6G (or IMT-2030) is still being defined, extensive work has gone into identifying the potential usage scenarios, applications and requirements, as well as new network capabilities, including at the International Telecommunication Union (ITU). This is also reflected in ongoing 6G trials and collaborative industry and research initiatives aimed at informing and shaping the future of 6G.[2]

Current expectations are that 6G will provide an incremental development beyond 5G standalone (SA) and 5G-Advanced, with a modular evolution.[3] This means it will build upon the features and capabilities introduced with 5G and deliver improvements across multiple performance dimensions. Key enhancements include higher spectral efficiency through advanced modulation and coding schemes, enhanced multiple input and multiple output (MIMO) capabilities and more sophisticated beamforming techniques.

These improvements will increase the capacity that can be delivered from existing spectrum assignments. The integration of AI into mobile networks, such as AI-RAN implementations, will help optimise resource management and spectrum utilisation efficiency. While 5G-Advanced has introduced AI and machine learning to optimise network management and performance, 6G is expected to take this further with an AI-native architecture, where intelligence is deeply embedded throughout the network. This means AI will not only support operations but will be integral to how the network is designed, managed and optimised in real time.

On the demand side, 6G capabilities will improve the performance of existing use cases such as video and gaming, potentially increasing data rate requirements and usage time. New and emerging applications enabled by 6G capabilities will also drive additional traffic demand with specific performance requirements. These are expected to include:

- enhanced human communication, including enriched communications such as immersive experience, telepresence and multi-modal interaction
- enhanced machine communications, including collaborative robotics
- other enabling services that require features such as high-accuracy location, mapping and sensing.

Enterprise use of mobile networks is also expected to expand significantly in the 6G era, driven by applications such as augmented reality for maintenance and training, real-time data analytics and automated systems integration. Industrial use cases, including collaborative robotics, automated manufacturing systems and smart infrastructure monitoring, will generate additional mobile traffic. Many of these applications will require guaranteed service levels and dedicated network resources, which will influence both spectrum allocation and network architecture design.

2 Examples include Next G Alliance, NGMN, XGMF, 6G Forum, Hexa-X, X-Net, 3GPP and Bharat 6G Alliance.
3 For example, see 6G Key Messages – An Operator View, NGMN, 2025

Table 1 sets out a summary of the existing use cases considered in this study, while Table 2 summarises the new and emerging use cases that could be enhanced by 6G.

Table 1:
Existing mobile use cases

Use case	Description
Video streaming	On-demand or live delivery of video content to users over the internet (e.g. Netflix, YouTube, TikTok, Josh, iQIYI)
Video communication	Real-time video-based interaction between individuals or groups for meetings, chats or telepresence (e.g. Zoom, Teams)
Live content creation	Real-time broadcasting of user-generated video content to online audiences (e.g. on TikTok Live, Twitch or Douyin Live).
Gaming	Online mobile gaming on a device, including cloud gaming that streams from remote servers (e.g. GeForce Now)
Social media	Platforms to create, share and interact with content, including images and video (e.g. Instagram, Kakao, VK)
Browsing/apps	Accessing web content and running applications for productivity, information, services or entertainment
Audio/music	Streaming or downloading of music, podcasts and other audio content (e.g. Spotify)
Messaging	Instant communication between individuals or groups across platforms, including text, audio and video (e.g. WhatsApp, Telegram)
Cloud	Access to computing, storage and services hosted on remote servers (e.g. AWS, Dropbox)
Generative AI	AI that creates original content – text, images, code or media – in response to user input (e.g. ChatGPT, Gemini).

Source: GSMA Intelligence

Table 2:
New and emerging mobile use cases

Use case	Description
XR[4]	XR is an umbrella term encompassing virtual reality (VR), augmented reality (AR) and mixed reality (MR), which involve immersive experiences blending the physical and digital worlds. XR devices include head-mounted displays (e.g. Oculus/Meta Quest), AR glasses, MR headsets (e.g. Microsoft HoloLens) and wearable haptics, enabling applications such as gaming, training, industrial maintenance and collaborative design.
Network sensing	Integrated sensing and communication (ISAC), or joint communication and sensing (JCAS), is a new use case envisioned for 6G. It will include applications such as object positioning and monitoring, imaging and real-time wireless map construction (including potentially 3D-mapping for automated transport and robot collaboration). It will also help to improve the performance and efficiency of the communication system itself, by optimising the utilisation of radio resources when sensing information is taken into account.
Digital twins	Digital twins are digital equivalents of the real world for interaction, control, maintenance and management (e.g. for manufacturing, construction, city infrastructure and smart cities). In a 6G environment, digital twins will enable users to explore, monitor and interact with real-world systems in a virtual space, potentially in real time and without temporal or spatial constraints, relying on high-capacity, low-latency network connections.
Network-assisted Mobility	Network-assisted mobility involves sensing and positioning being used together with communication and network intelligence to enable services such as physical scene analysis, tracking, context awareness, trajectory prediction, navigational support and collision avoidance (e.g. for cars, automated guided vehicles and drones). Connected cars could be a key 6G use case, particularly for the transfer of sensor data, processed telemetry, feature information, images and coordination messages that require real-time communication with the network or other vehicles. Data that is processed entirely in the vehicle or over fixed networks at home does not contribute to mobile network traffic, so only network-dependent exchanges impact the radio access network (RAN).
Collaborative robots	Collaborative robots include intelligent, collaborative and mobile robots with the ability to move, to sense their environment and perform a productive task. Application domains include home robots, robots for facility management and robots in daycares or hospitals. In the context of 6G, these robots may leverage network-assisted coordination, edge processing and real-time data exchange to enhance performance and safety.
Holographic communication[5]	Holographic communication involves real-time or non-real-time gestures and facial expressions presented by means of a holographic display and content obtained by means of capture, transmission and 3D-rendering techniques.

Source: GSMA Intelligence[6]

4 For mobile demand forecasts, we focus on smart glasses (e.g. Ray Ban Meta and Virture Luma) as they represent the most realistic mobile use case. This can be modelled based on requirements being bursty (short high-data interactions) or recurrent (regular streams), reflecting variability in network load.

5 For holographic communication, we assume non-real-time is the most likely mobile use case. This can be modelled in a similar manner to messaging, but with a much higher downlink and uplink requirement.

6 For further details on new 6G use cases, including potential performance requirements, see for example IMT-2030 (6G) Spectrum Needs Analysis, GSA, 2023; IMT-2030 (6G) use cases, GSA, 2022; 6G spectrum – enabling the future mobile life beyond 2030, Ericsson, 2024; Integrated Sensing and Communications, 5G Americas, 2025; Deliverable D1.2: 6G Use Cases and Requirements, Hexa-X-II, 2023; Deliverable D1.2: Expanded 6G vision, use cases and societal values, Hexa-X-II, 2021; and Deliverable D1.3: Targets and requirements for 6G – initial E2E architecture, Hexa-X-II, 2022.

HOW WILL AI IMPACT MOBILE TRAFFIC GROWTH?

The impact of AI on mobile traffic growth is the subject of ongoing debate. For the purposes of this study, the key question is how AI will impact traffic on the RAN.[7] We have identified four main impact channels, summarised in Figure 2.

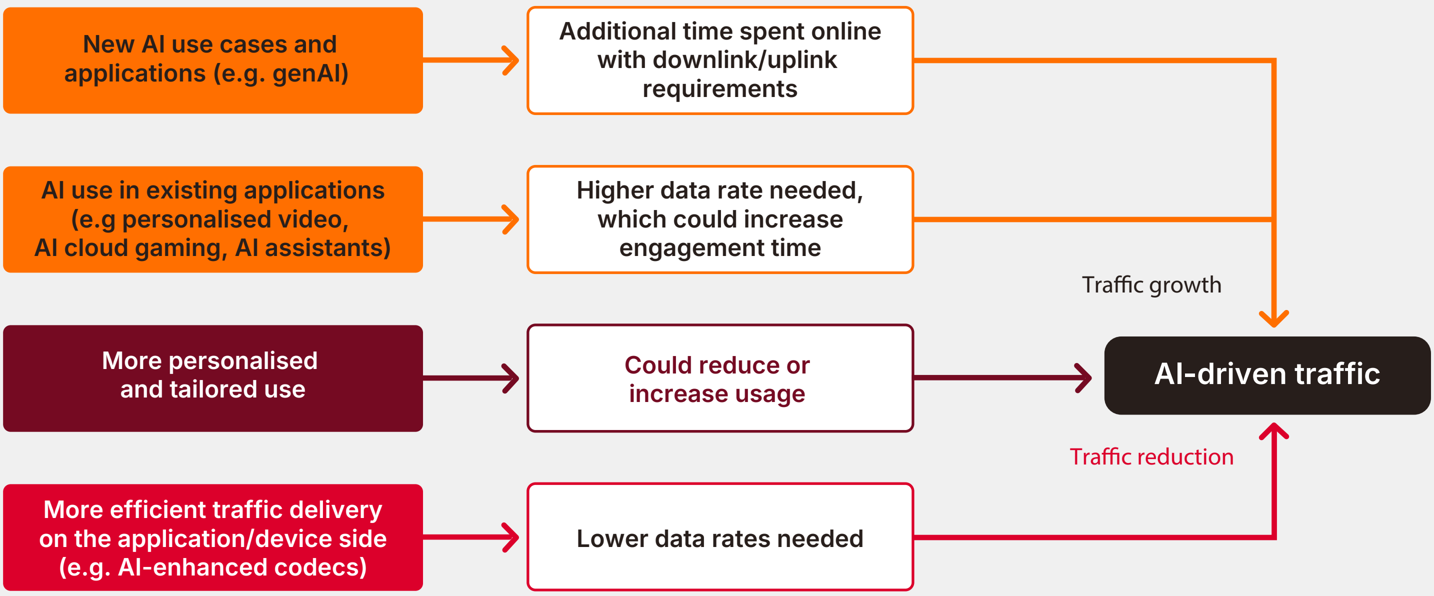
AI could increase traffic by enabling new use cases. For example, generative AI (genAI) enables at-scale, hyper-personalised content creation and processing. While most genAI application usage is currently text-based, and so drives minimal increases in traffic, the increased use of genAI-driven video assistants and immersive interactions may increase downlink and especially uplink traffic.

AI could also increase traffic by increasing the performance requirements of existing and emerging use cases, such as personalised video, running multi-modal queries and sensors to generate data for AI models. This has important implications because AI-driven traffic can be bursty and unpredictable, making it essential for networks to allocate resources efficiently.

AI could impact the amount of time that people spend on their connected devices – either increasing it by offering more personalised, useful and engaging content or by reducing the amount of time that users need to spend online.

On the other side, AI could reduce traffic by enabling more efficient traffic delivery, such as through content optimisation and video compression. We model the impact of these by considering the adoption of each use case that could be impacted by AI, the average time spent by users and the relevant performance requirements in terms of downlink, uplink and latencies. Further details are provided in Appendix 1.

Figure 2:
Impact of AI on mobile network traffic[8]



Source: GSMA Intelligence

7 AI will also significantly impact traffic on inter- or intra-data centre links and data processing within mobile devices, but this is not considered in the study, given that the focus is on spectrum needs for the radio network.
8 For more information on the potential impact of AI on mobile network traffic, see for example Impact of GenAI on mobile network traffic, Ericsson, 2025; Global network traffic report, Nokia Bell Labs, 2024; The AI revolution: Preparing for a surge in 5G uplink traffic, Nokia, 2024; AI Network Traffic Report Update for Europe: Projected Cellular Growth will Stress Access Infrastructure, Omdia, 2025

6G WILL BECOME THE PREDOMINANT GLOBAL MOBILE TECHNOLOGY BY 2040

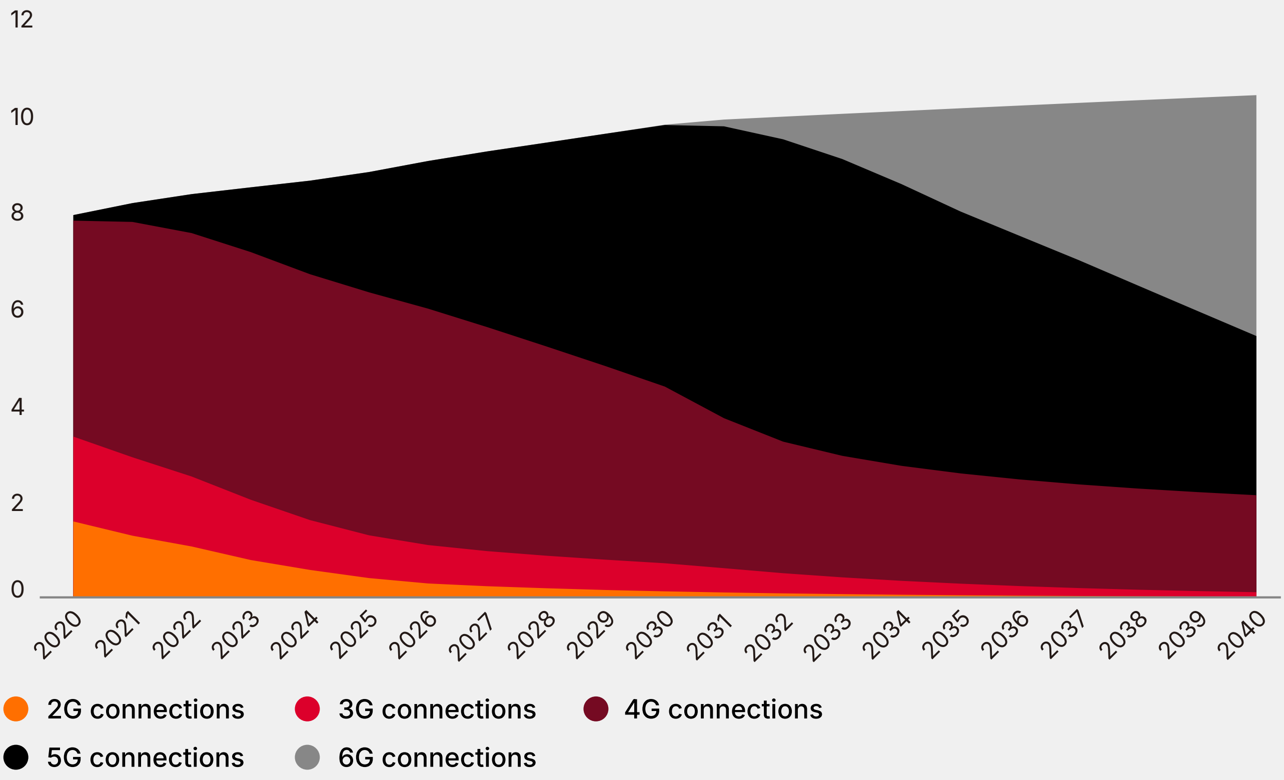
6G networks are expected to be deployed from 2030, with large initial rollouts like to occur in countries/regions such as China, Japan, South Korea, the US, the GCC states, Europe, Vietnam and India. Based on historical technology adoption patterns, particularly the 5G experience, 6G connections could reach more than 5 billion by 2040, representing approximately half of all mobile connections globally (see Figures 3a and 3b). This is a potentially conservative assumption given that adoption has accelerated with each technology (i.e. 5G has been adopted more quickly than 4G, which was adopted more quickly than 3G).[9]

However, similar to previous technologies, 6G adoption is likely to lag behind in many low- and middle-income regions. For example, by 2040 we expect 6G market penetration, based on number of connections,[10] to reach or exceed 100% in China, developed Asia Pacific, the GCC states, North America and Europe; however, we do not expect this in the rest of Asia Pacific, the Middle East, Sub-Saharan Africa or Latin America and the Caribbean. This means that 4G and especially 5G will remain important in the next decade too, respectively accounting for around 2 billion and 3 billion connections globally by 2040. This has important implications for spectrum planning, as it means not all existing bands can be entirely reused for 6G.

9 The State of 5G in 2024, GSMA Intelligence, 2024

10 Market penetration is calculated by dividing number of connections by total population. A connection is a unique SIM card that has been registered on a mobile network. Connections differ from subscribers in that a unique subscriber can have multiple connections.

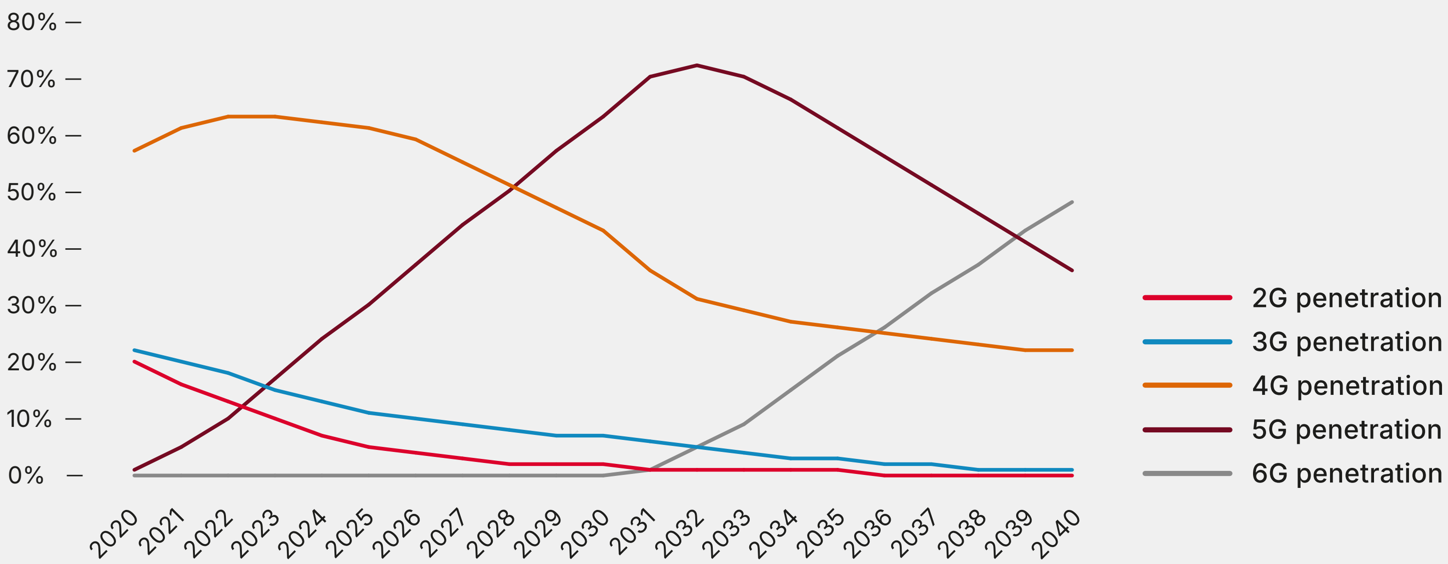
Figure 3a:
Mobile connections by technology, 2020–2040 (Billion)



Source: GSMA Intelligence

Note: A connection is a unique SIM card that has been registered on a mobile network. Connections differ from subscribers in that a unique subscriber can have multiple connections.

Figure 3b:
Market penetration by technology, 2020–2040



Source: GSMA Intelligence

Note: Market penetration is calculated by dividing number connections by total population.

3. DEMAND GROWTH

DEMAND WILL CONTINUE TO GROW – BUT BY HOW MUCH?

Growth in mobile traffic is expected to be driven by existing use cases as well as emerging and new use cases that will be enhanced by 6G. Existing use cases include video streaming and communication (video currently accounts for the majority of mobile network traffic), gaming, social media and web browsing. New and emerging use cases include XR, autonomous vehicles and network sensing. Based on the potential adoption and evolution of these, we have developed a range of traffic growth scenarios, summarised in Figure 4.

When calculating our forecasts, we estimate the demand for each use case based on the following:

1. The number of mobile users in a given country.
2. Adoption of each use case (e.g. the number of mobile users that stream video).
3. The performance requirement (e.g. the download or upload speed needed for the use case).
4. Time spent per use case per day on mobile. This parameter allows us to adjust for how much time users engage in each use case on fixed networks versus mobile. For example, in markets with high fixed broadband adoption, the majority of time spent will be fixed (meaning we will assume less time on mobile) whereas if fixed adoption is limited, we assume more time is spent on mobile.

Figure 4:
Traffic calculation method and traffic growth scenarios

Calculation

Number of mobile users × **Use case adoption** × **Performance requirement** × **Time spent per user per day** = **Traffic demand**

Low-growth scenario

- Continued growth of existing use cases (eMBB, FWA, enterprises)
- Growth is mostly driven by more use of video streaming and communication
- Limited uptake of 6G-era use cases (e.g. XR)

Medium-growth scenario

- Continued growth of existing use cases (eMBB, FWA, enterprises)
- More growth driven by 6G era use cases (XR, autonomous vehicles, sensing)

High-growth scenario

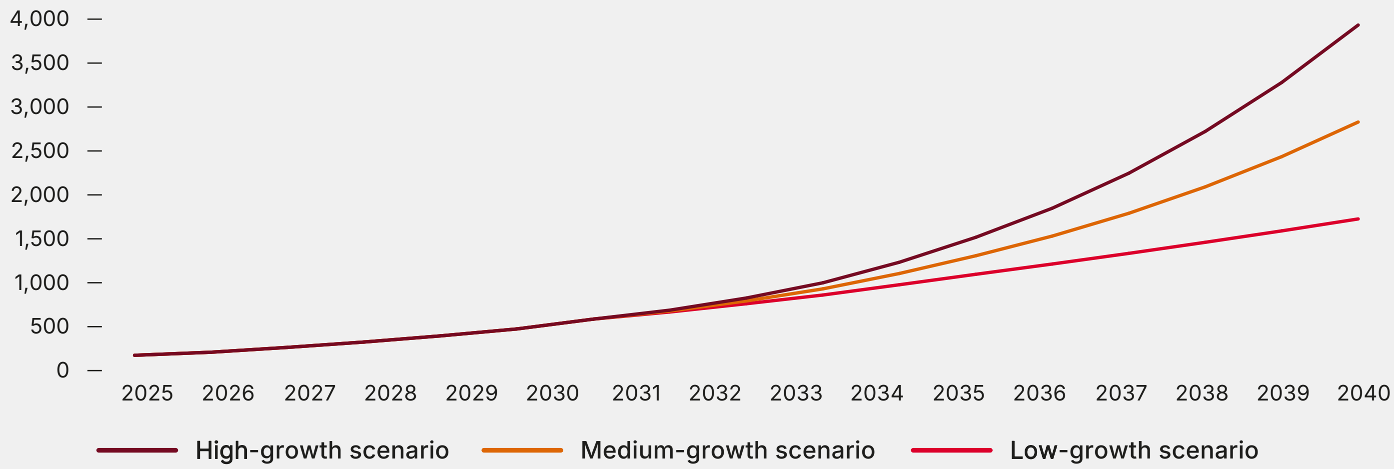
- Continued growth of existing use cases (eMBB, FWA, enterprises)
- Widespread take-up of new use cases linked to 6G (e.g. XR, autonomous vehicles, sensing)
- Adoption of more futuristic use cases (e.g. holograms)

Source: GSMA Intelligence

Demand forecasts at a global level are presented in Figures 5a and 5b. Regional traffic forecasts are presented in Appendix 1, along with comparisons to other third-party forecasts.

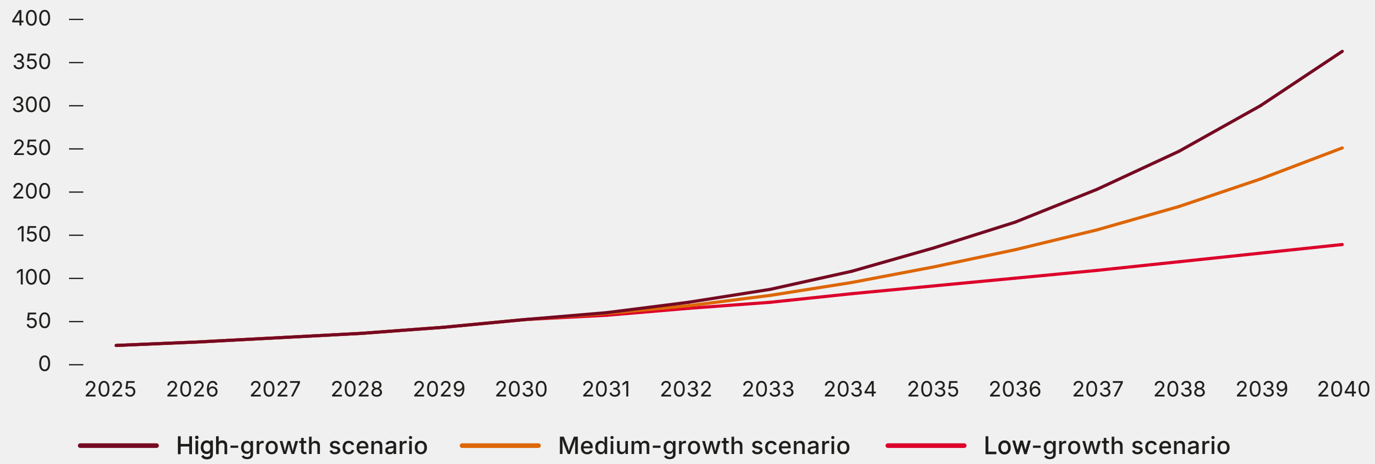
While the three scenarios diverge in 2030 – the expected launch date for 6G technologies – we have also developed scenarios where the three trajectories take both a longer and shorter timeframe, effectively 'slowing down' and 'accelerating' each scenario by up to three years. This results in slower and faster growth respectively, meaning in the 2025–2040 period, we consider growth rates that range between 10% and 25% on an annual basis. The total traffic estimates in Figure 5a include mobile, fixed wireless access (FWA) and IoT, while Figure 5b only includes mobile. In our scenarios, the amount of total traffic accounted for by IoT is small (less than 1–2% depending on the scenario), while FWA ranges from 10% to 50% depending on the region. We expect there will ultimately be a ceiling to FWA adoption given the addressable market, as it is unlikely to displace fibre and cable broadband (further details on our FWA and IoT forecast methodology is provided in Appendix 1).

Figure 5a:
Global traffic growth by scenario, 2025–2040 (EB/month)



Source: GSMA Intelligence
Note: Includes mobile, FWA and IoT traffic.

Figure 5b:
Global traffic growth by scenario, 2025–2040 (GB/connection/month)



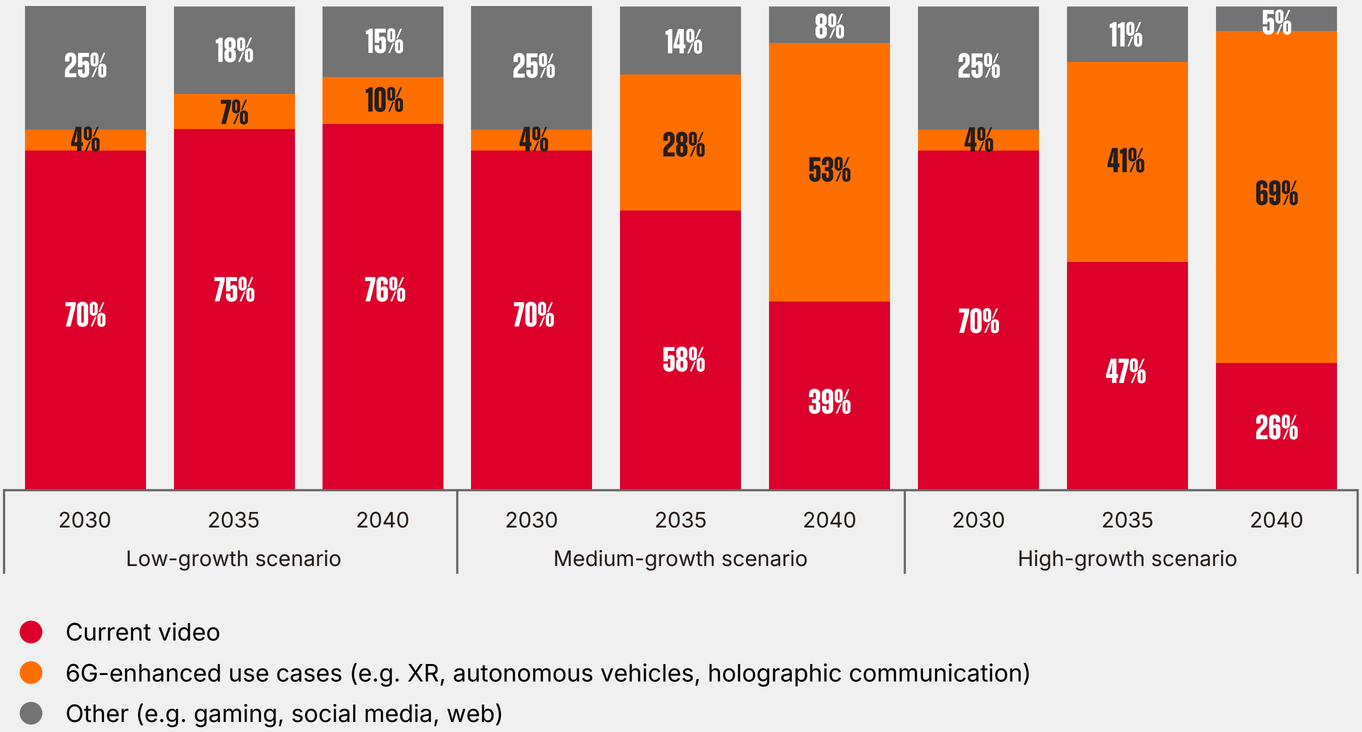
Source: GSMA Intelligence
Note: Only includes mobile traffic (excludes FWA and IoT). Shows traffic per connection rather than by device. It is therefore closer to the data usage expected by a mobile user across all their devices (e.g. a smartphone, wearables, smart glasses).

The scenarios we have developed reflect different usage patterns by consumers and enterprises. Figure 6a shows the adoption of applications across low-growth, medium-growth and high-growth scenarios. In the low-growth scenario, current video remains the predominant driver of traffic due to the limited adoption of new use cases. Growth in video is driven by a greater number of mobile consumers using video along with higher resolutions and potentially immersive formats and interactive features. In the medium-growth scenario, 6G-era use cases are forecast to drive around half of mobile traffic by 2040, while in the high-growth scenario they will drive almost 70% of mobile traffic by 2040.[11]

Figure 6b shows the evolution of traffic by downlink (data flowing to user devices) and uplink (data flowing from user devices). In the low-growth scenario, the downlink remains predominant at around 85% of total traffic, with uplink at 15%. However, in the medium- and high-growth scenarios, the share of uplink increases to around 25% and 35%, respectively, by 2040. This is driven by AI-enabled use cases that require more uplink, such as real-time image processing, video upload and content creation. Such a shift would have important implications for spectrum planning, as uplink and downlink capacity requirements must be balanced through appropriate frequency allocations and network design.

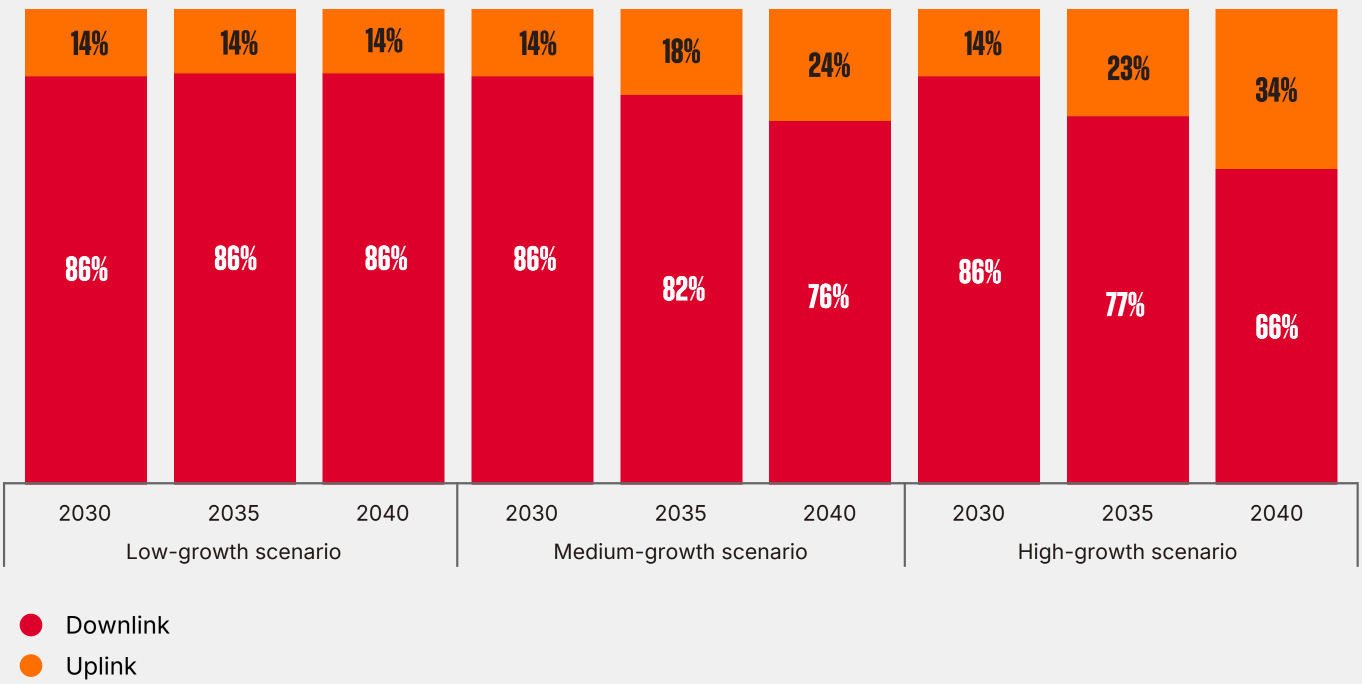
11 Note that video will also be behind a lot of new use cases (both for downlink and uplink), so the distinction between these categories is not clear cut. For the analysis, 'current video' refers to video that drives the majority of traffic today (streaming, calls and conferencing). Similarly, a lot of potentially new sophisticated multimedia content, including 3D and immersive formats, could be on social media platforms.

Figure 6a:
Traffic distribution by use case



Source: GSMA Intelligence

Figure 6b:
Traffic distribution by downlink and uplink



Source: GSMA Intelligence

MIGRATION TO 5G AND A POWER-USER BOOM WILL DRIVE MORE DEMAND

Given the strong growth in mobile data traffic in the past five years, one might expect the percentage growth in traffic to decline over time (although the absolute growth would remain significant). Globally, mobile traffic growth was almost 40% in 2019 and 2020, but it stood at just over 20% in 2024. Nevertheless, we expect annual growth to remain at 15–20% in the period up to 2030 and at least 10% in the 2030–2040 period, even in our low-growth scenario. We outline the reasons for this below.

First, most countries have yet to launch 5G or achieve 5G adoption at large scale (see Figure 7a). As operators and consumers migrate to 5G and higher-speed networks, this is expected to drive greater traffic growth. Figure 7b shows that countries with higher 5G adoption have higher data consumption. For example, in markets where 5G connections accounted for at least 30% of mobile broadband connections in 2024, data usage was 2.5× greater than in markets where 5G accounted for less than 10% of mobile broadband connections. Figure 7c shows that countries with higher-speed and better-quality networks also have higher data consumption. For example, in markets where average download speeds in 2024 were above 250 Mbps, data usage was almost 4× greater than in markets with average speeds of less than 50 Mbps in 2024.

Second, in many countries demand can be 'constrained' and the reported traffic data does not reflect the level of usage consumers would actually like to have. This could be for three reasons:

1. Consumers do not yet have the devices that allow them to use mobile as much as they would like. For example, at the end of 2024, one in six mobile internet users globally were using feature phones or 3G smartphones.[12]

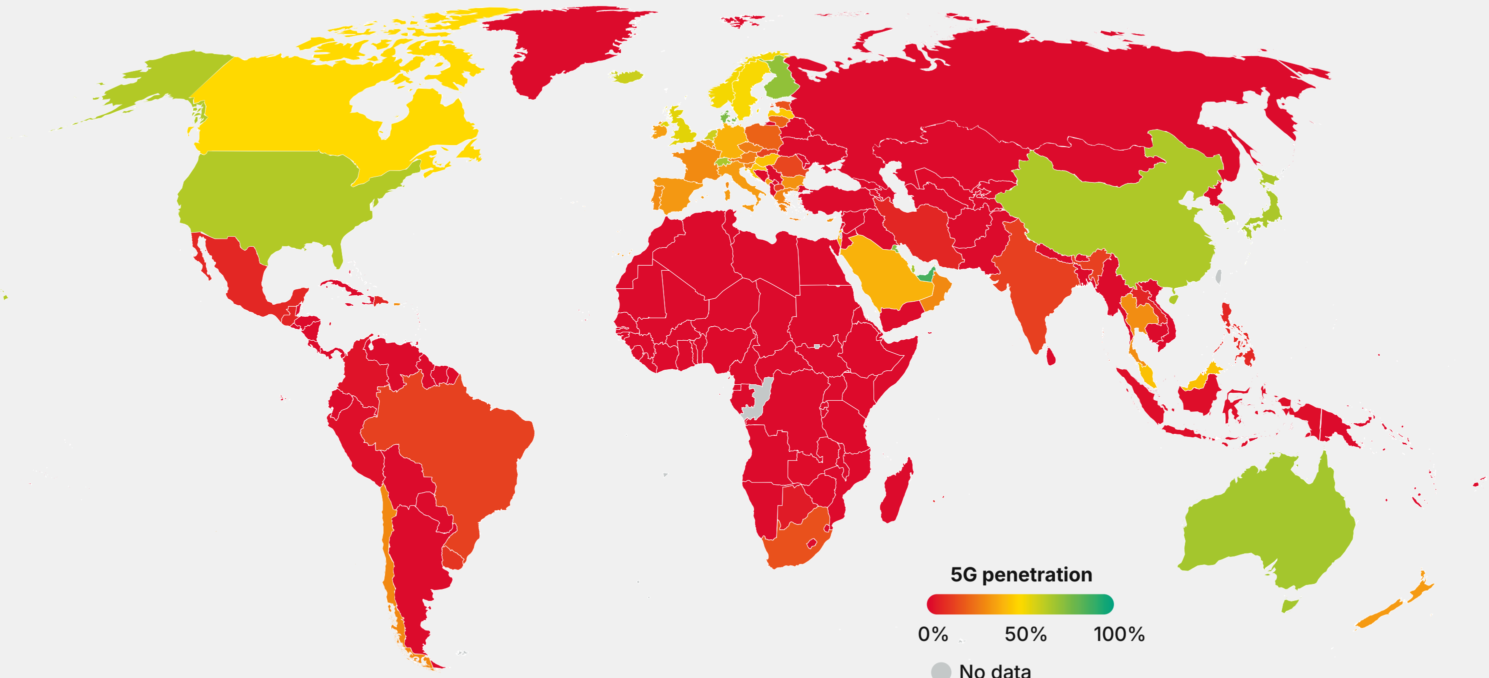
2. Within countries, there are coverage 'white-spots', where consumers may want to use high-speed mobile but are unable to. For example, analysis of Ookla data shows that 4% of mobile users in 2024 did not have coverage for most of the time they were connected.

3. Some locations are already capacity constrained. For example, in the UK in 2024, 78% of traffic was still on 4G networks[13] and analysis of Ookla data shows that peak-hour 4G speeds in dense urban areas in the UK (with a population density greater than 5,000 people per square kilometre) was 2 Mbps for the bottom 10% of users (i.e. one in 10 mobile users had speeds of 2 Mbps or lower during peak hours).[14] This means many users may not be able to engage in the use cases they would like during peak hours and would consume more data if there was more capacity.[15]

While it is important to address these challenges, for the purpose of estimating spectrum needs for a new mobile technology, it is appropriate to consider an 'unconstrained' demand scenario, especially as most governments have established targets to achieve widespread high-speed mobile connectivity.

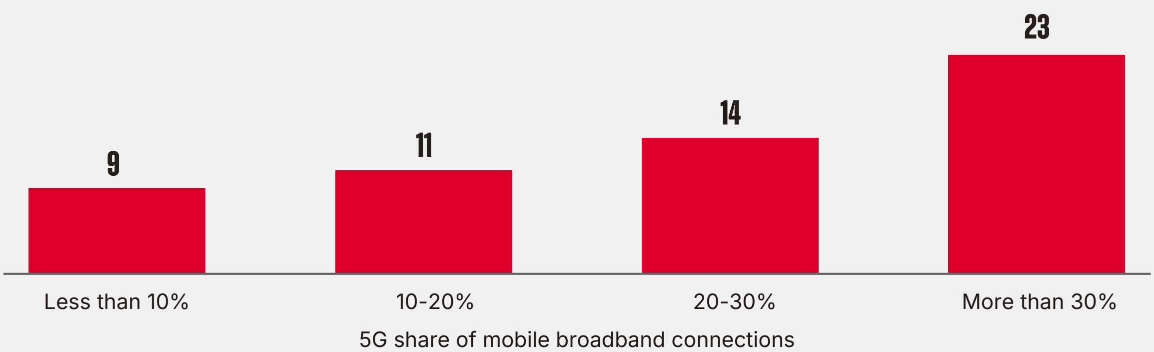
12 State of Mobile Internet Connectivity Report: Trends in Mobile Internet Connectivity, GSMA, 2025
13 Connected Nations: UK Report 2024, Ofcom, 2024
14 Results based on GSMA Intelligence analysis of Ookla® Speedtest Intelligence® network performance data for the UK in April 2025.
15 These capacity constraints are not necessarily driven by a spectrum shortage right now. For example, in the UK there remains scope for many users to migrate to 5G.

Figure 7a:
5G market penetration, 2024 (Percentage of population)



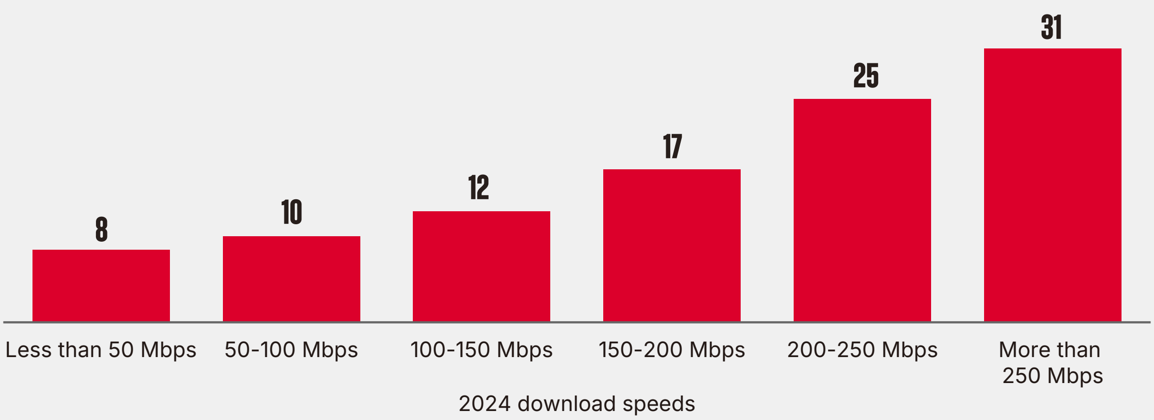
Source: GSMA Intelligence

Figure 7b:
Data traffic per connection per month by 5G connections share (Data traffic per month (GB))



Source: GSMA Intelligence, based on all countries

Figure 7c:
Data traffic per connection per month by download speed (Traffic per connection (GB/month))

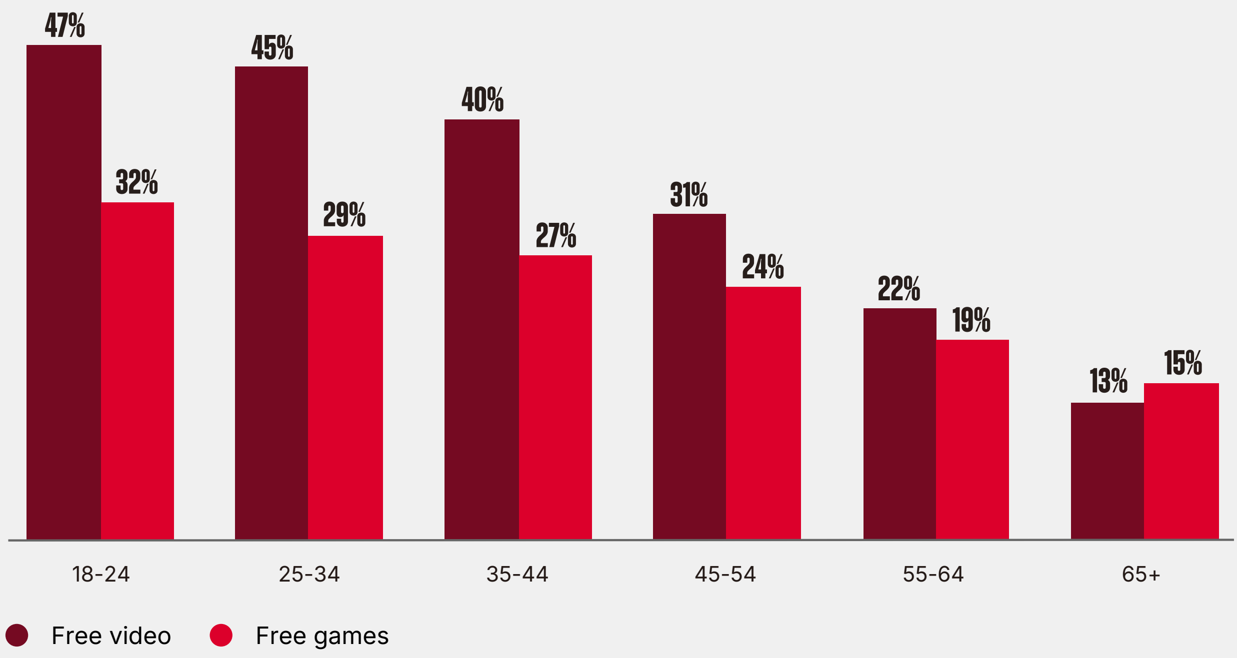


Source: GSMA Intelligence analysis across all countries, based on Speedtest Intelligence® data provided by Ookla®

Lastly, traffic is expected to grow due to an increase in the number of power or 'heavy' mobile users. To date, the vast majority of network traffic is driven by a minority of users. Reports by Ericsson show that in 2024, around 10% of subscribers generated around 65% of total traffic, while another 73% ('light' users) only generated 10% of total traffic.[16] If this distribution of traffic applied to a network that had an average monthly consumer data usage of 10 GB, it would mean the majority of 'light' users would consume around 1.5 GB per month, while the most extreme 'heavy' users would consume 120 GB per month. This skewness in data consumption is consistent with other data reported by mobile operators and regulators,[17] as well as by data from the GSMA Consumer Survey, which found that in the majority of markets surveyed in 2024,[18] less than one third of adult mobile users watched online video on a mobile device every day.

However, the number of power users has been increasing – for example, the proportion of users consuming more than 20 GB per month doubled between 2020 and 2024.[19] In the medium-to-long term, this shift will continue as younger generations that are more frequent and intense users of mobile (shown in Figure 8) get older and consume more data than today's older generation. Meanwhile the next 'young' generation will consume either the same or even more than those aged 18–24 today.

Figure 8:
Share of mobile users that watch free online video or play free games at least once a day by age group, 2024



Source: GSMA Intelligence

Note: Aggregate responses of the GSMA Consumer Survey in 12 markets (Australia, China, France, Germany, Italy, Japan, Poland, South Korea, Spain, the UAE, the UK and the US).

16 Ericsson Mobility Report June 2025
17 For further examples, see the 2022, 2023 and 2024 editions of the State of Mobile Internet Connectivity Reports, GSMA
18 Including the US, Spain, Japan, Italy, Egypt, Australia, Poland, the UK, France, Germany, Nigeria and Kenya. Further details on the GSMA Consumer Survey can be found in State of Mobile Internet Connectivity Report, GSMA, 2025 and Consumers in Focus: Device User Behaviour Survey Dashboard 2025, GSMA Intelligence, 2024
19 Ericsson Mobility Report June 2025

SPECTRUM NEEDS NOT JUST DRIVEN BY DOWNLOAD AND UPLOAD REQUIREMENTS

While downlink and uplink demand are the primary drivers of network capacity, and therefore spectrum requirements, they will not be the only factors in the 6G era. Specifically, latency, reliability and sensing will also be important. Many use cases for 6G, such as network-assisted mobility, digital twins and immersive communication, will require latencies of 10 ms or below, and achieving this requires wider channels to reduce transmission delay and avoid congestion. Appendix 1 provides further details on how we incorporate latency requirements in our demand scenarios.

Furthermore, when it comes to network sensing, high-resolution sensing requires wide bandwidth to achieve fine-grained spatial and temporary accuracy. For example, a requirement for sensing resolution of 20 cm would require 750 MHz of bandwidth, 10 cm would require 1.5 GHz of bandwidth and 5 cm would require 3 GHz of bandwidth.[20] While very-high-resolution sensing use cases would need to rely on high mmWave bands (e.g. local-area and indoor industrial use cases), certain outdoor use cases, such as traffic management and environmental monitoring, are more likely to be reliant on mid-bands.

20 Bandwidth calculations are based on the calculation $B = c/2\Delta r$ *where B = required bandwidth, c = speed of light and* Δr *= the range resolution*

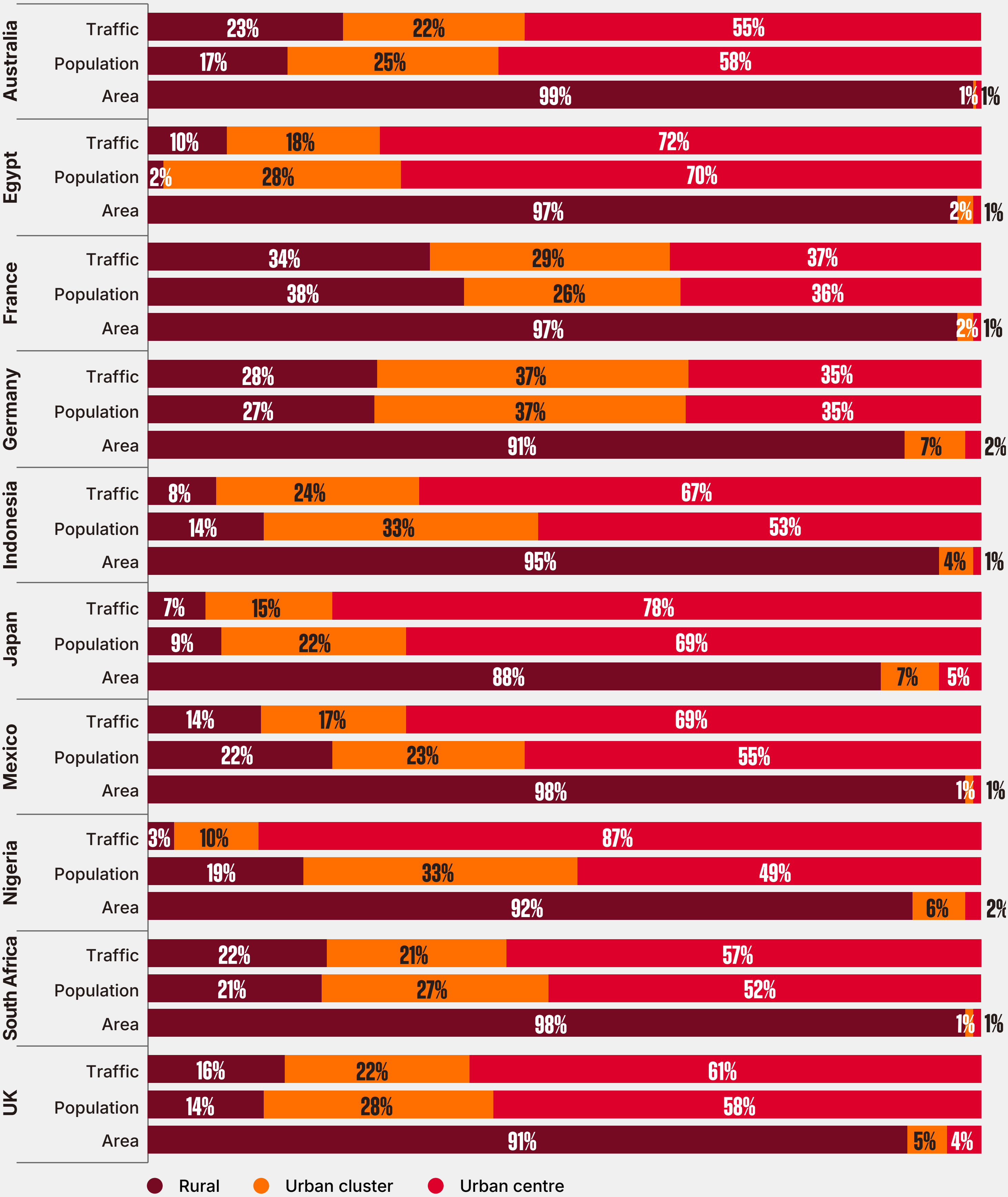
SPECTRUM NEEDS MUST ACCOUNT FOR HIGH-DEMAND AREAS

While overall traffic demand is forecast at an aggregate level by country or region, it is not evenly distributed across countries. Understanding how mobile traffic is distributed geographically is fundamental to a spectrum-needs assessment because while national traffic averages provide the broader context, spectrum requirements are ultimately determined by demand in the most congested locations during peak-usage periods. Operators must provision networks to handle capacity requirements in high-demand areas, making localised analysis essential for accurate spectrum planning.

Figure 9 shows the distribution of mobile traffic, population and geographic area in 10 countries. On average, 83% of mobile traffic is in urban areas that only account for around 5% of geographic area. It is notable that in mature mobile markets with high mobile broadband adoption, traffic distribution closely follows population distribution. However, in emerging markets (e.g. Nigeria), traffic is disproportionately higher in urban areas, due to the urban–rural digital divide.

Applying these results to other countries shows that traffic per square kilometre in very dense urban areas (with population densities above 5,000 people per square kilometre) is 9× greater than in other urban clusters and almost 700× greater than in rural areas (in some countries, it is more than 1,000× greater than in rural areas). Even modest traffic growth in dense urban locations can therefore quickly exceed available network capacity, necessitating additional spectrum resources. As such, these are the areas in which capacity is most needed and where our spectrum-needs assessment is determined. Further details on the dense urban definitions we use are provided in Appendix 1.

Figure 9:
Distribution of traffic, population and area by geography, Q2 2025



Source: GSMA Intelligence analysis, based on Cell Analytics™ data provided by Ookla

Note: Rural, urban clusters and urban centres are defined based on Global Human Settlement Layer (GHSL) classifications.[21]
Due to rounding, percentages may not sum to 100%.

21 See Global Human Settlement Layer

It is important to note that while cellular traffic closely follows population distributions, this may not be the case for FWA. While the majority of dense urban areas have widespread fibre or cable rollout, FWA provides a competitive solution in peri-urban and rural areas where high-speed fixed broadband is underserved.[22]

However, it is a fact that many countries have significant FWA adoption in urban areas.[23] We therefore include some FWA traffic in dense urban areas, but we distribute a lower share of total FWA traffic to dense urban areas than we do for mobile. The geographic distribution of FWA demand will influence spectrum planning, as operators must provision networks to handle both mobile and FWA traffic in their coverage areas.

22 See The 5G FWA opportunity: Disrupting the broadband market, GSMA Intelligence, 2021 and The rise of 5G FWA globally: customer adoption forecast to 2030, GSMA Intelligence, 2025
23 For example, see 5G Fixed Wireless Access (FWA) Success in the US: A Roadmap for Broadband Success Elsewhere?

4. NETWORK CAPACITY EVOLUTION

The amount of network capacity in a given area is primarily a function of the amount of spectrum available, spectral efficiencies and the number of sites (or site densification).

Figure 10:
Network capacity methodology

Spectrum assigned × **Spectral efficiencies** × **Number of sites** = **Capacity supply**

Source: GSMA Intelligence

OPERATORS WILL DEPLOY 6G IN BOTH NEW AND EXISTING BANDS

In terms of spectrum assigned, we assume that in the long term all countries will assign the bands identified for IMT in their region. These are summarised in Appendix 1. While some countries have not yet assigned all IMT bands – for example, because they are yet to be cleared or due to high spectrum prices – we would expect all IMT spectrum to be assigned by the time countries start deploying 6G networks.

An important assumption related to this is what spectrum will be used for 6G and older technologies. In the long term (by 2040), we assume all existing IMT bands can and will be reused for 6G[24] to enable an efficient use of spectrum. However, the full amount of spectrum resources cannot be dedicated to 6G given that 4G and especially 5G will remain in use by the end of the next decade. In existing bands, we therefore assume that multi-RAT spectrum sharing (MRSS) will be enabled, meaning operators can deploy 6G in existing IMT bands but keeping some of the capacity for 4G and 5G.[25]

24 Though deploying 6G in all bands is unlikely to be possible in the initial years, at which point it is more likely that one or two existing bands would be used. This is similar to when operators deployed 5G using dynamic spectrum sharing (DSS) in bands such as 2.1 and 2.6 GHz when they launched 5G before having access to 3.5 GHz spectrum.
25 Appendix 1 provides details on how we allocate existing spectrum to 4G, 5G and 6G as well as the overhead assumptions for MRSS.

SPECTRAL EFFICIENCIES

Almost all governments and policymakers aim to ensure spectrum is used efficiently. With each technology cycle, mobile operators have made more efficient use of spectrum.

Table 3 sets out the spectral efficiency ranges that we assume for mid-bands for cellular services (we assume higher spectral efficiencies for FWA, as explained below).[26] Our starting point is based on the real-world performance of current networks, with a focus on average spectral efficiency rather than theoretical peak efficiencies. We then assume this will increase over time due to:

1. integration of AI into RANs, which even without 6G could increase spectral efficiencies by 10–20%[27]
2. 6G technologies driving improved spectral efficiencies compared to 5G.

Bands in the upper 6 GHz and 7–8 GHz range could enable greater spectral efficiencies than 3.5 GHz due to the use of larger channels, enhanced MIMO and higher modulation, as well as better beamforming utilisation. However, as they are higher frequencies, they will also suffer from propagation losses, which would impact average spectral efficiency in a given cell area.[28] We therefore assume they could offer a 0–25% improvement on spectral efficiencies compared to 3.5 GHz.

Lastly, when estimating capacity for FWA, we assume spectral efficiencies are 50% higher than those of mobile/cellular. This reflects the different nature of FWA, which has predictable links, stable channels and directional antennas and avoids mobility, interference and handover overheads that impact cellular systems.

Table 3:
Spectral efficiency assumption range (bps/Hz)

Spectrum band	Downlink	Uplink
1–3 GHz	2–3	1–2
3.5 GHz	4–6.5	2–3
Upper 6 GHz	4.5–7	2–3.5
7–8 GHz	5–7	2–3.5

Source: GSMA Intelligence

Note: These represent spectral efficiency ranges for mobile. For FWA, we assume efficiencies that are 50% higher.

26 In practice, spectral efficiencies are influenced by many factors, including network grid density technology upgrades, distribution of the users in the cell and devices penetration. Each cell will have a different spectral efficiency due to all these factors.

27 For example, see AI in the Mobile RAN, AvidThink, 2025 and "Ericsson and Bell Canada successfully test AI-native link adaptation to boost network speed and efficiency", Ericsson, April 2025

28 Despite the fact that the 6–8 GHz bands have greater propagation losses, they remain well suited to providing urban demand both indoor and outdoor, as higher MIMO orders can be used to compensate for coverage losses. See Mobile Evolution in 6 GHz, GSMA, 2024 for examples of trials that have shown 6 GHz can deliver comparable indoor coverage to the 3.5 GHz range, as well as, Exploring Upper-6GHz and mmWave in Urban 5G Networks: A Direct on-Field Comparison, Morini et al, 2025

NETWORK DENSIFICATION

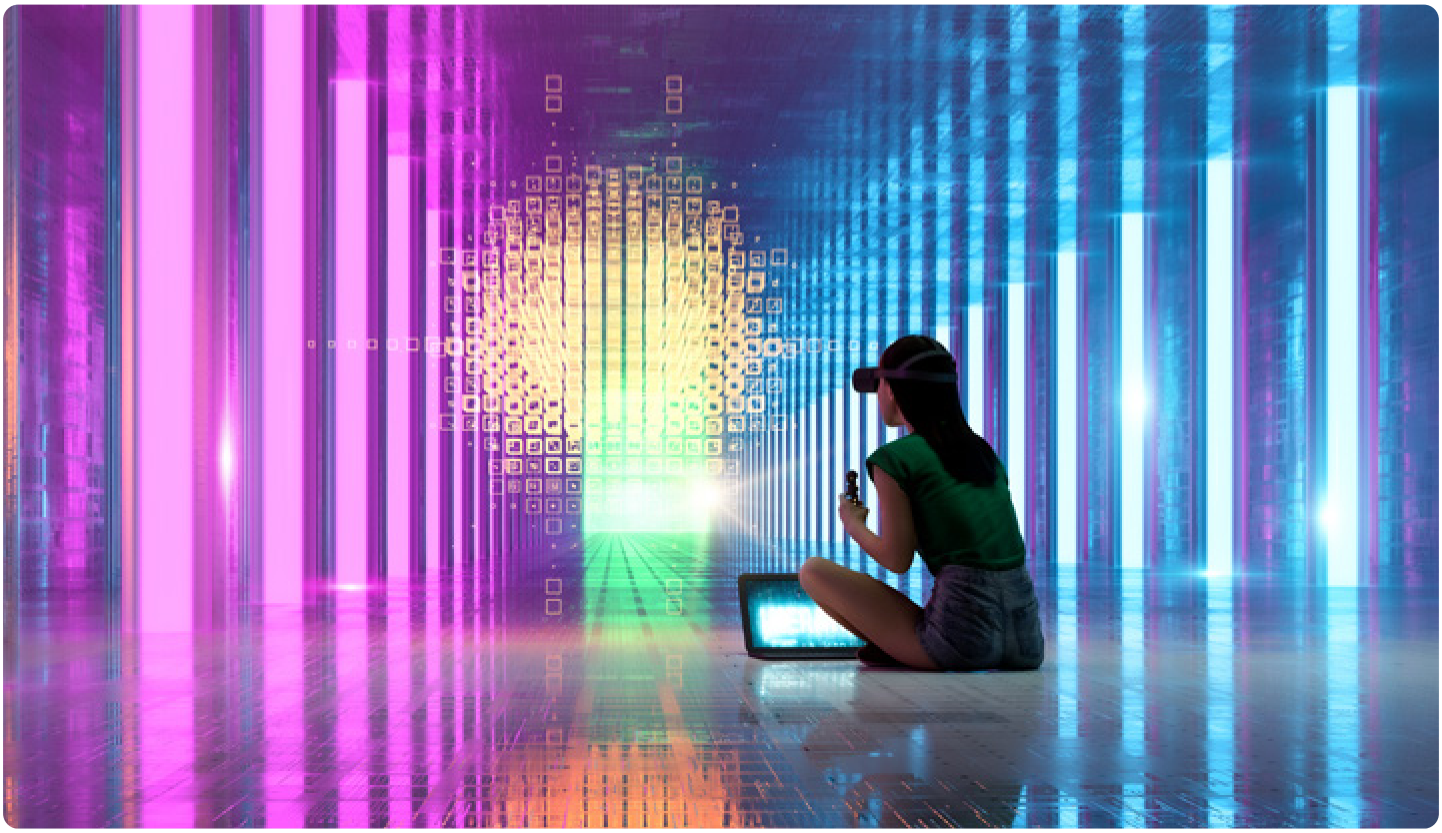
The level of network densification in dense urban areas varies significantly based on the country and area in question. We therefore apply country-specific assumptions, based on reported site data and crowd-sourced data from OpenCellID. For the purposes of the model, the majority of countries' dense urban areas are assumed to have a site density of 1,000–3,000 people per site, which generally implies an inter-site distance within the range of 200 m to 800 m. More densification is expected in high-use markets (e.g. in East Asia and the GCC states) and less densification is expected in lower-use and low-income markets, where it is more costly to deploy new infrastructure (e.g. in Sub-Saharan Africa).

TRAFFIC DISTRIBUTION BY BAND

Previous GSMA studies have shown that 80–90% of urban traffic (including indoor usage) is provided by mid-bands.[29] We therefore assume that low bands will address 10–20% of dense urban traffic, which will capture deep-indoor use.

mmWave bands are currently not widely assigned or deployed in most countries. But going forward, these high bands are well placed to support extreme capacity in very localised deployments, either in ultra-high-density environments, certain local enterprise networks (e.g. smart factories) or specific events that drive high mobile usage (e.g. concerts and sporting events).[30] We therefore assume that such bands will address 5–10% of dense urban traffic in the long term. We do not consider it realistic for mmWave bands to address significantly more traffic demand, due to the higher path loss and lower propagation (especially indoors). To meet increased demand using only mmWave bands would require operators to densify networks to a degree that would be both technically and economically unsustainable.[31]

29 See Mobile Evolution in 6 GHz, GSMA, 2024; 6 GHz in LATAM, GSMA, 2025; and Response to the RSPG Consultation on the Draft RSPG Opinion on 6 GHz
30 For example, see "Verizon customers used 52.34 TB of data in and around Allegiant Stadium for Super Bowl LVIII", Verizon, December 2024
31 For further information on mmWave deployment, see 5G mmWave Deployment Best Practices Whitepaper, GSMA, 2022 and 5G mmWave Coverage Extension Solutions Whitepaper, GSMA, 2022



FIXED NETWORK AND WI-FI OFFLOAD

Our spectrum-needs analysis is based on the amount of time users spend on mobile networks and so it reflects the fact that in many (though not all) regions, users already spend the majority of their time on fixed networks. Globally, fixed broadband accounts for around 80% of traffic, although mobile delivers more traffic than fixed in countries accounting for almost 40% of the global population (mostly in South Asia and Sub-Saharan Africa).[32]

However, fixed broadband and Wi-Fi are not always available or suitable, so consumers and enterprises should have the option to access the type of connectivity that best meets their needs at any given time. It has also been suggested that mobile operators could deploy or utilise their own Wi-Fi networks (along with other small cells) to increase network capacity at lower cost.

In practice, however, Wi-Fi does not provide a widespread capacity solution because the traffic is unmanaged and cannot be coordinated. When deploying 5G and eventually 6G, given the demanding performance requirements, operators will need to use licensed spectrum that they have complete control over.[33]

The remaining assumptions regarding network capacity, such as network loading factor, small cell deployment and peak hour traffic, are provided in Appendix 1.

32 See Mobile Evolution in 6 GHz, GSMA, 2024
33 For further details on this, see The socioeconomic benefits of the 6 GHz band: Considering licensed and unlicensed options, GSMA Intelligence, 2022

5. SPECTRUM NEEDS IN 2035–2040

Our long-term forecasts, which have a horizon of 10–15 years, require our analysis to consider multiple scenarios for both demand and supply factors. The previous chapters highlighted that for almost all our key inputs (traffic demand, spectral efficiencies, low-band and mmWave offload etc.), we consider a range of possible values. We do not consider it appropriate to take the most extreme cases (e.g. lowest possible demand with greatest possible capacity or greater possible demand with lowest possible capacity), as it will produce a spectrum-needs range that is not helpful for future planning. Instead, we have run multiple simulations based on different input assumptions to produce a lower- and upper-bound of spectrum needs in the 2035–2040 period, which acknowledges forecasting uncertainty.

GLOBAL

The range of simulated results is shown based on three approaches.

- **Global average** takes a simple country-level average of the lower and upper bound of spectrum needs. This shows that total mid-band requirements in 2035–2040 could range between 1.6 GHz and 2.3 GHz.
- **Global weighted average** takes a population-weighted average of spectrum needs (i.e. giving more weight to countries with larger dense urban populations). This shows that total mid-band requirements could range between 1.9 GHz and 2.9 GHz.
- **Global top half** takes an average of the countries with highest urban demand and spectrum needs.[34] This shows that these countries have total mid-band spectrum requirements between 2.5 GHz and 4 GHz.

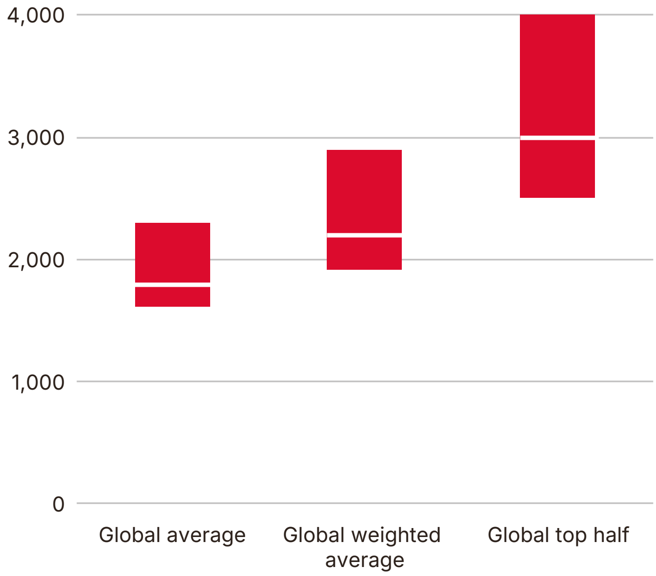
The same results are subsequently reported per region.

When considering existing IMT mid-band allocations, the majority of countries would expect to have (or assign) around 1 GHz of mid-band spectrum (with some variations by country, see Appendix 1). This can be used as a reference to estimate the additional mid-band spectrum needs in the rest of the chapter. For example, where the global weighted average spectrum requirement range is 2–3 GHz, we can say that the additional spectrum requirement range is 1–2 GHz.

We estimate spectrum needs over a period of years (2035–2040) because our forecasts are not fixed based on a specific trajectory. Instead, we reflect the demand scenarios following different paths This means the interpretation of the weighted average result is that 2–3 GHz will be needed during the 2035–2040 period. The practical implication of this is that at least 2 GHz of mid-band spectrum must be allocated, assigned and operational well in advance of 2035 to ensure networks can handle expected traffic.

Network congestion will start several years before this and regulators need to keep well ahead of spectrum needs to avoid congestion. Our analysis suggests that over 50% of dense urban populations globally will live in areas with network congestion in 2030 (when 6G is to be deployed) if no additional spectrum is made available on top of the currently allocated 1 GHz of mid-band spectrum for mobile use. Having 2 GHz of mid-band spectrum by 2030 is therefore critical.

Figure 11:
Total mid-band spectrum needs in 2035–2040, global (MHz)



Source: GSMA Intelligence

Note: The box represents the 25th percentile, median and 75th percentile of spectrum needs estimates based on our scenario analysis.

34 'Top half' means we rank countries by spectrum needs and we take an average of the top half of the global dense urban population.

DEVELOPED ASIA PACIFIC

The developed Asia Pacific region – encompassing Japan, South Korea, Australia, New Zealand, Singapore and Brunei – is among the leading 5G regions in terms of network deployment, adoption and data usage.[35] We expect this to continue going forward, and the majority of these markets are expected to be early adopters of 6G, reaching a 6G market penetration rate of around 60% by 2035. We therefore estimate a spectrum requirement of approximately 2.5–3.6 GHz in the first two results, while spectrum needs for the highest-demand populations will be between 2.7 GHz and 4 GHz.

2040 mobile traffic forecast:

85-200 EB/month

2040 traffic per connection:

235-620 GB/month

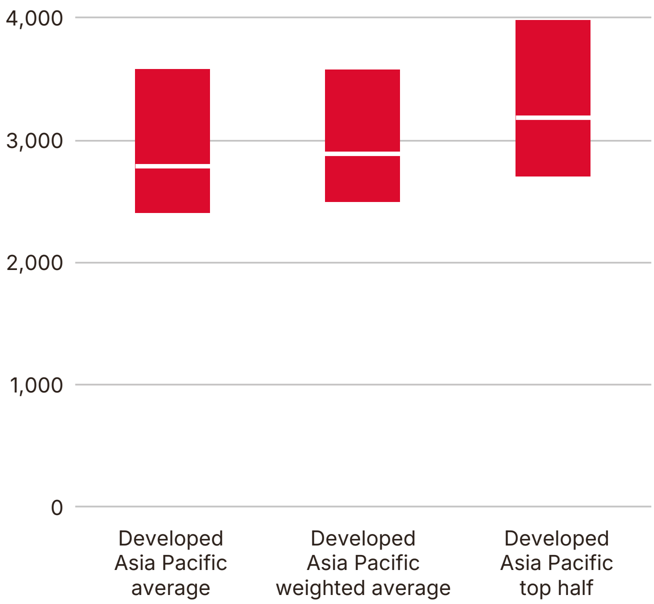
2040 6G connections:

250 MILLION (124% penetration)

2040 5G connections:

50 MILLION (23% penetration)

Figure 12:
Total mid-band spectrum needs in 2035–2040, developed Asia Pacific (MHz)



Source: GSMA Intelligence

Note: The box represents the 25th percentile, median and 75th percentile of spectrum-needs estimates based on our scenario analysis.

35 See the 5G Connectivity Index

SOUTHEAST ASIA

Southeast Asia includes Malaysia and Thailand, which have some of the highest data usage rates (per connection) globally. Both of these markets, along with Vietnam, are expected to lead the region in 6G deployment into the mid-2030s. While usage may not be as high in the two largest countries in the region – Indonesia and the Philippines – these markets have very high population densities in urban centres. For example, Manila is one of the most population-dense cities in the world. Most cities in the region do not have the same level of site densification as higher-income and more mature markets (e.g. North America, China and the GCC states) and are unlikely to reach such a level in the long term. This translates to high spectrum requirements in the region, with a weighted average between 1.9 GHz and 2.8 GHz, and spectrum needs for the highest-demand populations between 2.3 GHz and 3.8 GHz.

2040 mobile traffic forecast:

110-270 EB/month

2040 traffic per connection:

95-255 GB/month

2040 6G connections:

340 MILLION (45% penetration)

6G

2040 5G connections:

530 MILLION (70% penetration)

5G

Figure 13:
Total mid-band spectrum needs in 2035–2040, Southeast Asia (MHz)

Source: GSMA Intelligence

Note: The box represents the 25th percentile, median and 75th percentile of spectrum-needs estimates based on our scenario analysis.

SOUTH ASIA

South Asia's spectrum requirements are primarily driven by India, where the recent growth of 5G has been particularly noteworthy: within two years of launch, the number of 5G connections reached more than 250 million and 5G accounted for 35% of mobile data traffic in the country.[36] The country ranks in the top 25 markets globally in terms of data traffic per connection, with a greater share of broadband traffic delivered over mobile networks than fixed networks. Combined with extremely high population densities in urban areas, along with the fact that India is expected to be one of the early adopters of 6G (outlined in its Bharat 6G Vision), it means spectrum requirements will range between 2.1 GHz and 3.2 GHz for South Asia and between 2.4 GHz and 3.7 GHz for the highest-demand populations. When considering the country-level average across the region, the spectrum needs range from 1.6 GHz to 2.4 GHz, driven by the lower spectrum requirements for smaller markets such as Maldives, Afghanistan and Nepal. Spectrum needs for the other large-population countries in the region (Bangladesh, Pakistan and Iran) are expected to fall between the spectrum needs in India and the smaller countries in the region.

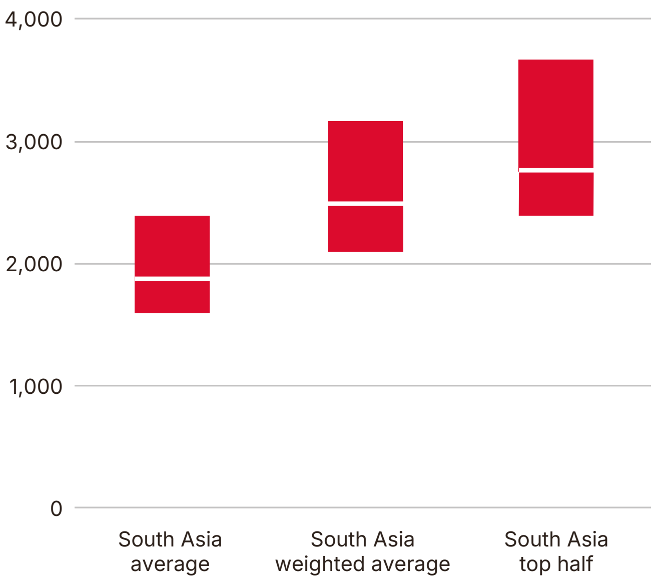
2040 mobile traffic forecast:
275-640 EB/month

2040 traffic per connection:
115-290 GB/month

2040 6G connections:
760 MILLION (34% penetration)

2040 5G connections:
460 MILLION (20% penetration)

Figure 14:
Total mid-band spectrum needs in 2035–2040, South Asia (MHz)



Source: GSMA Intelligence
Note: The box represents the 25th percentile, median and 75th percentile of spectrum-needs estimates based on our scenario analysis.

36 India Mobile Broadband Index 2025, Nokia, 2025

OTHER ASIA PACIFIC

Other Asia Pacific primarily consists of countries in the Pacific Islands, along with Mongolia and North Korea. Due to the fact that few of these countries are expected to have widespread 6G adoption by the mid-2030s, in addition to the lower population densities even in urban centres (compared to the rest of Asia), we estimate spectrum needs will be between 1.2 GHz and 1.8 GHz overall and between 1.3 GHz and 2.3 GHz for the highest-demand urban centres.

2040 mobile traffic forecast:

2-4
EB/month

2040 traffic per connection:

70-170
GB/month

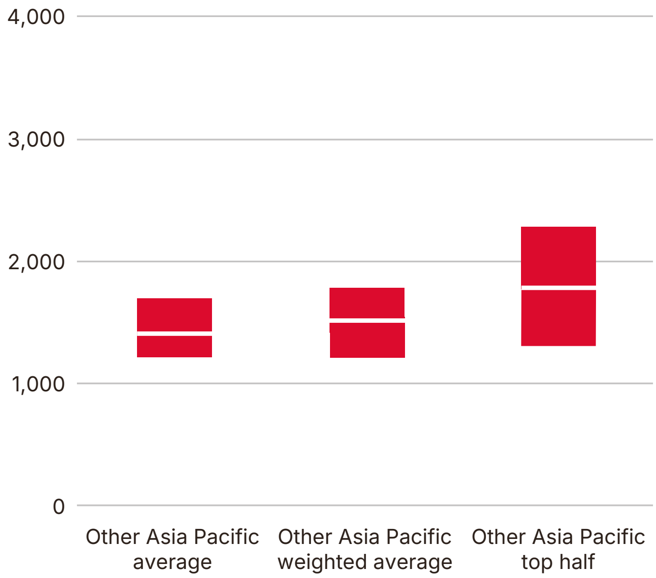
2040 6G connections:

4 MILLION
(7% penetration)

2040 5G connections:

13 MILLION
(26% penetration)

Figure 15:
Total mid-band spectrum needs in 2035–2040, other Asia Pacific (MHz)



Source: GSMA Intelligence

Note: The box represents the 25th percentile, median and 75th percentile of spectrum-needs estimates based on our scenario analysis.

GREATER CHINA

As Greater China consists of few markets, only the weighted average result is presented. China, Hong Kong, Macao and Taiwan have all been among the leading 5G markets in terms of deployment, adoption and data usage. In mainland China, all operators have deployed 5G SA, while 5G-Advanced was deployed in 2024. China is expected to be one of the leading countries in terms of 6G deployment, reaching more than 60% market penetration for 6G by 2035. As a result, it has a mid-band spectrum-needs requirement in the 2035–2040 period of 2.6–3.7 GHz.

2040 mobile traffic forecast:

555–1,345
EB/month

2040 traffic per connection:

240–640
GB/month

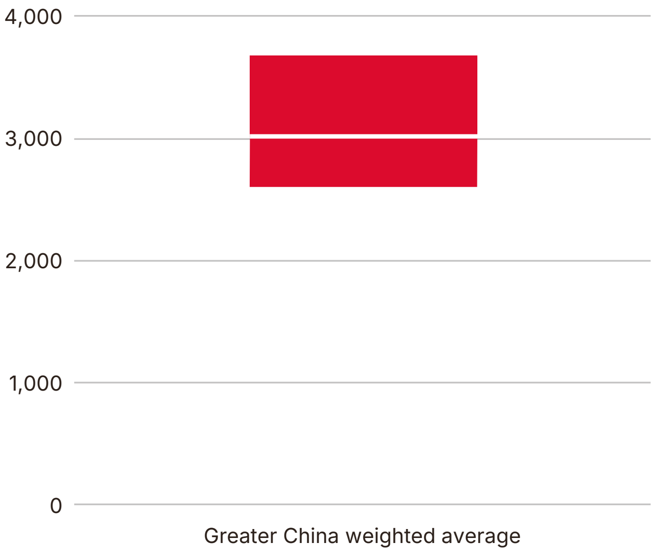
2040 6G connections:

1.6 BILLION
(116% penetration)

2040 5G connections:

300 MILLION
(21% penetration)

Figure 16:
Total mid-band spectrum needs in 2035–2040, Greater China (MHz)



Source: GSMA Intelligence

Note: The box represents the 25th percentile, median and 75th percentile of spectrum-needs estimates based on our scenario analysis.

NORTH AMERICA

North America consists of two markets, so only the weighted average result is presented. Led by the US, the region has achieved more than 95% 5G population coverage as well as the deployment of 5G SA. The US has also seen significant growth in 5G FWA, with more than 11 million connections at the end of 2024. The country is expected to be one of the first to deploy 6G, which is expected to drive market penetration of 6G in North America to over 60% by 2035. As such, the region has a mid-band spectrum-needs requirement in the 2035–2040 period of 2.7–3.8 GHz.

2040 mobile traffic forecast:

210–375 EB/month

2040 traffic per connection:

240–575 GB/month

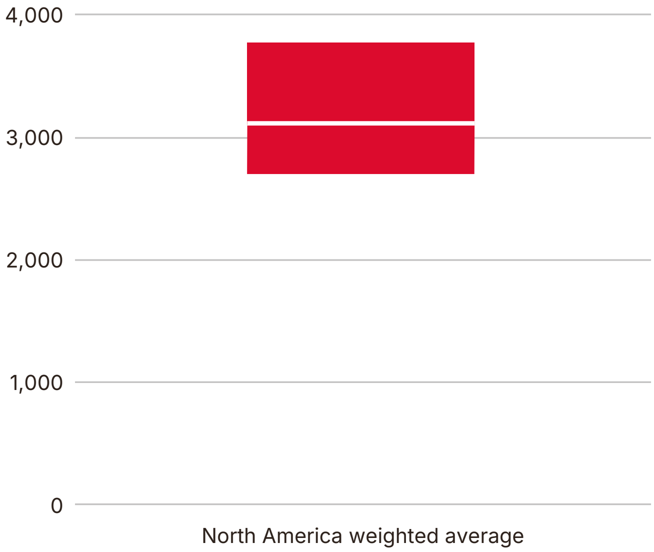
2040 6G connections:

440 MILLION (107% penetration)

2040 5G connections:

70 MILLION (18% penetration)

Figure 17:
Total mid-band spectrum needs in 2035–2040, North America (MHz)



Source: GSMA Intelligence

Note: The box represents the 25th percentile, median and 75th percentile of spectrum-needs estimates based on our scenario analysis.

LATIN AMERICA AND THE CARIBBEAN

The results for Latin America and the Caribbean reflect the diversity of the region's geography, population distribution and market development. We estimate the population-weighted average spectrum needs to be between 1.6 GHz to 2.3 GHz. The country-level average is lower because the region encompasses small Caribbean islands as well as much larger geographies and populations in South America and Mexico. When considering the top half, mid-band spectrum needs range between 2.1 GHz and 3 GHz, driven in significant part by increasing mobile demand in dense urban centres in Brazil.

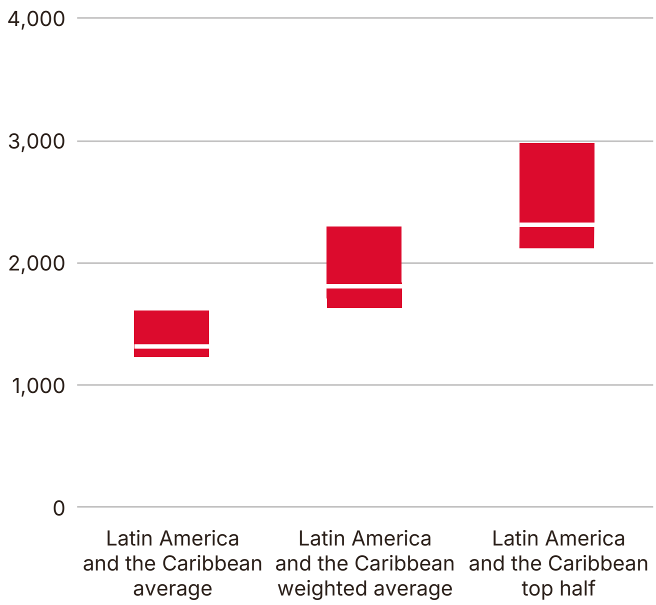
2040 mobile traffic forecast:
70-180 EB/month

2040 traffic per connection:
85-235 GB/month

2040 6G connections:
340 MILLION
(46% penetration)

2040 5G connections:
320 MILLION
(44% penetration)

Figure 18:
Total mid-band spectrum needs in 2035–2040, Latin America and the Caribbean (MHz)



Source: GSMA Intelligence

Note: The box represents the 25th percentile, median and 75th percentile of spectrum-needs estimates based on our scenario analysis.

GCC STATES

The GCC states have been the leading region when it comes to 5G deployment and adoption, and they account for some of the highest data usage levels (per connection) in the world, such as in Kuwait and Saudi Arabia. This is expected to continue going forward, with the region forecast to achieve more than 50% penetration of 6G connections by 2035.

As a result, we estimate spectrum needs to be within a range of 2.2 GHz and 3.4 GHz. This is not as high as the range estimated for other leading 5G (and eventually 6G) regions such as developed Asia Pacific, Greater China and North America, primarily because urban population densities are not as high in the GCC states as countries such as India and China.

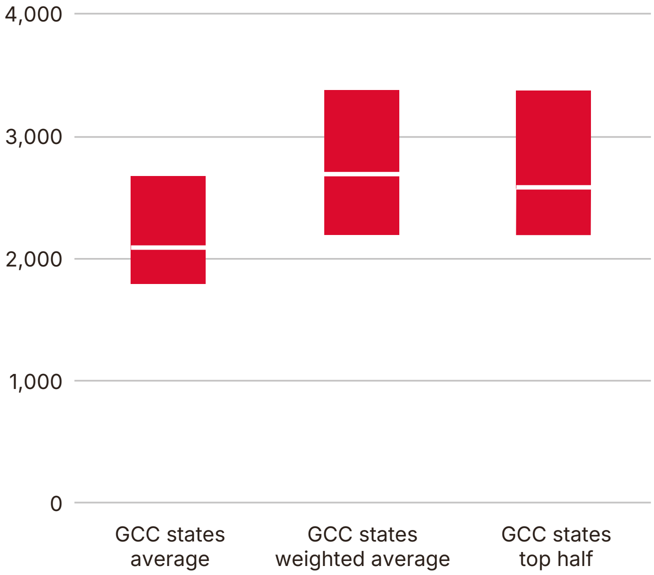
2040 mobile traffic forecast:
40-100
EB/month

2040 traffic per connection:
245-655
GB/month

2040 6G connections:
100 MILLION
(135% penetration)

2040 5G connections:
20 MILLION
(26% penetration)

Figure 19:
Total mid-band spectrum needs in 2035–2040, GCC states (MHz)



Source: GSMA Intelligence

Note: The box represents the 25th percentile, median and 75th percentile of spectrum-needs estimates based on our scenario analysis.

MIDDLE EAST AND NORTH AFRICA

In the Middle East and North Africa (which excludes the GCC states), we estimate the population-weighted average spectrum needs to be between 1.5 GHz and 2.2 GHz. The country-level average is slightly lower because the region encompasses a diverse group of countries, with more mature and higher usage markets such as Jordan and Egypt and lower usage markets such as Yemen and Sudan. When considering the highest-demand populations in the region, we estimate a total mid-band spectrum requirement between 2 GHz and 3.1 GHz.

2040 mobile traffic forecast:

50–110
EB/month

2040 traffic per connection:

90–215
GB/month

2040 6G connections:

6G

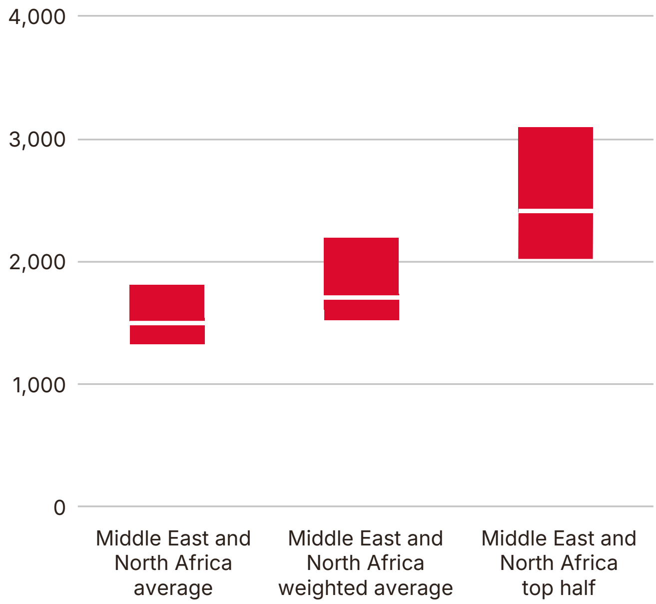
240 MILLION
(33% penetration)

2040 5G connections:

5G

320 MILLION
(45% penetration)

Figure 20:
Total mid-band spectrum needs in 2035–2040, Middle East and North Africa (MHz)



Source: GSMA Intelligence

Note: The box represents the 25th percentile, median and 75th percentile of spectrum-needs estimates based on our scenario analysis.

SUB-SAHARAN AFRICA

Similar to regions such as the Middle East and North Africa and Latin America and the Caribbean, the Sub-Saharan Africa region includes a diverse group of countries in terms of geography, population distribution and market development.

6G is expected to develop later in many Sub-Saharan African countries; hence, their spectrum needs will continue to develop beyond the study period. Weighted average mid-band spectrum needs are expected to range from 1.4 GHz to 2 GHz. However, when considering the areas with highest demand – which also reflect some of the most population-dense urban areas in the region such as Kenya, Tanzania, Cote d'Ivoire and Nigeria – estimated mid-band requirements range between 1.9 GHz and 2.9 GHz. This is also driven by the fact that network densification is not expected to reach the levels seen in most other regions.

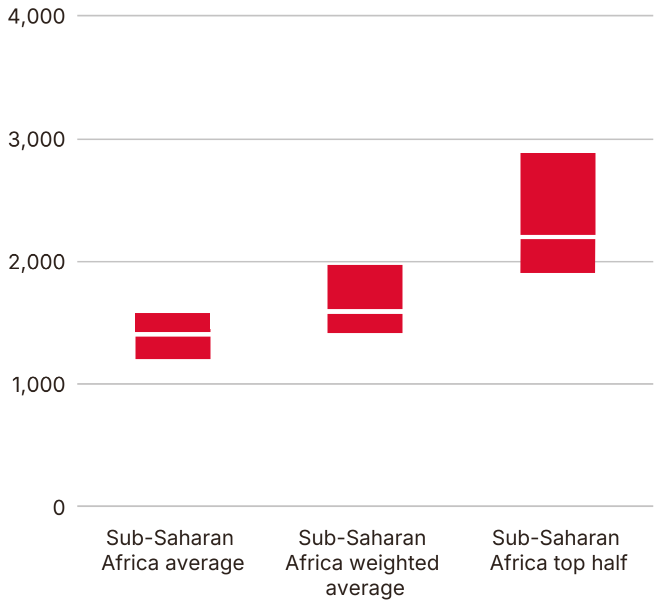
2040 mobile traffic forecast:
70-140
EB/month

2040 traffic per connection:
30-70
GB/month

2040 6G connections:
240 MILLION
(14% penetration)

2040 5G connections:
820 MILLION
(46% penetration)

Figure 21:
Total mid-band spectrum needs in 2035–2040, Sub-Saharan Africa (MHz)



Source: GSMA Intelligence

Note: The box represents the 25th percentile, median and 75th percentile of spectrum-needs estimates based on our scenario analysis.

EUROPE

While 5G has been deployed across Europe, much of the region not seen the same level of adoption and network quality as in the GCC states, developed Asia Pacific, North America and China. Most operators in Europe have also yet to deploy 5G SA.[37]

There are some notable exceptions to this, such as in Scandinavia as well as the Baltic states, where levels of data usage are high (the seven countries in these sub-regions were all in the top 30 countries globally when it came to data usage per connection in 2024). Going forward, as operators eventually complete the deployment of 5G SA and launch 6G, we expect most of Europe to catch up with the other leading regions by the 2035–2040 period. In this context, we estimate weighted average mid-band requirements to be between 2 GHz and 3.1 GHz. When looking at the highest-demand locations, such as in Scandinavia and the Baltic states, total spectrum needs range from 2.5 GHz to 3.9 GHz.

2040 mobile traffic forecast:
195–405 EB/month

2040 traffic per connection:
225–590 GB/month

2040 6G connections:
550 MILLION (96% penetration)

2040 5G connections:
170 MILLION (30% penetration)

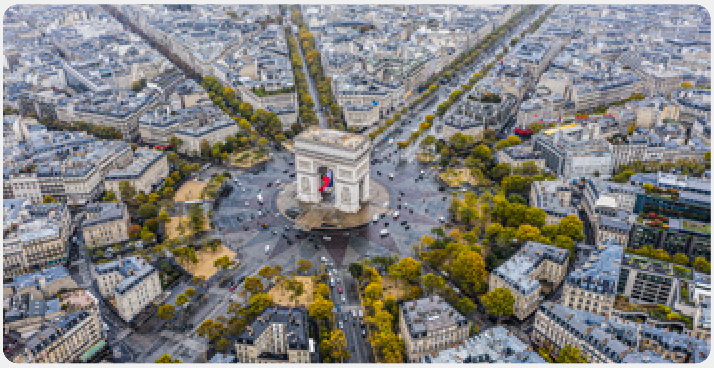
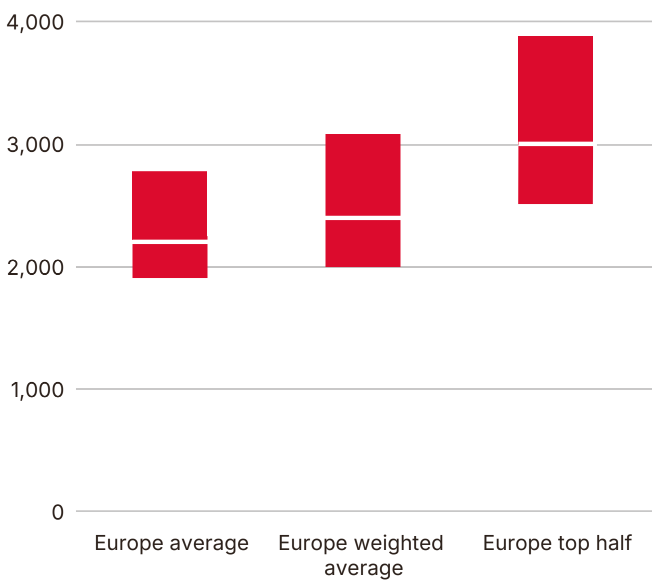


Figure 22:
Total mid-band spectrum needs in 2035–2040, Europe (MHz)



Source: GSMA Intelligence

Note: The box represents the 25th percentile, median and 75th percentile of spectrum-needs estimates based on our scenario analysis.

37 See the 5G Connectivity Index

EURASIA

None of the countries in Eurasia are expected to be early adopters of 6G, but market penetration of 6G is expected to reach more than 40% by 2040. The regional weighted average mid-band requirements in the region are between 1.9 GHz and 2.9 GHz. This is also similar to the top-half range, as both results are led by Russia, the region's largest country.

2040 mobile traffic forecast:

50–130 EB/month

2040 traffic per connection:

115–345 GB/month

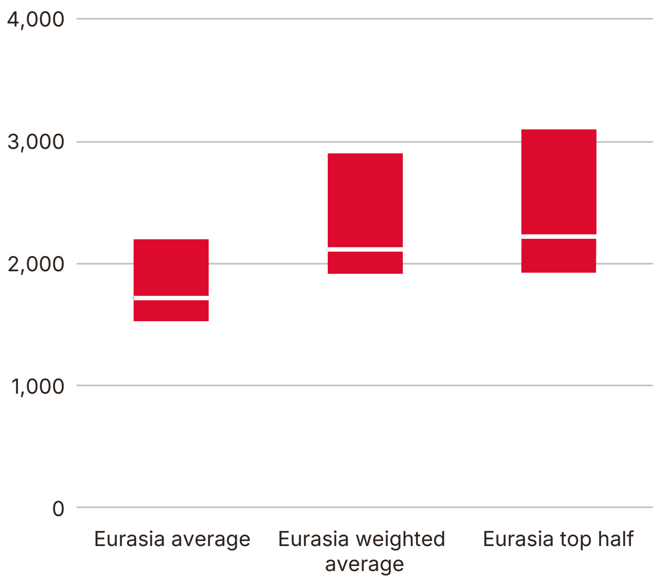
2040 6G connections:

110 MILLION (42% penetration)

2040 5G connections:

220 MILLION (84% penetration)

Figure 23:
Total mid-band spectrum needs in 2035–2040, Eurasia (MHz)



Source: GSMA Intelligence

Note: The box represents the 25th percentile, median and 75th percentile of spectrum-needs estimates based on our scenario analysis.

APPENDIX 1: METHODOLOGY

Spectrum-needs framework

There are three primary methods to estimate future spectrum needs:[38]

1. **Traffic forecast–based approach:** This method estimates future spectrum by projecting mobile traffic growth (e.g. data per user, number of users, busy-hour demand) and translating it into spectrum requirements based on the evolution of network capacity (which is determined by site densification, existing spectrum and spectral efficiencies).

2. **Application-based approach:** This method starts from the requirements of specific services and applications (e.g. required data rates) and aggregates their needs to determine total spectrum demand. It is more scenario-driven and use-case specific.

3. **Technical performance–based:** This method models network performance against key performance indicators (e.g. data rate, coverage requirement, area capacity) and calculates how much spectrum is needed to meet these.

In this study, we implement a traffic-based approach but incorporate application requirements.

Mobile demand forecasts

We model aggregate traffic demand for both downlink and uplink in each country using the approach described in Chapter 3, meaning traffic is a function of:

1. the number of mobile users in a given country (sourced from GSMA Intelligence data)

2. adoption of each use case by country e.g. the number of mobile users that stream video (sourced from the GSMA Consumer Survey)

3. the performance requirement e.g. the download or upload speed needed for a use case (sourced from application requirements and also incorporates a utilisation factor for use cases that are periodic)[39]

4. time spent per use case per day on mobile by country (sourced from regulator reports and consumer surveys).

Many use cases have latency requirements that may impact spectrum needs. In order to incorporate this into our framework, we consider two methods:

- The first is to model a lower network loading factor (see Table A1), as this will enable more capacity to reduce transmission delay.

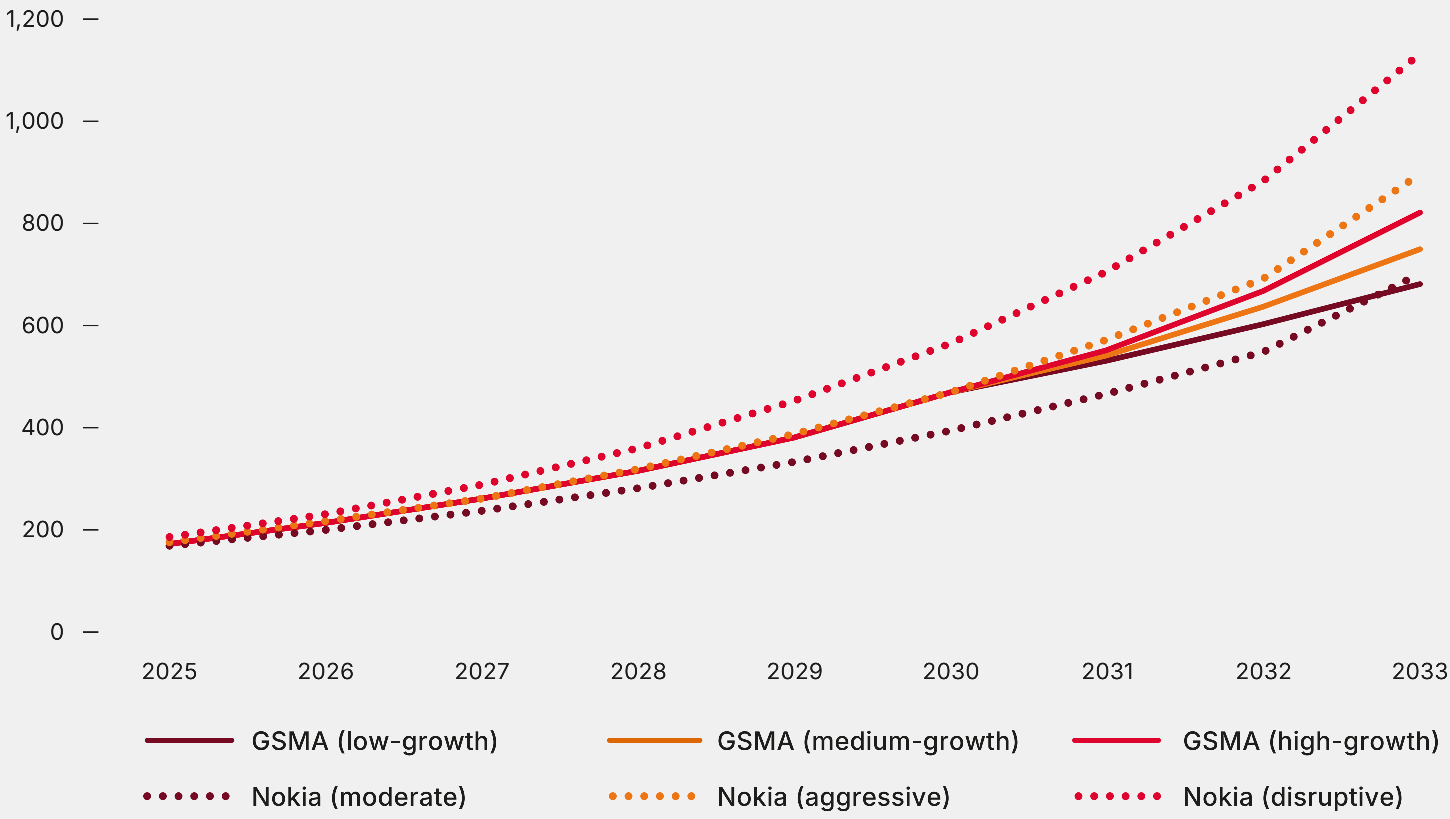
- The second is to convert a latency requirement into an implied downlink or uplink rate. For example, if a use case requires a latency of 10 ms and involves the upload of images with a pixel count of 1080×1920 and the amount of data per pixel is 0.1 bits, we can calculate the upload requirement as 0.1 bits * (1080*1920) pixels / 10 ms = 20 Mbps. We can then use this as the performance requirement in the framework described above.

38 For further details, see for example Spectrum Needs for the Terrestrial Component of IMT in the Frequency Range between 24.25 GHz and 86 GHz, ITU, 2017

39 This utilisation factor reflects the fact that some use cases require traffic in periods or 'bursts'. For example, web browsing or social media may require 3–5 Mbps to download new content, but when the user is viewing and not refreshing content they do not utilise the same bandwidth. In contrast, video streaming requires a constant and uninterrupted data rate while being used.

In Figure A1, we compare traffic forecasts in our three scenarios against third party-forecasts from Nokia Bell Labs[40] (which includes three scenarios, similar to our own approach).The results show that by 2033 (the year to which the other forecasts extend until), our forecasts are generally more conservative; even our high-growth scenario is lower than Nokia's aggressive and disruptive scenarios.[41] In practice, this means that our trajectory follows a slower path than the other forecasts – that is, we also assume a growth in mobile traffic but we assume it will take a longer time to reach 1,000 EB/month (which we forecast would occur in 2034 in our high-growth scenario, 2035 in our medium-growth scenario and 2037 in our low-growth scenario). This is one of the reasons why we also model scenarios where these levels are achieved more quickly, as well as more slowly (to account for the possibility of slower growth rates).

Figure A1:
Global traffic forecast comparisons (EB/month)

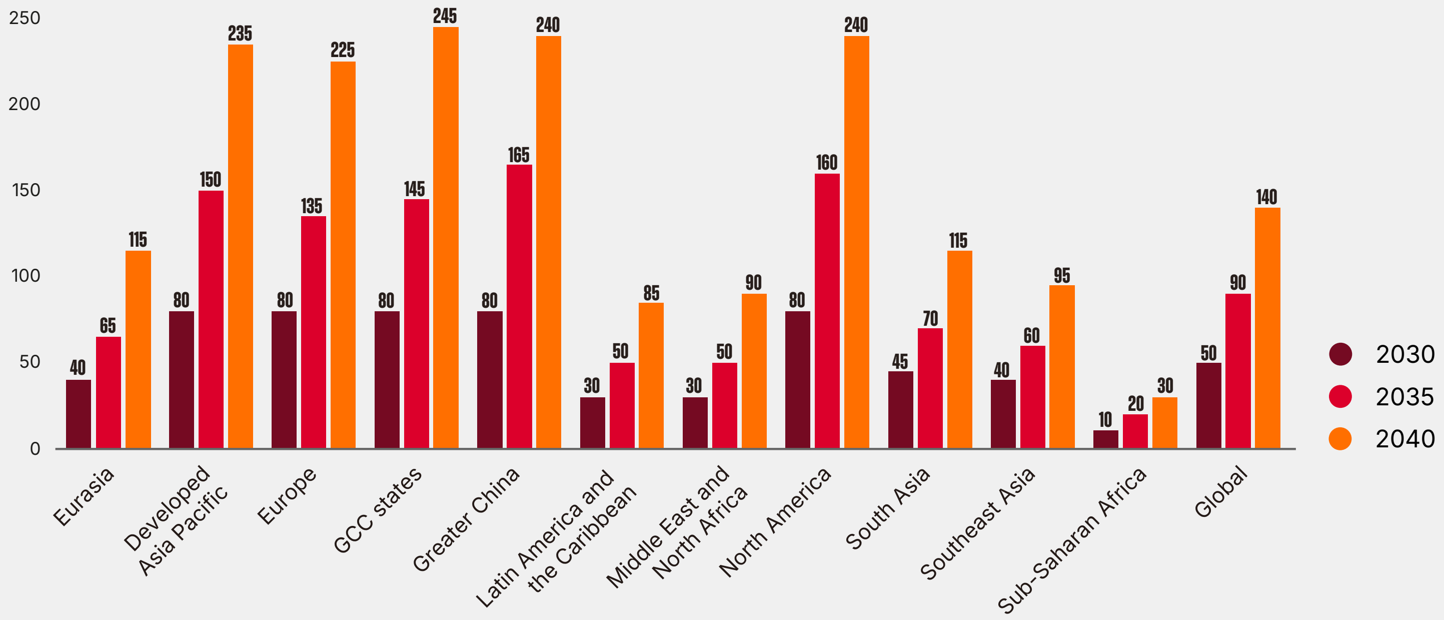


Source: GSMA Intelligence and Nokia Bell Labs

40 Global network traffic report, Nokia Bell Labs, 2024
41 Our global traffic forecasts are also more conservative than those produced by Omdia. See AI Network Traffic Report Update for Europe: Projected Cellular Growth will Stress Access Infrastructure, Omdia, 2025

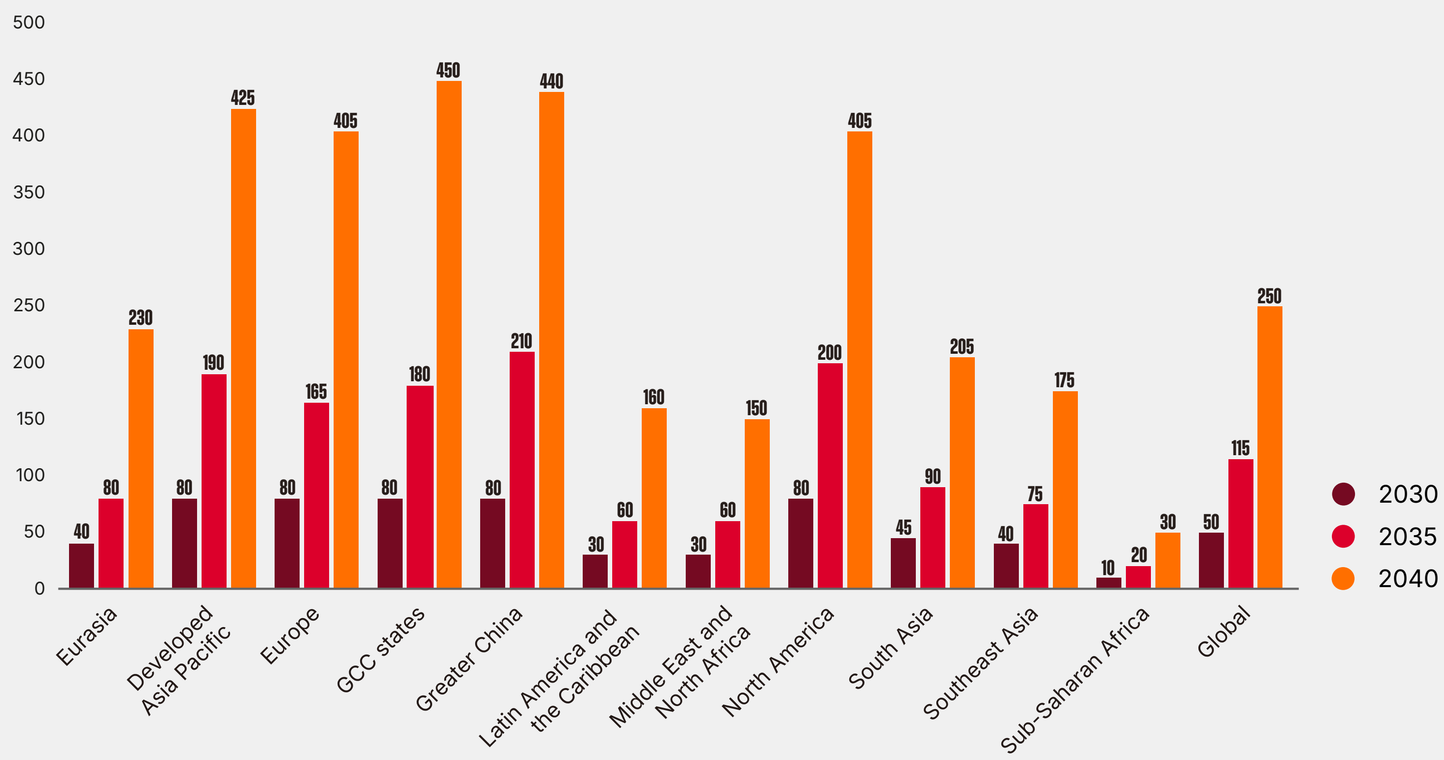
In Figure A2, we present forecasts for mobile traffic per connection per month in each region for the different scenarios. This can be considered a proxy for the amount of data usage expected per user across all their devices (a smartphone, wearables, smart glasses etc.), rather than a single mobile phone.

Figure A2a:
Regional traffic forecasts in the low-growth scenario, 2030–2040 (GB/connections/month)



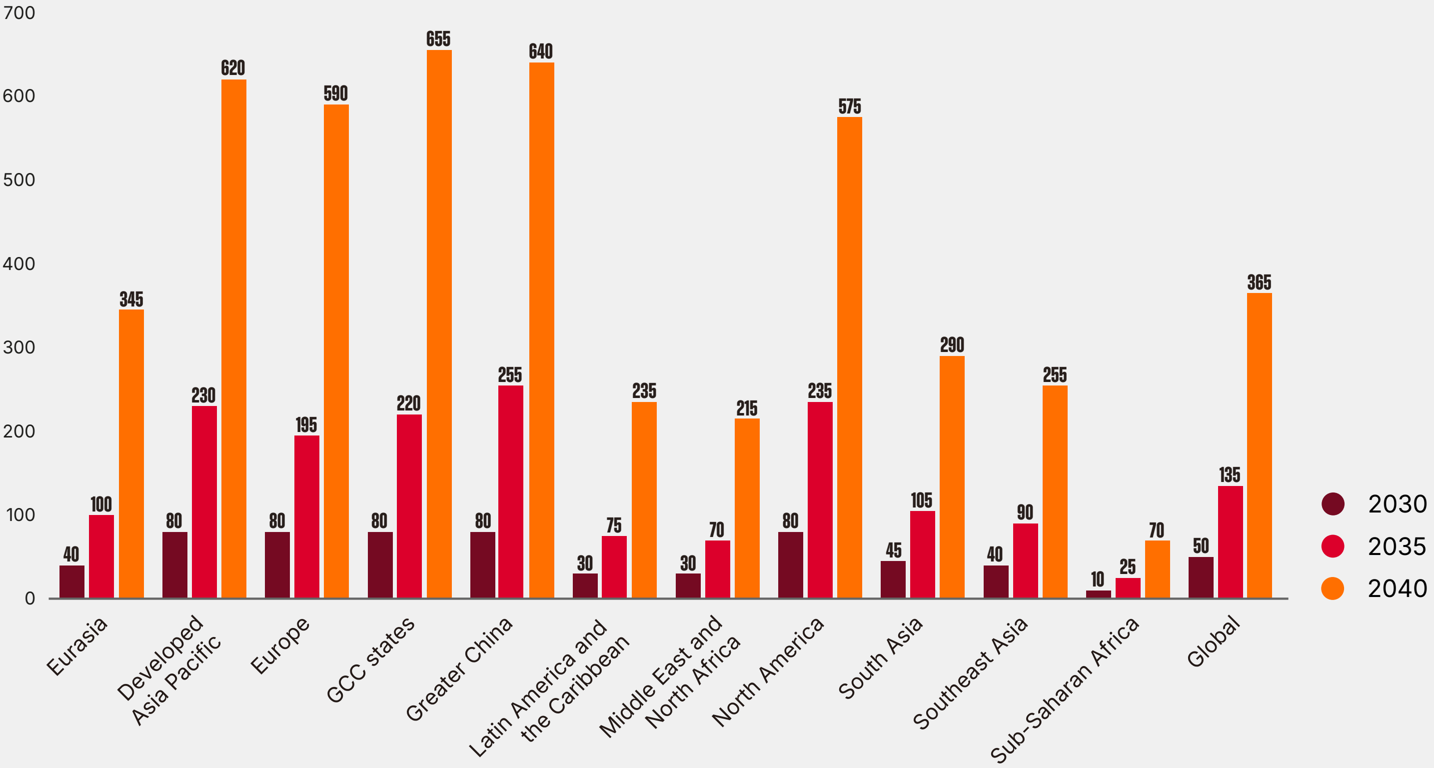
Source: GSMA Intelligence

Figure A2b:
Regional traffic forecasts in the medium-growth scenario, 2030–2040 (GB/connections/month)



Source: GSMA Intelligence

Figure A2c:
Regional traffic forecasts in the high-growth scenario, 2030–2040 (GB/connections/month)



Source: GSMA Intelligence
Note: Traffic forecasts per connection do not include FWA or IoT traffic.

FWA and IoT demand forecasts

The approach described above sets out our approach to forecasting mobile data traffic. We then also estimate FWA traffic by forecasting the number of FWA users per country and estimating the expected traffic per connection (the latter is informed by current ratios of traffic per connection for FWA compared to mobile). Similarly, we forecast IoT traffic based on the number of IoT connections and expected traffic per IoT connection, which varies based on the type of IoT connection (e.g. manufacturing, smart home). In our scenarios, the amount of total traffic accounted for by IoT is small (1–2% depending on the scenario), while FWA ranges from 10% to 50% depending on the region. We expect there will ultimately be a ceiling to FWA adoption given the addressable market, as it is unlikely to displace fibre and cable broadband (though once it reaches that limit, traffic per user will continue to grow).

Estimating demand in dense urban areas

In order to estimate demand in high-use areas, we first need to determine a definition of 'dense urban'.

We use the GHSL database[42] to categorise areas into rural and urban areas. This database was proposed by a consortium of international organisations – the EU, the OECD, the World Bank, UN-Habitat, FAO and ILO – and has been endorsed by the UN statistical commission. It combines built-up area with population density to classify settlements and is defined for each square kilometre for the entire globe (meaning that it is consistent across countries). The GHSL defines 'urban centres' as those with contiguous grid cells with a density of at least 1,500 inhabitants per square kilometre and with a population of at least 50,000. Gaps in this cluster are filled and edges are smoothed (and if needed, cells that are 50% built-up can be added).

While this provides a helpful starting point, we do not take GHSL 'urban centres' as our definition of dense urban areas for the purpose of modelling spectrum needs because there are a significant number of urban centre grids that fall below the 1,500 inhabitants per square kilometre threshold. This is due to the spatial aggregation approach that the GSHL applies. As a result, many countries have urban clusters with low-density grids, which has implications for distributing mobile traffic because using the GHSL grid could result in areas that are too large.

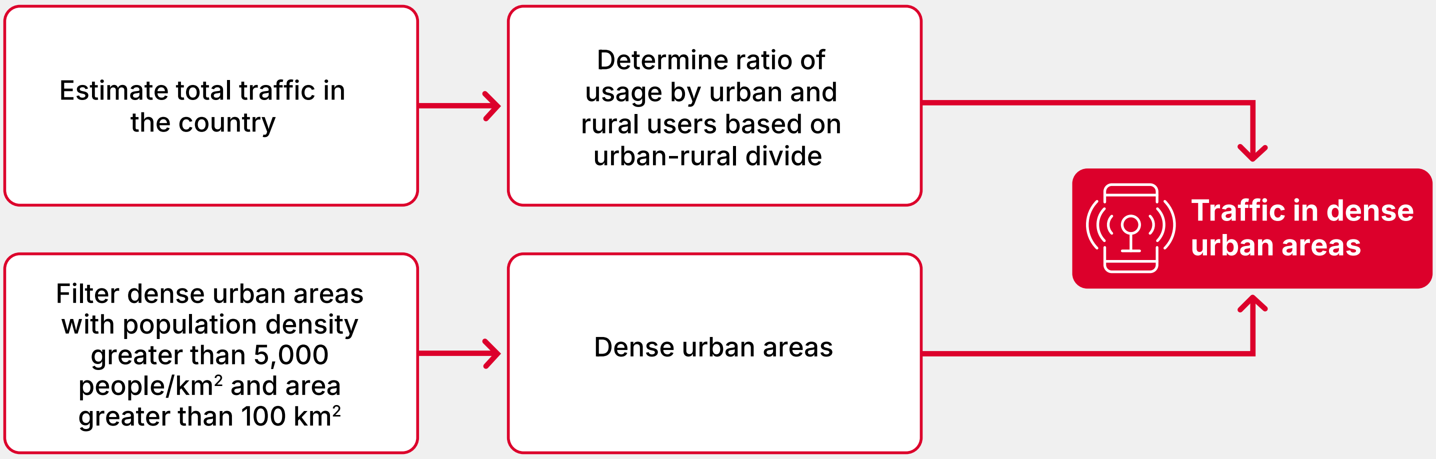
We therefore modify the definition for this study and consider urban centres with population densities above 5,000 inhabitants per square kilometre – this is based on the median population density that is observed in urban centre pixels. We also filter out areas smaller than 100 km^2 to avoid including very small hot-spot areas in the analysis.

In order to then validate the use of population data as a proxy for traffic demand, we leverage Ookla Cell Analytics data, which provides mobile usage data by location at an accuracy of 10 m. The analysis incorporates more than 1 billion data points. While Ookla data does not represent all users, as it is collected from users that opt in to tracking usage on its Speedtest or partner apps, when analysing Ookla data for the UK, for example, we find that it produces results that are strongly aligned with actual traffic distribution data. Specifically, Ofcom has reported that 60% of mobile traffic is contained in 5% of the geographic area of Great Britain,[43] while Ookla's data suggests 58% of traffic is contained in 4% of the geographic area. Ofcom also reports that 82% of monthly mobile data traffic is generated in urban and suburban areas,[44] while Ookla's data suggests that 83% of traffic is generated in these areas. This gives us confidence that Ookla's data provides a strong basis to understand the distribution of mobile network traffic.

42 See Global Human Settlement Layer
43 Hybrid sharing: enabling both licensed mobile and Wi-Fi users to access the upper 6 GHz band, Ofcom, 2023
44 Connected Nations: UK Report 2024, Ofcom, 2024

As noted in Chapter 3, we find that in mature mobile markets, traffic distribution closely follows population distribution, while in growing or emerging markets, traffic is disproportionately higher in urban areas (due to the larger urban–rural divide). We therefore follow the approach summarised in Figure A3 to distribute traffic within countries. We filter dense urban areas based on the population density and area thresholds described above and we then determine the ratio of usage in rural and urban areas. In countries where there is no urban–rural divide, we assume traffic is distributed in a similar manner to population (e.g. if dense urban areas account for 40% of the country's population, we assume they also account for 40% of total mobile network traffic, meaning that an urban resident generates the same traffic as a rural resident). In countries with an urban–rural divide, we distribute more traffic to population (e.g. if mobile internet adoption in urban areas is twice that of rural areas, we will assume that urban residents generate twice as much traffic as rural residents). For FWA, we allocate a proportion of traffic to urban areas based on the adoption of fibre and cable (e.g. if fibre or cable adoption by household is high, the majority of FWA traffic is allocated to rural and peri-urban areas, but if fibre adoption is low, we allocate more FWA traffic to urban centres).

Figure A3:
Approach to distributing traffic in dense urban areas



Source: GSMA Intelligence

Network-capacity forecasts

Network-supply analysis examines the capacity that mobile operators can provide using available spectrum resources, network infrastructure and technology capabilities. This analysis must consider the evolution of all these factors over the study period, including technology improvements, network densification and spectrum efficiency gains.

Table A1 sets out the key parameters assumed on the supply side, with the majority of inputs considering a range that is used in our simulation analysis. The assumptions on spectral efficiencies are presented in Chapter 3.

Table A1:
Mobile model data inputs

Parameter	Assumption
Network densification	Given that network densification can vary significantly by country (and will likely continue to do so), we set these assumptions at a country level, based on information from operators and crowd-sourced OpenCellID data. The majority of dense urban areas have a density of 1,000–3,000 people per site (meaning the inter-site distances generally range between 200 m and 800 m in our scenarios).
MRSS	Our analysis incorporates MRSS capabilities that will enable more efficient spectrum utilisation across different technology generations.[45] MRSS is expected to represent an improvement over current dynamic spectrum sharing (DSS) approaches, reducing overheads and enabling better resource allocation. MRSS will allow operators to deploy 6G without requiring immediate access to new spectrum bands by sharing existing allocations with 4G and 5G systems. Our modelling assumes an MRSS overhead of 10%, which is an improvement over the 15–25% overhead associated with DSS implementations. We assume that by 2040, all existing mid-bands will have MRSS enabled and so can be used for 6G. To support the continued use of 4G and 5G, we estimate the share of spectrum used for each technology based on our forecast of connections share by technology. For example, if by 2040 we forecast that 50% of a country's mobile connections are on 6G, 40% are on 5G and 10% are on 4G, then we assume that existing mid-bands will be utilised in a manner where 50% of the spectrum is used for 6G, 40% for 5G and 10% for 4G (after accounting for the 10% overhead). In the case of new bands, we assume the upper 6 GHz band would only be used for 5G and 6G (not 4G) and that 7–8 GHz would only be used for 6G (not 4G or 5G).
Network loading factor	We consider scenarios within the range of 60% and 80%.
Traffic distribution across sites	Within urban areas, traffic is not evenly distributed across sites. We consider scenarios where between 10% and 20% of sites account for 50% of traffic.
Number of sectors per site	We consider three sectors for macro sites and one sector for small cells.
Number of small cells per macro	We consider scenarios within a range of one small cell per 10 macro sites to one small cell per one macro site.
Share of traffic during peak hours	We consider scenarios with a range of 7% and 20%.
Proportion of traffic met by low bands	We consider scenarios with a range of 10% and 20%.
Proportion of traffic met by mmWave bands	We consider scenarios with a range of 5% and 10%.
FWA capacity	As we model different spectral efficiencies for FWA, we take an approach where we first estimate how much capacity is needed to meet mobile demand and then IoT demand. We then assume the amount of spectral resource 'left over' can be used for FWA, based on higher spectral efficiencies. If there is no resource left (i.e. if networks are capacity constrained due to mobile), the excess FWA demand is added to estimate total spectrum needs (using the higher spectral efficiencies).

Source: GSMA Intelligence

Spectrum assignment

In terms of spectrum assigned, we assume that in the long term all countries will assign the bands identified for IMT in their region. These are summarised in Table A2.

Table A2:
IMT spectrum assignments (MHz)

Band		Category	Region 1	Region 2	Region 3
n71	600 MHz	Low band	N/A	70	80
n12, n14, n28, n29	700 MHz	Low band	80	90	90
n20	800 MHz	Low band	60	N/A	N/A
n5	850 MHz	Low band	N/A	50	Up to 40*
n8	900 MHz	Low band	70	30	70
n50, n75	1.5 GHz	Lower mid-band	85	85	80
n3	1.8 GHz	Lower mid-band	150	N/A	150
n1	2.1 GHz	Lower mid-band	120	N/A	120
n2, n25	PCS	Lower mid-band	N/A	120	N/A
n66, n70	AWS	Lower mid-band	N/A	120	N/A
n40	2.3 GHz**	Lower mid-band	N/A	N/A	100
n41, n90, n38, n7	2.6 GHz	Lower mid-band	190	190	190
n77	3.5 GHz***	Upper mid-band	400	400	400

Source: GSMA Intelligence

* Several Region 3 markets are using the 850 MHz band but not in full; if so, they would not have the whole 900 MHz available.

** 2.3 GHz band is only available in some countries in Regions 1 and 2.

*** Our starting assumption is that countries will assign 400 MHz in the 3.5 GHz range. However, some countries have assigned more spectrum in this band, such as Saudi Arabia and Japan. A small number of countries (e.g. Japan) have also assigned spectrum in the 4.4–5 GHz range.

Spectrum-needs calculation

Having calculated demand and capacity in each dense urban area, if capacity exceeds demand, then there are no additional spectrum requirements. If demand exceeds capacity, we calculate the additional spectrum requirement by dividing excess demand by the relevant spectral efficiency.

APPENDIX 2: LIST OF MARKETS BY REGION

Market	Region
Afghanistan	South Asia
Albania	Europe
Algeria	Middle East and North Africa
Andorra	Europe
Angola	Sub-Saharan Africa
Antigua and Barbuda	Latin America and the Caribbean
Argentina	Latin America and the Caribbean
Armenia	Eurasia
Australia	Developed Asia Pacific
Austria	Europe
Azerbaijan	Eurasia
Bahamas	Latin America and the Caribbean
Bahrain	GCC states
Bangladesh	South Asia
Barbados	Latin America and the Caribbean
Belarus	Eurasia
Belgium	Europe
Belize	Latin America and the Caribbean
Benin	Sub-Saharan Africa
Bhutan	South Asia
Bolivia	Latin America and the Caribbean
Bosnia and Herzegovina	Europe
Botswana	Sub-Saharan Africa
Brazil	Latin America and the Caribbean
Brunei Darussalam	Developed Asia Pacific
Bulgaria	Europe
Burkina Faso	Sub-Saharan Africa
Burundi	Sub-Saharan Africa
Cabo Verde	Sub-Saharan Africa
Cambodia	Southeast Asia
Cameroon	Sub-Saharan Africa
Canada	North America
Central African Republic	Sub-Saharan Africa
Chad	Sub-Saharan Africa
Chile	Latin America and the Caribbean
China	Greater China
Colombia	Latin America and the Caribbean
Comoros	Sub-Saharan Africa
Congo	Sub-Saharan Africa
Democratic Republic of Congo	Sub-Saharan Africa

Market	Region
Costa Rica	Latin America and the Caribbean
Côte d'Ivoire	Sub-Saharan Africa
Croatia	Europe
Cuba	Latin America and the Caribbean
Cyprus	Europe
Czechia	Europe
Denmark	Europe
Djibouti	Sub-Saharan Africa
Dominica	Latin America and the Caribbean
Dominican Republic	Latin America and the Caribbean
Ecuador	Latin America and the Caribbean
Egypt	Middle East and North Africa
El Salvador	Latin America and the Caribbean
Equatorial Guinea	Sub-Saharan Africa
Eritrea	Sub-Saharan Africa
Estonia	Europe
Eswatini	Sub-Saharan Africa
Ethiopia	Sub-Saharan Africa
Fiji	Other Asia Pacific
Finland	Europe
France	Europe
Gabon	Sub-Saharan Africa
Gambia	Sub-Saharan Africa
Georgia	Other Asia Pacific
Germany	Europe
Ghana	Sub-Saharan Africa
Greece	Europe
Grenada	Latin America and the Caribbean
Guatemala	Latin America and the Caribbean
Guinea	Sub-Saharan Africa
Guinea-Bissau	Sub-Saharan Africa
Guyana	Latin America and the Caribbean
Haiti	Latin America and the Caribbean
Honduras	Latin America and the Caribbean
Hong Kong	Greater China
Hungary	Europe
Iceland	Europe
India	South Asia
Indonesia	Southeast Asia
Iran	South Asia
Iraq	Middle East and North Africa
Ireland	Europe

Market	Region
Israel	Middle East and North Africa
Italy	Europe
Jamaica	Latin America and the Caribbean
Japan	Developed Asia Pacific
Jordan	Middle East and North Africa
Kazakhstan	Eurasia
Kenya	Sub-Saharan Africa
Kiribati	Other Asia Pacific
North Korea	Other Asia Pacific
South Korea	Developed Asia Pacific
Kosovo	Europe
Kuwait	GCC states
Kyrgyzstan	Eurasia
Laos	Southeast Asia
Latvia	Europe
Lebanon	Middle East and North Africa
Lesotho	Sub-Saharan Africa
Liberia	Sub-Saharan Africa
Libya	Middle East and North Africa
Liechtenstein	Europe
Lithuania	Europe
Luxembourg	Europe
Macao	Greater China
Madagascar	Sub-Saharan Africa
Malawi	Sub-Saharan Africa
Malaysia	Southeast Asia
Maldives	South Asia
Mali	Sub-Saharan Africa
Malta	Europe
Marshall Islands	Other Asia Pacific
Mauritania	Sub-Saharan Africa
Mauritius	Sub-Saharan Africa
Mexico	Latin America and the Caribbean
Micronesia	Other Asia Pacific
Moldova	Eurasia
Monaco	Europe
Mongolia	Other Asia Pacific
Montenegro	Europe
Morocco	Middle East and North Africa
Mozambique	Sub-Saharan Africa
Myanmar	Southeast Asia
Namibia	Sub-Saharan Africa
Nauru	Other Asia Pacific

Market	Region
Nepal	South Asia
Netherlands	Europe
New Zealand	Developed Asia Pacific
Nicaragua	Latin America and the Caribbean
Niger	Sub-Saharan Africa
Nigeria	Sub-Saharan Africa
North Macedonia	Europe
Norway	Europe
Oman	GCC states
Pakistan	South Asia
Palau	Other Asia Pacific
Palestine	Middle East and North Africa
Panama	Latin America and the Caribbean
Papua New Guinea	Other Asia Pacific
Paraguay	Latin America and the Caribbean
Peru	Latin America and the Caribbean
Philippines	Southeast Asia
Poland	Europe
Portugal	Europe
Qatar	GCC states
Romania	Europe
Russian Federation	Eurasia
Rwanda	Sub-Saharan Africa
Saint Kitts and Nevis	Latin America and the Caribbean
Saint Lucia	Latin America and the Caribbean
Saint Vincent and the Grenadines	Latin America and the Caribbean
Samoa	Other Asia Pacific
Sao Tome and Principe	Sub-Saharan Africa
Saudi Arabia	GCC states
Senegal	Sub-Saharan Africa
Serbia	Europe
Seychelles	Sub-Saharan Africa
Sierra Leone	Sub-Saharan Africa
Singapore	Developed Asia Pacific
Slovakia	Europe
Slovenia	Europe
Solomon Islands	Other Asia Pacific
Somalia	Sub-Saharan Africa
South Africa	Sub-Saharan Africa

Market	Region
South Sudan	Sub-Saharan Africa
Spain	Europe
Sri Lanka	South Asia
Sudan	Middle East and North Africa
Suriname	Latin America and the Caribbean
Sweden	Europe
Switzerland	Europe
Syria	Middle East and North Africa
Taiwan	Greater China
Tajikistan	Eurasia
Tanzania	Sub-Saharan Africa
Thailand	Southeast Asia
Timor-Leste	Southeast Asia
Togo	Sub-Saharan Africa
Tonga	Other Asia Pacific
Trinidad and Tobago	Latin America and the Caribbean
Tunisia	Middle East and North Africa
Türkiye	Europe
Turkmenistan	Eurasia
Tuvalu	Other Asia Pacific
Uganda	Sub-Saharan Africa
Ukraine	Europe
UAE	GCC states
UK	Europe
US	North America
Uruguay	Latin America and the Caribbean
Uzbekistan	Eurasia
Vanuatu	Other Asia Pacific
Venezuela	Latin America and the Caribbean
Vietnam	Southeast Asia
Yemen	Middle East and North Africa
Zambia	Sub-Saharan Africa
Zimbabwe	Sub-Saharan Africa

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