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Ericsson Mobility Report

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Letter from the publisher

Meeting evolving network requirements

Despite geopolitical unrest and a macroeconomic slowdown in some markets, communications service providers worldwide are continuing to invest in 5G, driven by the prospect of superior connectivity and emerging opportunities.

New major 5G markets such as India are witnessing massive network deployments as part of their Digital India initiative, making it the fastest-growing 5G market globally. Meanwhile, North America is in the second wave of 5G build-outs and user adoption, where the addition of mid-band spectrum now enables superior multi-band 5G experiences for many users.

With over 1 billion 5G subscriptions worldwide, service providers in leading 5G markets are experiencing positive revenue growth, in keeping with growth trends over the past 2 years. However, the 5G rollout is still in progress, and the deployment of 5G mid-band spectrum, which offers high capacity and good coverage for superior user experiences, remains limited to around 25 percent of 4G sites globally, with North America ahead and Europe behind.

As global mobile network data traffic continues to grow, with a CAGR of around 25 percent projected until 2028, smart network modernization becomes imperative. Efficiently managing this growth while improving the mobile user experience requires a careful balance. Notably, 5G mid-band build-out is proving to be more energy-efficient and cost-effective compared to the expansion of 4G networks.

In this edition, we uncover key insights into the trends shaping the future of network evolution, based on analysis of data traffic growth and patterns across different locations in mobile networks.

As you dive deeper into the report, we address the challenges posed by the next wave of 5G applications, emphasizing the need for new models to rate mobile quality of experience (QoE) to enable the design of networks that meet future service performance needs. As the use of augmented reality (AR) services for mobile devices grows, mobile networks need to be prepared for increased performance requirements, primarily by adding new spectrum and functionality on existing sites. We also explore how Singtel's deployment of 5G network slicing at the 2022 Singapore Grand Prix demonstrated the commercial opportunities of differentiated connectivity services.

We trust that you will find this report engaging and that it provides useful insights as we navigate the ever-evolving world of 5G and network evolution.

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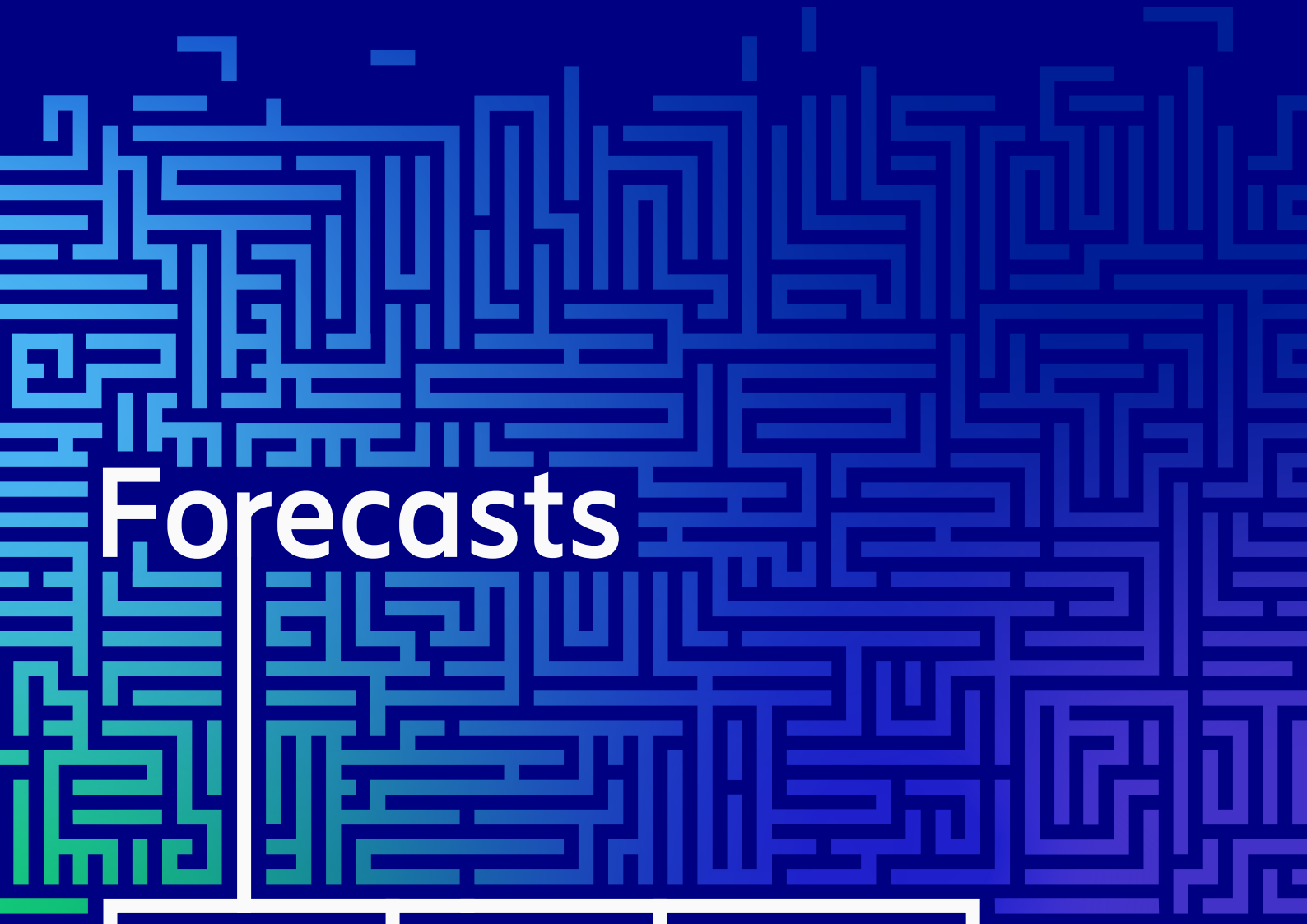
5G uptake is growing fast – total 5G subscriptions is projected to pass the 1.5 billion mark this year, growing by 0.5 billion in just one year. Growth comes in spite of a challenging macroeconomic climate, which has seen subscriptions grow a little slower than expected in some regions. Globally, around 240 commercial 5G networks have been launched so far, and service providers in the top 20 5G markets have enjoyed growing revenue that correlates with growing subscription penetration.



Forecasts

5G mobile subscriptions are set to reach 1.5 billion globally by the end of 2023.

1.5bn

Revenue is rising for service providers in the top 20 5G markets, increasing by 7 percent in the last 2 years.

7%

More than 100 service providers are now offering Fixed Wireless Access services over 5G.

100

The monthly global average usage per smartphone is expected to exceed 20 GB at the end of 2023.

20GB

5G mobile subscriptions to reach 1.5 billion in 2023

During the first quarter of 2023, 125 million 5G subscriptions were added, lifting the total to around 1.1 billion worldwide

Service providers continue to deploy 5G despite a weaker global economy and geopolitical uncertainties. Around the world, 249 service providers have now launched commercial 5G services, and around 40 have deployed or launched 5G standalone (SA).[1] The most common 5G services launched by service providers for consumers are enhanced mobile broadband (eMBB), Fixed Wireless Access (FWA), gaming and some AR/VR-based services.

Strong 5G subscription growth in North America

The uptake of 5G subscriptions[2] in North America has been stronger than expected, and at the end of 2022 the region had the highest 5G subscriptions penetration at 41 percent. In North East Asia the penetration was 30 percent, followed by the Gulf Cooperation Council countries at 18 percent and Western Europe at 13 percent. In 2028, it is projected that North America will have the highest 5G penetration at 91 percent, followed by Western Europe at 88 percent.

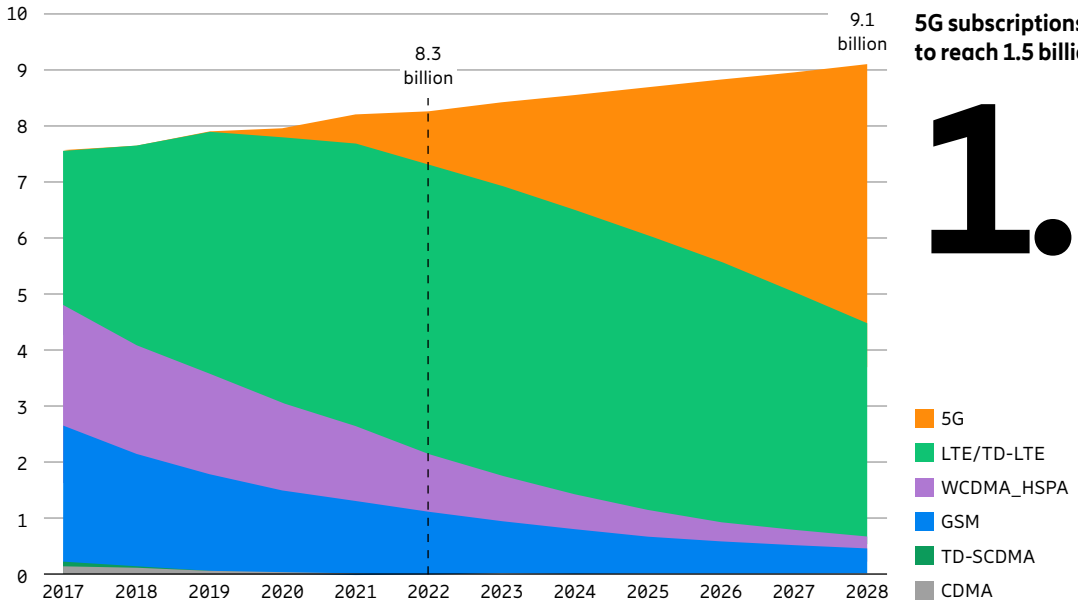
The global 5G subscriptions forecast has been adjusted to take into account delayed spectrum auctions in several countries and continued difficult macroeconomic conditions. 5G subscriptions are now forecast to reach 4.6 billion globally by the end of 2028, making up more than 50 percent of all mobile subscriptions. 5G will become the dominant mobile access technology by subscriptions in 2028.

Subscriptions for 4G continue to increase, growing by 59 million during Q1 2023 to 5.2 billion. 4G subscriptions are projected to start declining from this year to around 3.8 billion by the end of 2028 as subscribers migrate to 5G.

During the quarter, 3G subscriptions declined by 85 million, while GSM/EDGE-only subscriptions dropped by 59 million and other technologies[3] decreased by about 4 million.

China, Bangladesh and Nigeria had the greatest net additions of subscriptions during the quarter, with 4 million added in each country.

Figure 1: Mobile subscriptions by technology (billion)



5G subscriptions are forecast to reach 1.5 billion in 2023.

1.5bn

[1] GSA (March 2023).
[2] A 5G subscription is counted as such when associated with a device that supports New Radio (NR), as specified in 3GPP Release 15, and is connected to a 5G-enabled network.
[3] Mainly CDMA2000 EVDO, TD-SCDMA and Mobile WiMAX.

Continued revenue growth in leading 5G markets

The top 20 5G markets are continuing to convert 5G capabilities into business value, growing revenues by 7 percent over the past 2 years.

Analysis of developments in leading 5G markets shows a strong correlation between increased 5G subscription penetration and service revenue. When data from Q4 2022 is added to previous analysis by Ericsson,[1] it is evident that the positive revenue trend is continuing. As shown in Figure 2, the launch of 5G services in the top 20 5G markets,[2] is followed by a positive revenue development of 3.5 percent CAGR per year over the last 2 years, or 7 percent over the same 2-year period.

Service providers promoting 5G value in times of surging inflation

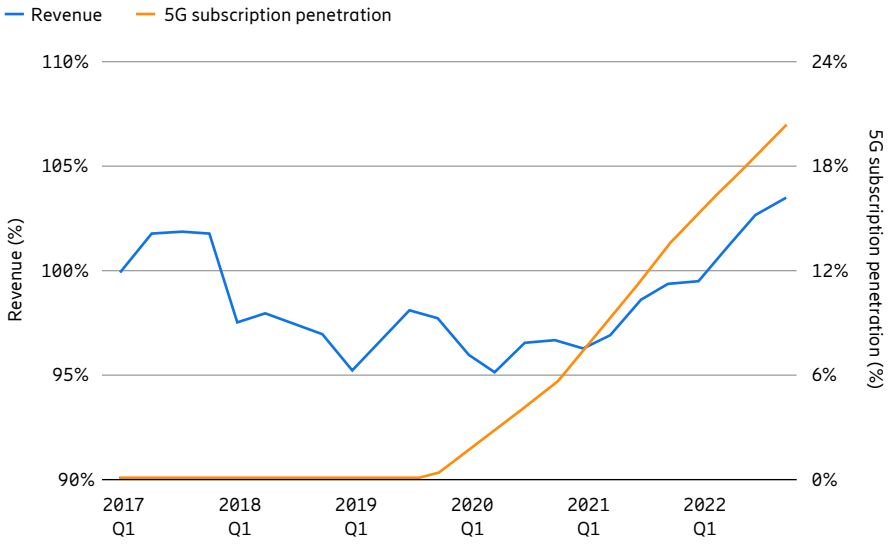
Historically, service providers have found it challenging to increase consumer prices for mobile subscriptions in line with inflation. With the current surge of inflation across many areas, some service providers have now started to adjust their tariffs in relation to the Consumer Price Index (CPI). So far, adjustments have been significantly lower than inflation and this practice is still far from commonplace. As these adjustments only apply to entirely new or renewed contracts, they would have had little impact on revenue growth during 2022.

In contrast to such reactive price adjustments, which provide no incentive for consumers to pay more, the launch of 5G services has proven to be an effective tool for service providers to proactively drive a shift to higher mobile tariffs, while adding value for consumers. Although there is some overlap in the timings of 5G market introduction and surging inflation, this does not diminish the importance of 5G as a catalyst for revenue growth.

Value of connectivity strengthened by new 5G services

5G has created new value for consumer and enterprise customers, with service offerings of larger data buckets, higher speeds, and increased user experiences. For service providers, the additional value provided to consumers and enterprises translates into opportunities for upsell and revenue increase. The revenue trend in Figure 2 indicates this value capture has already begun. As 5G networks and ecosystems mature, with more services and applications being developed and offered, even more value for customers will be unlocked.

Figure 2: Revenue vs. 5G subscription penetration – top 20 5G markets (percent, reference point Q1 2017)



Methodology

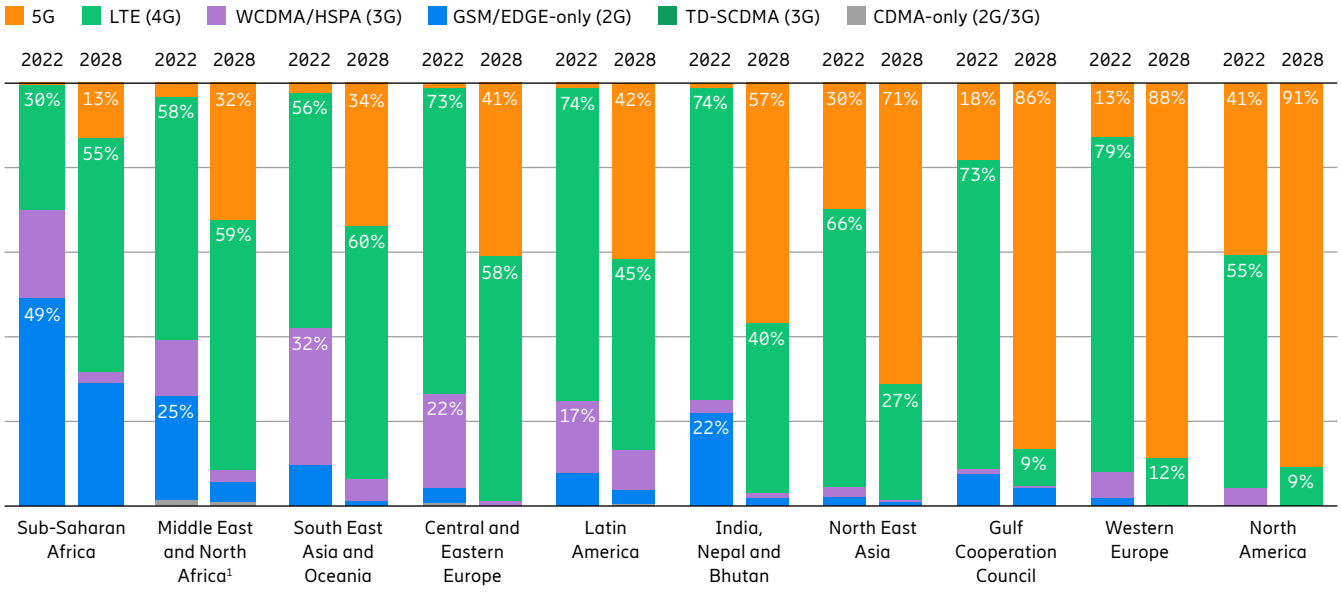
A list of the top 20 5G markets was identified, based on 5G subscription penetration ranking. For each service provider in these markets, relative revenue development was calculated, using the first quarter of 2017 as a reference point (index 1). The development was calculated as a rolling 4-quarter average, to filter out potential seasonal peaks. Finally, individual developments were aggregated into an average development representing all service providers in the top 20 5G markets.

[1] Ericsson Mobility Report – Business Review edition (February 2022).
[2] Markets categorized as the "top 20 5G markets": Australia, Bahrain, China, Denmark, Finland, Hong Kong, Ireland, Japan, Kuwait, Monaco, Norway, Qatar, Saudi Arabia, Singapore, South Korea, Switzerland, Taiwan, UAE, UK, US.

5G subscriptions rising in every region

Uptake is strong in North America, and the region reached a 5G subscription penetration of 41 percent at the end of 2022.

Figure 3: Mobile subscriptions by region and technology (percent)



Sub-Saharan Africa

Despite the challenging macroeconomic environment, nations in Sub-Saharan Africa are expected to invest in network infrastructure, driven by a large youthful population and a high demand for connectivity. This will also enable new growth opportunities for service providers driven by advanced mobile data and value-added services such as mobile banking and payments.

Migration to 3G and 4G networks continues to accelerate. 4G will be the main contributor to new connections up to 2028, accounting for more than half of all mobile subscriptions at the end of the period. While 2G remains an important technology in the region due to low-priced devices, affordability of service plans and a large number of rural subscribers, 2G connections are forecast to decline by 5 percent annually between 2022 and 2028, at which point they will account for 29 percent of the total connections.

5G is forecast to have the fastest growth in subscriptions at around 89 percent annually, attributed primarily to coming from a low base. More than 10 countries in Sub-Saharan Africa have launched commercial 5G networks to date, with more planned, raising the forecast of 5G subscriptions to 13 percent of the total subscriptions base in 2028.

Middle East and North Africa

Service providers are continuing to invest in 4G and are predicted to see subscriptions rise by 4 percent annually between 2022 and 2028, to account for 60 percent of the total subscriptions base in the region at the end of the period.

Strong growth in 5G subscriptions will see these account for 32 percent of the total in 2028, as more countries issue licenses and spectrum to enable 5G network investment.

The focus is on 4G and 5G, driven by the exploration of service offerings requiring high bandwidth and low latency, and the availability of a wide range of devices at attractive price points. As a result, 2G subscriptions will experience a significant decline of close to 15 percent annually between 2022 and 2028, to account for around 5 percent of total subscriptions at the end of the period.

Mobile financial services are expected to continue to gain momentum, with an increase in mobile connectivity and expansion of propositions from basic transfers. Merchant payments to remittances, insurance and other more sophisticated services will also be factors to increase the usage of mobile financial services.

[1] All Middle East and North Africa figures include GCC countries.

Gulf Cooperation Council (GCC)
GCC countries are frontrunners in global 5G network deployments and service offerings, with strong regulatory policies and frameworks as well as public sector initiatives driving acceleration of growth of the 5G market. The GCC region is forecast to experience a slight overall growth in subscriptions, of 1 percent, in the period up to 2028 despite strong economic growth driven by high-priced commodity exports. This will be due to the current high penetration maturity of a relatively small subscriber base. 5G subscriptions are projected to grow steadily at an average annual rate of 30 percent, from 13 to 70 million between 2022 and 2028, accounting for 86 percent of the total subscriber base at the end of the period.

Accounting for 73 percent of total subscriptions currently, 4G is forecast to decline by 29 percent annually as service providers in the region increasingly move subscriptions to 5G, and offer various services such as enhanced mobile broadband (eMBB) and Fixed Wireless Access (FWA). Additionally, service providers will continue to explore enterprise opportunities, as major digital transformation projects take place across various industries.

Central and Eastern Europe
Technology adoption and subscription uptake are typically slower in this region than in Western Europe. This is due in part to slower spectrum allocation processes, as well as consumers being reluctant to upgrade to more expensive subscriptions. 4G is the dominant technology, accounting for 73 percent of all subscriptions at the end of 2022. Mobile subscription growth has flattened and is expected to be virtually zero in the coming years. However, the migration from 2G/3G to 4G continues to look strong up to 2024. From 2025, 5G is expected to be the only growing subscription type.

During the forecast period, there will continue to be a significant decline in 3G subscriptions, from 22 percent of mobile subscriptions to just 1 percent.

South East Asia and Oceania
Service providers are continuing to expand their 5G population coverage. By the end of 2022, 5G was available to 50 percent of the population in Malaysia and 66 percent in the Philippines. At the same time, more than 80 percent of the population in Australia and Thailand had access to the technology, and Singapore achieved more than 95 percent coverage by mid-2022.[2]
Leading service providers in Indonesia that launched commercial 5G services using their existing spectrum holdings are awaiting the release of new 5G spectrum bands to expand their networks. Meanwhile, service providers in Vietnam are making good progress with trials as they await spectrum availability.
5G subscriptions are forecast to reach around 430 million by the end of the forecast period. This is an adjustment to the previous forecast of 620 million, impacted by delayed spectrum auctions in several countries and slower-than-expected growth.

Service providers continue to focus on creating innovative products and services for both consumers and businesses. An example of this is utilizing the capabilities of 5G standalone (SA) to build network slicing use cases. There is significant momentum around 5G FWA. While service providers in Australia and the Philippines continue to expand their commercial 5G FWA offerings, a 5G FWA trial with sub-6 spectrum and mmWave is being carried out in Indonesia. Service providers are also forging partnerships and actively expanding the 5G ecosystem.

Latin America
4G is currently the dominant radio access technology in the region, accounting for 74 percent of all subscriptions at the end of 2022. 4G subscription growth is strong, with close to 59 million added during 2022. However, 3G subscriptions are declining as users migrate to 4G and 5G. Many service providers will sunset 3G networks in the next two years to enable the reuse of radio spectrum for 4G deployments.

The forecast for 5G subscriptions has been pushed forward one year, based on slow uptake and expected continued difficult macroeconomic conditions in the region. There were around 7 million 5G subscriptions at the end of 2022. A more substantial uptake is expected from 2024 onwards. By the end of 2028, 5G will account for 42 percent of all mobile subscriptions.

India, Nepal and Bhutan
Following the launch of 5G services in India in early October 2022, India is seeing aggressive 5G network deployments by service providers. Fast-growing network availability across cities, attractive 5G pricing and the growing availability of 5G smartphones has seen 5G subscriptions reach around 10 million by the end of 2022. Pan-Indian availability of 5G networks by the end of 2023/early 2024 will further fuel growth. 5G subscriptions are expected to reach 700 million and are estimated to account for 57 percent of mobile subscriptions in the region by the end of 2028. Already eMBB and FWA are emerging as the initial use cases for 5G.

Meanwhile, 4G continues to be the dominant subscription type driving connectivity and fuelling data growth in the region. 4G subscriptions are forecast to decline from 820 million in 2022 to 500 million by the year 2028. Total mobile subscriptions in the region are estimated to grow to 1.23 billion in 2028.

North East Asia
Service providers have been investing in 5G to improve coverage and capacity, with a focus on indoor coverage. Strong 5G subscription growth continued in 2022, adding around 240 million subscriptions. 5G is the only growing subscription type and is expected to reach 1.1 billion in the region at the end of 2024. The rapid growth of 5G subscriptions, supported by the availability of more 5G device models, has positively impacted service providers' financial performance. Major service providers in leading 5G markets, such as mainland China, Taiwan and South Korea, have reported a positive impact of 5G subscribers on service revenues and ARPU.

Western Europe
4G is widely deployed and has had the highest penetration of all regions at 79 percent at the end of 2022.
5G subscription growth was strong during the year, rising from 32 million in 2021 to 69 million at the end of 2022.

4G is expected to decline in favor of substantially increased 5G subscription uptake from 2023 onwards. 5G subscriptions are anticipated to reach 143 million at the end of 2023, and penetration will reach 88 percent by the end of 2028. Many service providers will be sunsetting 3G networks in the next few years to enable the reuse of radio spectrum for 4G and 5G.

North America
5G is in the second wave of build-outs and user adoption. The addition of mid-band spectrum now enables superior multi-band 5G experiences for many users. In 2023, 5G adoption is continuing to grow strongly, with more than 200 million smartphone subscriptions expected by the year-end. High-speed internet access to homes and small businesses with FWA has become the primary technology fueling fixed broadband growth in North America. 5G is also growing in the enterprise segment with wireless WAN to branch office locations and to serve ultra-mobile professions. By 2028, around 420 million 5G subscriptions are expected, accounting for over 90 percent of mobile subscriptions.

[2] Population coverage figures for each of these countries as reported by service providers in the region.

North East Asia: A closer look

The North East Asia region consists of five distinct, vibrant markets at the center of modern digital innovation, with 5G being one of the key enabling technologies.

Service providers in the North East Asia region made significant investments in early 5G deployments. South Korea was the first country to launch commercial 5G networks, and these were available in all five markets by 2020. Currently, 5G population coverage and subscription uptake in the region is ahead of most of the rest of the world.

The region is home to key players from across the 5G ecosystem, including leading service providers, Radio Access Network (RAN) vendors, chipset manufacturers, terminal providers and over-the-top (OTT) players. This has helped to realize 5G monetization opportunities in the region with tariff premiums, content aggregation and new service introductions such as Fixed Wireless Access (FWA) and network slicing.

Supported by strong macroeconomics, healthy financial results for service providers and a full ecosystem of wireless and digital industries, regulators and service providers have the ambition to be leaders in the next phase of 5G, as well as 6G in the future.

Japan: Dynamic in technology, steady in deployment

The Japanese mobile market has a strong focus on both the introduction of advanced technologies and sustainability. Major service providers in the country are actively exploring the potential for Cloud RAN, making it a leading market in introducing this technology. The focus on sustainability in Japan is backed up by aggressive plans to be carbon neutral in its own activities by 2030.

In the telecom business environment, Japanese service providers have been impacted by a government-led initiative pressuring them to introduce lower tariff plans, causing ARPU declines since March 2020. However, in recent quarters they have turned this around, and now show a modest increase in ARPU. In addition, they are proactively looking for other revenue opportunities from enterprises and consumer financial services.

Compared to some countries in North East Asia, Japan still has room for additional mid-band deployment, which is the easiest way for consumers to experience high-performance 5G. Service providers are expected to accelerate their investment in 5G deployment, especially with active antennas for achieving better experiences. This will continue to drive a positive experience for consumers and help to realize 5G monetization opportunities.

Mainland China: Leading 5G in scale

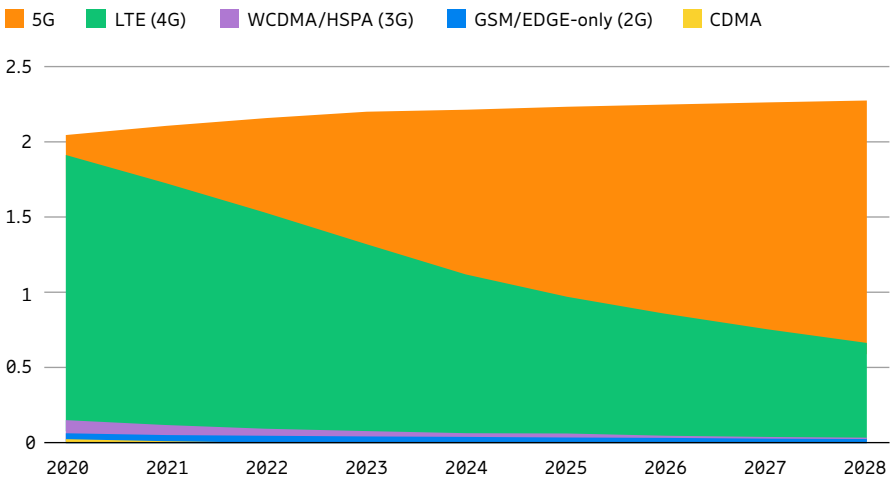
2023 is the fourth year since the commercial launch of 5G. There were 2.64 million 5G sites in the country by the end of the year's first quarter, including mid-band massive MIMO in 2.6 GHz and 3.5 GHz, FDD 700 MHz and 2.1GHz for national coverage, and plenty of dedicated 5G indoor sites.

Around one-third of all mobile subscriptions are currently for 5G. More than 200 million 5G smartphones had been delivered to the market in 2022, which accounted for 35 percent of all global shipments.

The upgrade to SA took place just one year after the 5G commercial launch. Now, all 5G sites and the majority of 5G smartphones have SA capability. Currently, more than 95 percent of 5G traffic is carried by 5G SA technology. Based on SA, new network capabilities have been commercially available for over a year, including network slicing for service separation and differentiated offerings, and VoNR for the evolution of voice. The latest network capability, RedCap, which reduces cost, power consumption and network resource needs from 3GPP R17, is under field trials for cellular IoT solutions.

Leveraging early 5G SA deployment, service providers in mainland China have successfully harnessed 5G private networks as a new growth engine. According to MIIT, more than 14,000 virtual private networks using network slicing were in service by 2022.[1]

Figure 4: North East Asia region mobile subscriptions by technology (million)



[1] MIIT, www.miit.gov.cn/zwgk/zcjd/art/2023/art_9f5022af3cdf48789484117d9da03c58.html.

South Korea: Advanced in 5G adoption and service innovation

Since South Korean service providers launched 5G commercial services in April 2019, they have been at the forefront of 5G deployment and performance. Focus is on 5G mid-band, with no low- or high-band services available yet. However, 5G population coverage has already reached 94 percent. To expand 5G coverage nationwide, service providers have introduced RAN sharing for cost-effective deployment in suburban and rural areas. Service providers have plans to achieve 100 percent population coverage during 2024.

By the end of February 2023, 5G subscription penetration reached over 37 percent, and 5G generated 78 percent of total mobile data traffic. 5G data consumption was around 3.6 times higher than for 4G users when comparing the average across all types of data plans. When comparing data consumption on unlimited plans the difference is around 1.6 times. The government supports service providers' 5G ambitions and the need for capacity, and plans to allocate additional spectrum bands to three service providers. Additionally, the 3.40–3.42 GHz band has already been assigned. South Korean service providers have set targets to achieve Net Zero by 2050. They promote the utilization of renewable energy for RE100 roadmap implementation, an international climate initiative targeting 100 percent renewable energy for business activities.[2]

When it comes to monetization strategies, service providers offer service bundling and innovation in XR/the metaverse. Each service provider is also expanding their business market field from B2C to B2B with AI, data centers and cloud.

Taiwan: Winner in 5G benchmarking

Service providers are continuously improving network performance and are ranking highly in third-party as well as local government benchmarking. Taiwan service providers often appear near the top of 5G global benchmarks.

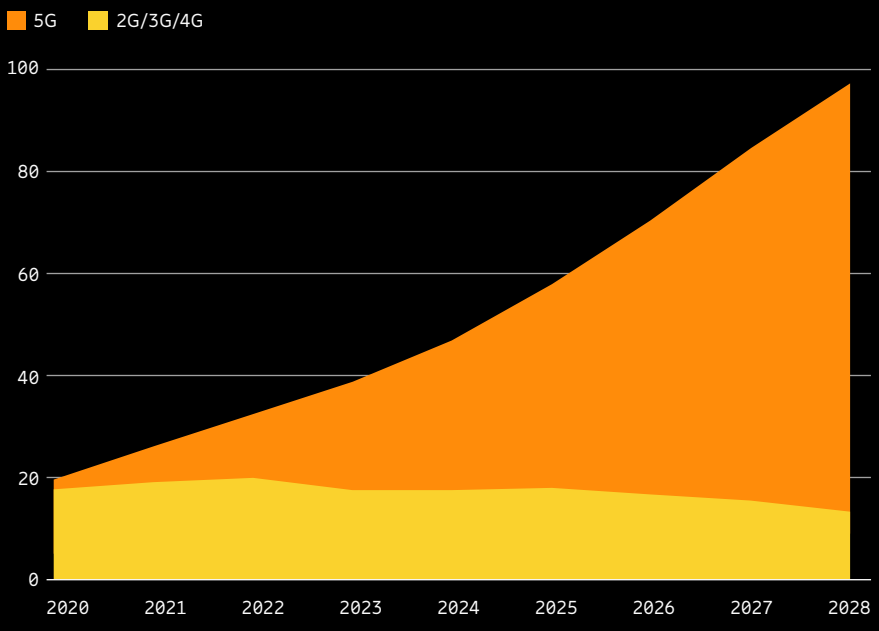
5G subscriptions reached 7 million in Taiwan in Q1 2023, which translates to 30 percent penetration. Major service providers expect penetration to reach 40 percent by the end of 2023. This uptake in 5G has driven an increase in mobile service ARPU over the last 24 months.

As unlimited data plans are prevalent in Taiwan, monthly data consumption is among the highest globally, with an average of 30 GB. A government survey shows 46 percent of consumers connect to mobile networks for internet access even at home.

Hong Kong: Positive 5G uptake

While total mobile subscription growth remains flat-to-slightly-increasing, the transition to 5G continues, with penetration increasing from around 20 percent at the end of 2021 to over 30 percent at the end of 2022. The outlook is positive for 2023, with 5G uptake expected to continue, plus the return of revenue from roaming after the pandemic. 5G FWA and enterprise solutions are regarded as the new business growth areas for service providers.

Figure 5: North East Asia region mobile data traffic (EB per month)



[2] RE100, www.there100.org/

Weak smartphone sales in 2022, potential for market recovery at the end of 2023

2022 marked the worst year for smartphone sales volume in 10 years, with the hope of recovery starting in the second half of 2023. The high-end segment shows some resilience, and global market leaders performed better than average.

Weak smartphone market is not stopping 5G adoption

- The fourth quarter of 2022 saw a double-digit decline in the smartphone market, continuing the previously reported trend in the first three quarters. The trend continued at the beginning of 2023, with global shipments dropping by 13 percent year-on-year in the first quarter.
- Over 870 5G smartphone models have been launched in total, with more than 80 so far in 2023.
- 5G smartphone models accounted for 57 percent of smartphones shipped in 2022. This is expected to rise to around 62 percent in 2023.
- Foldable device shipments grew by 26 percent in 2022, despite the weak smartphone market. This category represents 1 percent of the smartphone market and is expected to increase to 3 percent by 2026.

Evolution of network slicing and 5G SA

The network slicing market continues to evolve, with the recent introduction of this technology for laptops running Microsoft Windows 11, enabling applications for both enterprise and consumer use cases. A growing number of service providers are enabling New Radio standalone (SA) in their networks. As non-standalone (NSA) and SA support can coexist in a network, and SA-capable devices retain support for the NSA mode of 5G, many SA deployments are carried out in a stepwise fashion. Device manufacturers can upgrade the software on devices when sufficient testing has been performed. With increased carrier aggregation capabilities in networks and devices, the SA proposition is now deemed to be on par with NSA in terms of data rates, while adding to the many benefits of the new 5G core network.

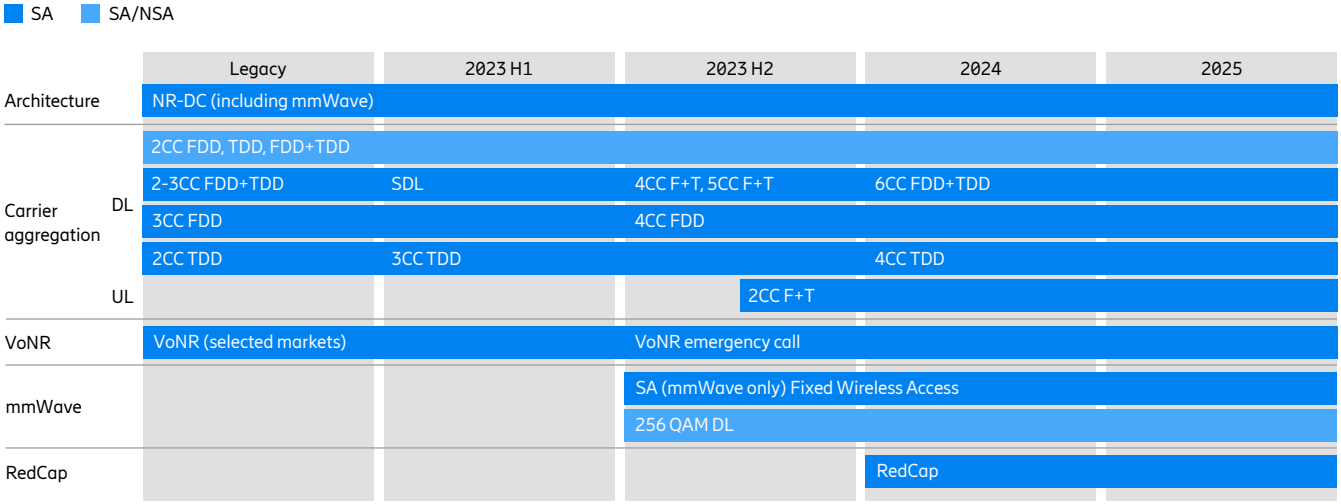
Redcap – the new kid on the block

SA technology is further strengthened by the introduction of reduced capability (RedCap), that utilizes the benefits of SA. Since the last Ericsson Mobility Report, the first RedCap devices have been announced. These are based on 3GPP Release 17 and are expected to target the current market for LTE Cat-4 devices such as smart watches, pocket routers and IoT. A second wave of RedCap devices are expected to come to market a few years later, competing with and replacing the low-cost and power-efficient IoT devices currently using LTE Cat-1. The presence of LTE fallback is expected to remain for the foreseeable future.

Non-terrestrial networks (NTN)

Support for non-terrestrial connections in ordinary smartphones has started to emerge in the last year. Satellite-based networks can provide outdoor coverage in nearly any location globally, but find it challenging to provide the capacity of a ground-based network. The first initiatives have targeted emergency and personal safety use cases based on proprietary solutions. The use of 3GPP-based NTN technology is expected to open this market on a global scale.

Figure 6: 5G technology market readiness



Note: The graph illustrates the availability of network functionality, as well as support in devices.

4G/5G IoT connections rising as 2G/3G declines

LTE Cat-1 devices are increasingly being used for a variety of use cases.

The Massive IoT technologies NB-IoT and Cat-M – supporting wide-area use cases involving large numbers of low-complexity, low-cost devices with long battery lives and low-to-medium throughput – continue to be rolled out around the world. Globally, 125 service providers have deployed or commercially launched NB-IoT networks and 56 have launched Cat-M, while 39 have deployed both technologies.[1] The number of devices connected by these technologies reached almost 500 million at the end of 2022. The growth of Massive IoT technologies is enhanced by added capabilities in the networks, enabling Massive IoT to co-exist with 4G and 5G in FDD bands, via spectrum sharing.

IoT devices connected via 2G and 3G are in slow decline, and are predicted to have a negative annual growth rate of around 20 percent up to 2028, as the rate of switch-off for both technologies will continue to increase in the coming years.

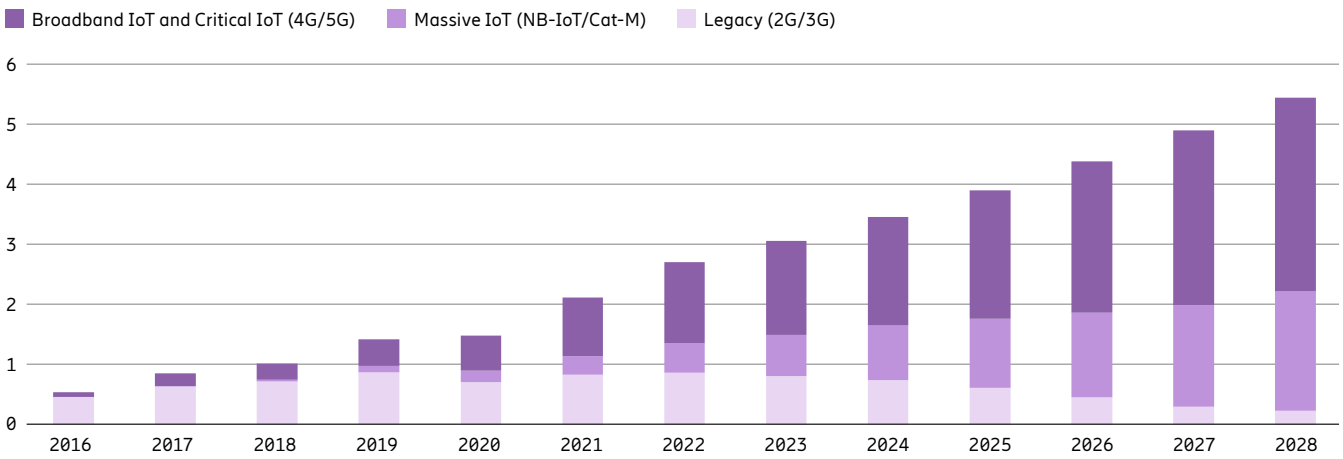
In 2022, broadband IoT (4G/5G) reached 1.3 billion connections, and is the technology that connects the largest share of all cellular IoT devices. This segment mainly includes wide-area use cases that require higher throughput, lower latency and larger data volumes than can be supported by Massive IoT devices. LTE Cat-1 devices, which support 10 Mbps downlink and 5 Mbps uplink speeds, are increasingly being used for a variety of use cases. Broadband IoT will be further strengthened by the introduction of RedCap. By the end of 2028, almost 60 percent of cellular IoT connections are forecast to be broadband IoT, with 4G connecting the majority. As 5G New Radio (NR) is being introduced in old and new spectrum, throughput data rates will increase substantially for this segment.

North East Asia is the leading region in terms of the number of cellular IoT connections, and is expected to pass 2 billion connections in 2023.

Figure 7: IoT connections (billion)

IoT	2022	2028	CAGR
Wide-area IoT	2.9	6.0	13%
Cellular IoT[2]	2.7	5.4	12%
Short-range IoT	10.2	28.7	19%
Total	**13.2**	**34.7**	**18%**

Figure 8: Cellular IoT connections by segment and technology (billion)



[1] Source: GSA March 2023.
[2] These figures are also included in the figures for wide-area IoT.

FWA services now offered by 80 percent of service providers worldwide

A total of 40 percent of Fixed Wireless Access (FWA) service providers are offering services over 5G. North America and Western Europe have the highest regional adoption with close to 70 percent of FWA service providers offering it over 5G.

FWA is growing solidly in terms of:
- number of mobile service providers offering FWA
- proportion of those offering FWA over 5G
- proportion of those offering FWA with speed-based tariff structures
- amount of traffic served as both number of connections and traffic volume per connection increase.

Global FWA momentum
An updated Ericsson study of retail packages offered by mobile service providers showed that around 80 percent had an FWA offering, up from 77 percent in November 2022. There are now 100 service providers, representing 40 percent of FWA service providers, offering services over 5G.

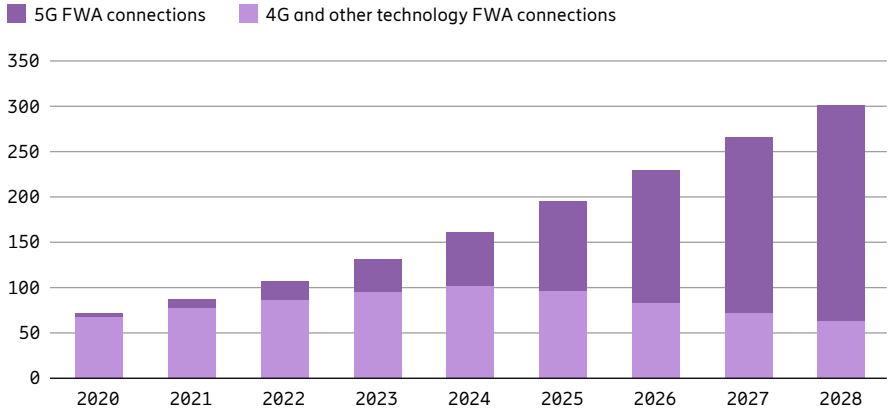
Continued increase of speed-based tariff plans
Speed-based tariff plans are commonly offered for fixed broadband services such as those delivered over fiber or cable. This type of plan is well understood by consumers, enabling service providers to monetize FWA as a broadband alternative.

Over one-quarter of service providers now offer speed-based tariff plans (also referred to as quality of service, or QoS). The remaining three-quarters are still best-effort, with volume-based tariff plans (buckets of GB per month).

Regional variations
There are large regional variations in the proportion of service providers adopting FWA:
- In North America, Western Europe, Central and Eastern Europe as well as Middle East and Africa, over 80 percent of mobile service providers offer FWA.
- Currently, North America stands out as the region in which all of the service providers studied have an FWA offering.
- North America is also on top for the percentage of service providers offering speed-based tariff plans, with it being provided by 90 percent.
- In both North America and Western Europe, 70 percent of FWA service providers are offering services over 5G.
- The US has now passed 5 million 5G FWA connections.

FWA service provider advancements
- A major service provider in India has expressed the goal of serving 100 million homes and businesses with a combination of 5G FWA services and fiber in the coming 2 to 3 years.
- A service provider in Norway has become the first in Europe to close its copper DSL network, and replace 51,000 of its connections with FWA services. This enabled energy savings comparable to usage levels of a medium-sized Norwegian city.
- Oman – where 41 percent of all broadband connections are FWA – experienced a 95 percent annual 5G FWA revenue increase in 2022 (year-on-year).
- All major service providers have launched 5G FWA over SA (standalone) in Japan, with one leading provider reporting that connections grew 9 times in the last 7 quarters to reach 664,000.

Figure 9: FWA connections (millions)



Definition of FWA
FWA is a connection that provides primary broadband access through mobile network-enabled customer premises equipment (CPE). This includes various form factors of CPE, such as indoor (desktop and window) and outdoor (rooftop and wall-mounted). It does not include portable battery-based Wi-Fi routers or dongles.

Figure 10 : Global FWA service provider adoption: 2020–2023

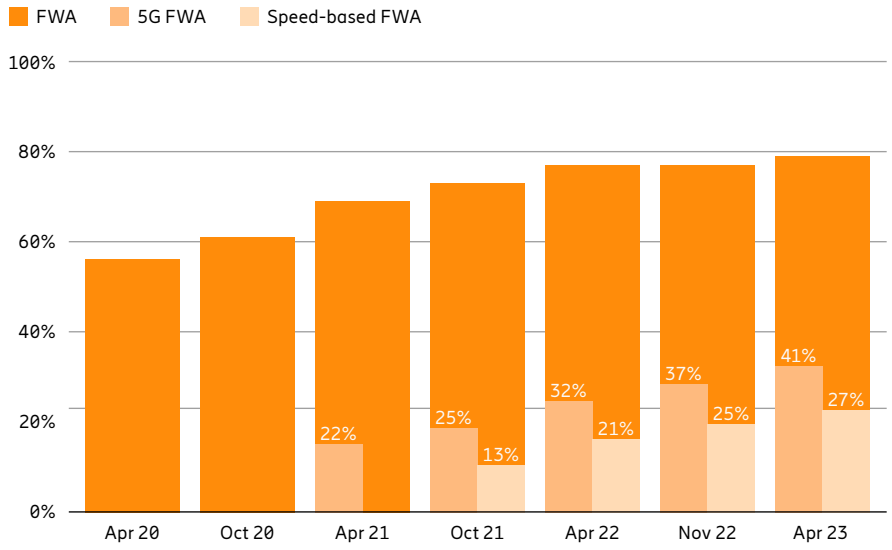


Figure 11 : Regional FWA service provider adoption 2023

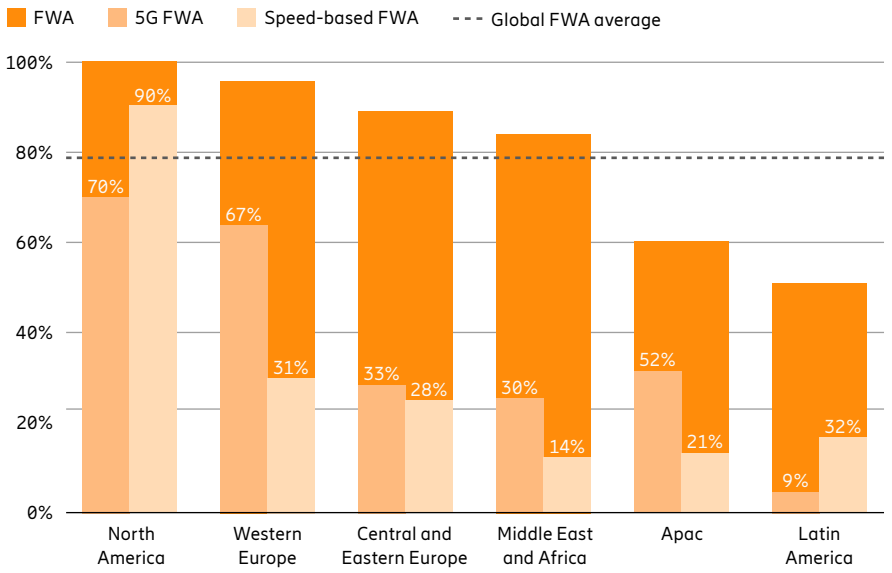
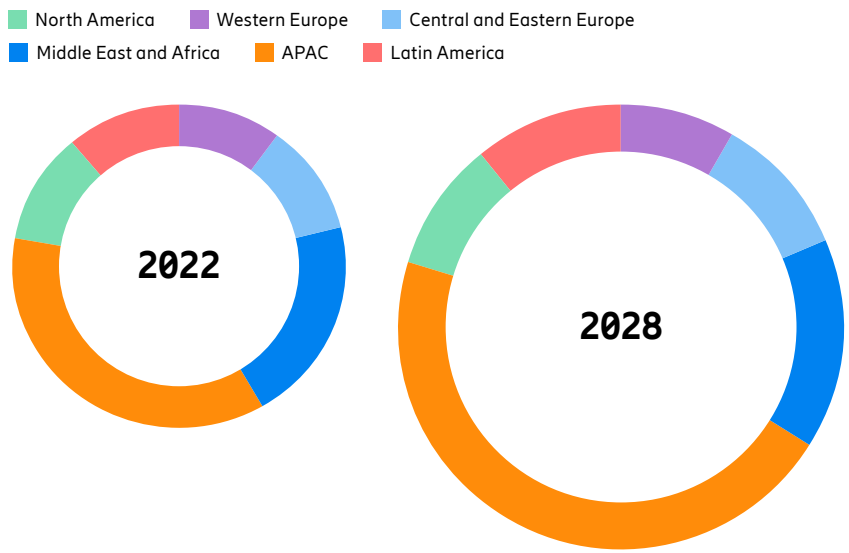


Figure 12: Regional split in FWA connections: 2022–2028



By 2028, 5G will account for almost 80 percent of FWA connections.

80%

Over 300 million FWA connections by 2028
From 100 million at the end of 2022, FWA connections worldwide are projected to increase to 300 million by the end of 2028. This represents 17 percent of all fixed broadband connections. Of the 300 million projected connections, nearly 80 percent are expected to be over 5G.

Almost half of global FWA connections in Asia-Pacific (APAC) by 2028
The forecast has taken the high ambitions of 5G FWA in emerging markets into account, increasing the number of connections as well as the share of 5G FWA connections. Higher volumes of 5G FWA in large, high-growth countries such as India have the potential to drive economies of scale for the overall 5G FWA ecosystem, resulting in affordable CPE that will have a positive impact across low-income markets.

The number of FWA connections in APAC is expected to nearly triple, increasing its share of global FWA connections from 30 to 46 percent by 2028.

FWA's impact on global mobile data traffic
FWA data traffic represented 21 percent of global mobile data traffic at the end of 2022 and is projected to grow more than 5 times to nearly reach 130 EB in 2028 – about 30 percent of mobile data traffic.

Almost half of global FWA connections will be in APAC by 2028

50%

FWA to represent 30 percent of global mobile data traffic by 2028

30%

5G continues to drive innovation in mobile service packaging

As 5G begins to be seen as the default offering for consumers, service providers are actively seeking to move subscribers from older generation networks.

Key insights

- As 5G matures, service providers are making it the standard choice for consumers. Only 22 percent of service providers that still offer 4G are differentiating the price of their 5G offerings.
- Around 58 percent of 5G service providers offer bundles with entertainment services included, such as television and music streaming or cloud gaming platforms.
- On a country level, there is often very little or no differentiation between the prices and packages for smartphones and subscriptions offered by different service providers.

An updated Ericsson study[1] of retail packages offered by 310 mobile service providers worldwide shows that as 5G matures, service providers are making it the standard choice for consumers. Only 22 percent of the 182 service providers offering 4G are showing a price difference which the consumer needs to pay in order to gain access to 5G service. Interviews undertaken in December 2022 and January 2023 reveal that many service providers want to actively move users over to 5G, as it is the more efficient technology.

The practice of having long-term contracts as the default for SIM-only plans seems to continue and expand among service providers, with most of them setting the default option on their websites to 24-month contracts instead of 30 days. Additionally, most offer a discount on the 24-month option to incentivize users to choose this over to the 30-day contract option.

Some form of data buckets are available from nearly 99 percent of the surveyed service providers, while 43 percent offer at least one unlimited data package to consumers. Service providers with 5G commonly have more unlimited packages available, sometimes limiting bucket packages to prepaid offers. Around 17 percent of the service providers offering unlimited data have some boundary conditions tied to the offer. The majority (79 percent) with such terms and conditions are among those who offer 5G.

There is a continuous shift back and forth among the base offers, and during the 6 months since the previous survey, 16 service providers have removed their unlimited offers, while 17 have newly introduced this type of package. This represents over 10 percent of the mobile service providers in the survey. Similar changes have been seen in the past, revealing some uncertainties and a lot of experimentation. An example of this change is a service provider that removed unlimited data from the general offerings and made it exclusive to those customers who subscribe to a bundle combining a fixed and a mobile subscription.

Nearly 70 percent of the service providers who removed their unlimited offerings now provide service-based connectivity packages instead. With this type of package consumers can purchase some form of add-on package, such as a "streaming pass" that allows consumption of video at an attractive price without using data from the base bucket.

The total number of service providers offering some type of service-based connectivity has reduced from 179 to 176. At the same time, those who target high-consumption services like video streaming, cloud gaming, or high-definition audio remain at the same level (119).

Some shifts can be seen in this area, with a small drop in service providers offering monthly unlimited packages, while there is an increase in those offering time-based packages instead. These are designed either as "buckets of hours," for example video streaming, to be consumed over a month, or for a few continuous hours of unlimited consumption, which consumers simply buy "on demand" before starting a movie or a gaming session.

A new type of connectivity package which emerged during the pandemic typically offers discounted GB to use when working or studying from home. These types of packages started in South East Asia, expanded into Eastern Europe, and are now also appearing in a few countries in Latin America.

Extracting a premium rate for 5G

The number of service providers that offer 5G continues to increase and around 59 percent of those surveyed have now launched 5G for smartphones. Of these, 22 percent charge a premium for 5G over 4G, down from 25 percent in the November survey. This number is expected to continue to decrease as 5G matures and service providers actively move users from their previous generation networks.

Only 22 percent of service providers offering 4G have a price difference for 5G services.

22%

[1] May 2023

Content aggregation and gaming attract consumers to 5G

It is common to offer bundles with various popular entertainment services included, such as television, music streaming or cloud gaming platforms. Around 58 percent of 5G service providers are doing this in various forms. The most common practice is to increase the bundle value (content) as the price of the tiers increases. Another way of offering value-added services is for service providers to act as content aggregators. Here, the service provider offers a menu where the consumer can choose from a (sometimes large) variety of monthly or yearly subscriptions. In most cases, this menu is available regardless of which tier a subscriber is on, and the consumer has almost complete flexibility in terms of the number of services that can be added. The most proactive service providers place these offers clearly in the path of any customer shopping for a smartphone or SIM card subscription. The value-add offered is not limited to digital content or streaming services but can include things like football season tickets, cooking classes or yoga sessions. Besides being able to find all services in one place and sign up in a simple manner, a key benefit to consumers is often a small discount when selecting two or more of these services.

Using speed tiers to segment offerings

In our November 2022 updated study, it was found that 24 percent of 5G service providers differentiated their offerings for smartphones by using speed tiers. This number remains at 24 percent, although the total number of service providers with 5G has increased from 174 to 182 in the survey. Around 68 percent of these service providers use speed tiers in some combination with data buckets, and 39 percent have a hybrid version (speed in combination with both data buckets and unlimited data tiers). Two service providers with 4G networks are also using speed to differentiate their packages.

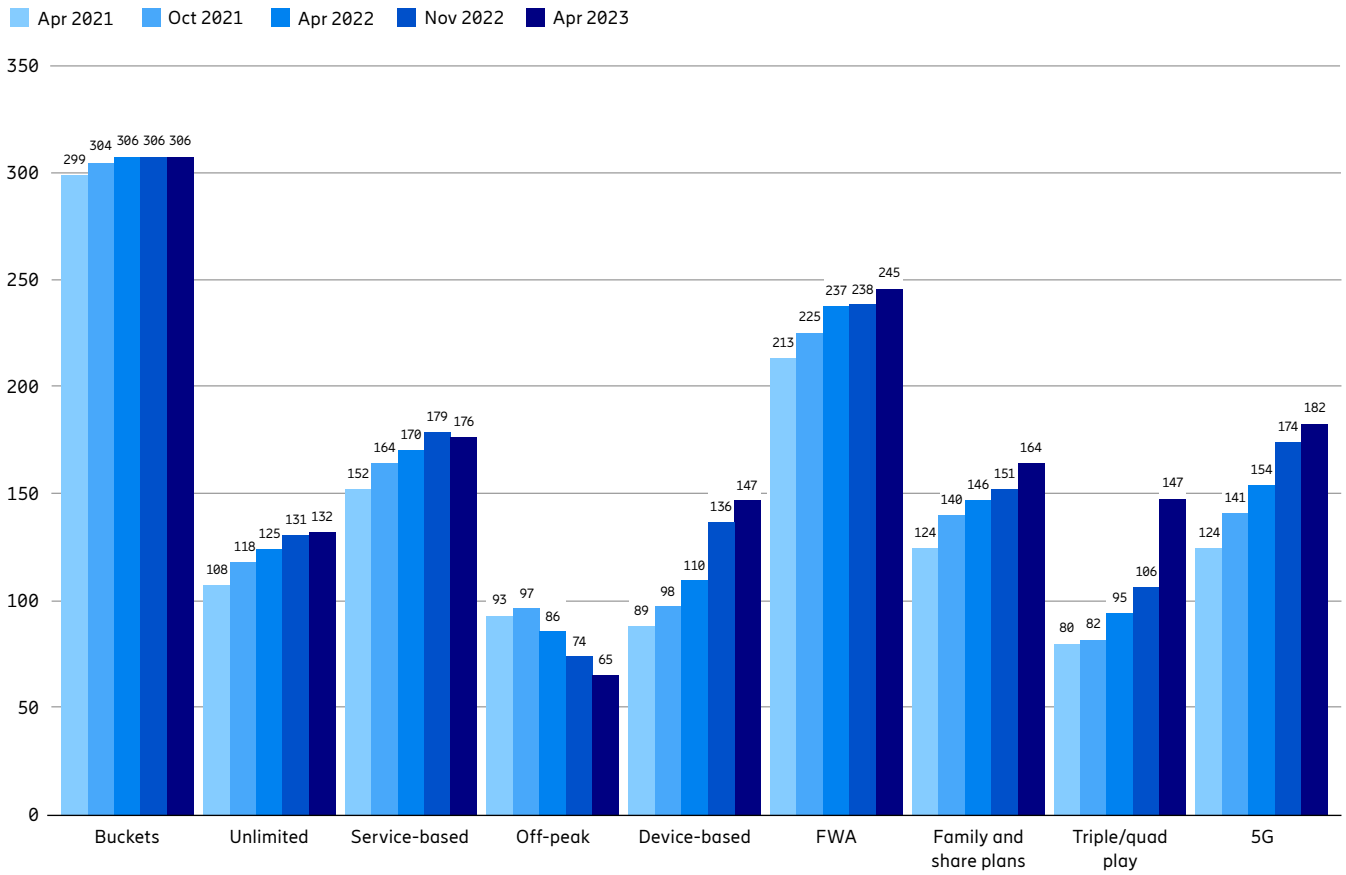
This model is most common in Western Europe, where the highest proportion of unlimited offerings can be found. Here, around 60 percent of all service providers use speed tiers in combination with data buckets and 15 percent have a hybrid version (speed in combination with both buckets and unlimited data tiers).

Lack of local differentiation

On a global level, there is considerable variation and the number of different packages used, as well as choices available to consumers, are increasing. However, at a country level, there is often very little or no differentiation at all. For a consumer who is shopping for a new phone or subscription, the prices and packages from the service providers in the country are generally very similar. This is especially apparent in Western Europe where there appears to be more focus on price than other differentiating factors. In rare cases, there is one challenger service provider that has tried to streamline its offering, limiting it to only two or three packages. However, in most cases they simply mimic their larger competitors, with some small price benefit for the consumer. Where new packaging schemes are being introduced, it seldom takes more than a few months before others follow with very similar packaging.

This is especially obvious where new ideas are being introduced, such as speed tiers. In most countries where speed tiers exist, most or all service providers in that country offer them. However, it is quite common for the challenger to stand out by offering only the maximum speed across all its price tiers.

Figure 13: Operator service offerings



High-data users driving mobile traffic

A significant proportion of traffic is generated by a limited number of users, while application mix changes across subscriber clusters.

Traffic measurements from mobile networks in two advanced mobile broadband markets show similarities and differences in application usage among different subscribers, grouped in clusters based on their monthly data traffic consumption.

The analysis is restricted to data consumption on devices over cellular networks, and subscriber groups have been clustered based on their monthly data usage. It is based on data from traffic measurements in two commercial 4G and 5G networks in Europe and North America.

One-tenth of users generate 70 percent of traffic

The distribution of subscribers across different clusters and their data consumption varies from market to market, mostly depending on available data tariff plans. However, the traffic contribution of the top percentile of users (in terms of data consumption) is usually very similar. In both networks sampled, the top 10 percentile of users generated around 70 percent of the total traffic. In the North American network, users consuming over 20 GB per month represented only around 14 percent of all users, but generated 80 percent of the total traffic. A similar pattern was found in the European network, where users with consumption over 20 GB per month represented around 17 percent of all users, but generated 81 percent of the total traffic. Users with a monthly data consumption of over 50 GB represented only around 5 percent of users in the North American network and 7 percent in the European network.

Light consumers of data, those consuming less than 5 GB per month, make up 63 percent of all users in the European network. Among these users, a significant share of traffic, 16 percent, comes from communications services (messaging, VoIP, video calls and so on) and web browsing, while over 30 percent of traffic comes from a long tail of various apps.[1]

Application mix and traffic share in sampled networks

When analyzing the application mix and share of traffic in the sampled networks, it should be considered that these might not represent the absolute shares of the total traffic, as some traffic could not be classified. For example, the absolute share of video traffic is presumably higher across all subscriber clusters, as part of it is included in the category "Other". However, it remains true that analyzing the relative changes in application mix over subscriber clusters provides insights into different data consumption patterns.

Video consumption: The dominant activity across all subscriber clusters. Intense and extreme users have the highest percentages of video consumption, accounting for over 60 percent[2] of total traffic in the sampled networks. Share of video increases by more than 20 percentage points when comparing light to intense users in both networks.

Social networking: The second most-consumed application after video. The highest share of social traffic is in the moderate to medium user group in both sampled networks.

Audio: There is a difference between the sampled networks, where the North American network share is 2–3 percent across subscriber clusters, while it is less than 1 percent in the European network.

Gaming[3] and software downloads: This category represents a relatively low percentage of traffic. For gaming, it is below 1 percent across subscriber clusters up to intense users, with an increasing percentage share for clusters with higher data consumption. This suggests that heavy and extreme users are more likely to engage in downloading software and gaming compared to other clusters. The share of gaming for extreme users in the European network was around 3 percent and in the North American network around 2 percent.

In both networks, the share of traffic for software downloads, file sharing and gaming was significantly higher for the extreme users compared to all other clusters.

Traffic share increase for video-on-demand among high-data users

In both sampled networks, social media-generated video is decreasing, while Video-on-Demand (VoD) streaming services are increasing their traffic share across subscriber clusters when going from light users to extreme users.

North America: Social media-generated video is experiencing a decline in its share of video traffic, from 88 to 49 percent, while the share of VoD streaming services is increasing from 4 to 23 percent.

In the North American network, YouTube has the highest share of video traffic across all user groups, with light and moderate users having the highest percentage. This is followed by Facebook and TikTok up to and including heavy users. For subscriber groups with more than 50 GB per month of data consumption, TikTok has a higher share than Facebook.

Europe: Social media-generated video is experiencing a decline in its share of video traffic, from 93 to 71 percent, while the share of VoD streaming services is increasing from 1 to 17 percent.

In the European network, Facebook has the highest share of video traffic across all user clusters, with light and moderate users having the highest percentage.

[1] For example: email, location services, photo sharing, weather, presence, health or fitness.
[2] Unclassified video traffic is part of the category "Other."
[3] Includes both app-based and cloud gaming.

Figure 14: European service provider: Subscriber and traffic volume per application type of different subscriber clusters

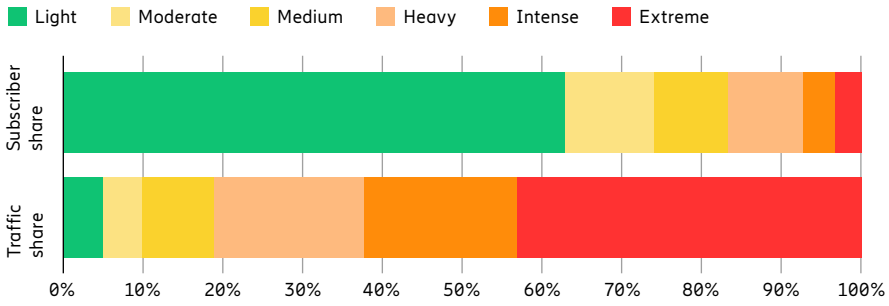


Figure 15: North American service provider: Subscriber and traffic volume per application type of different subscriber clusters

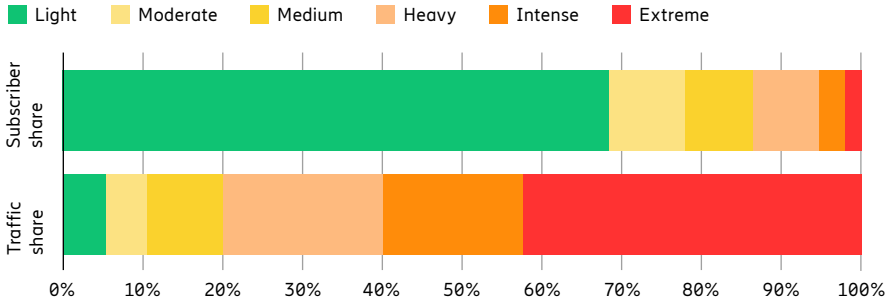


Figure 16: European service provider: Traffic volume per application type of different subscriber clusters

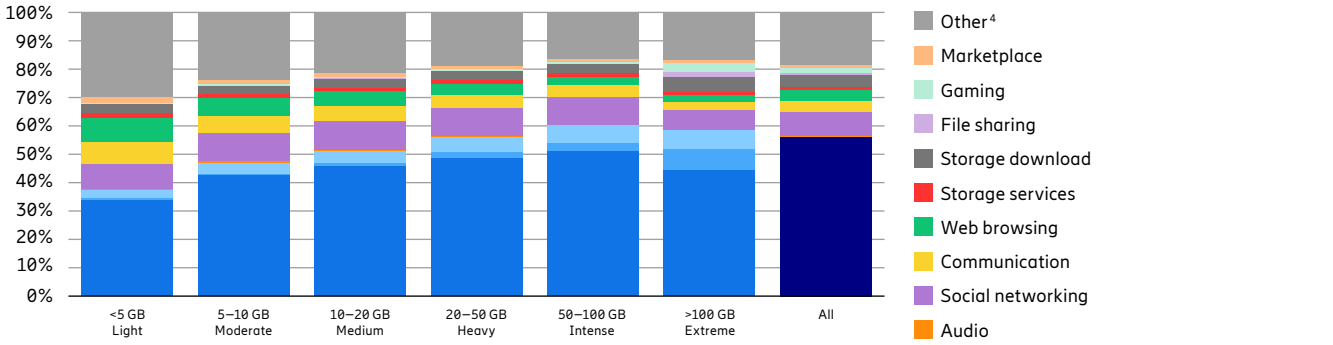
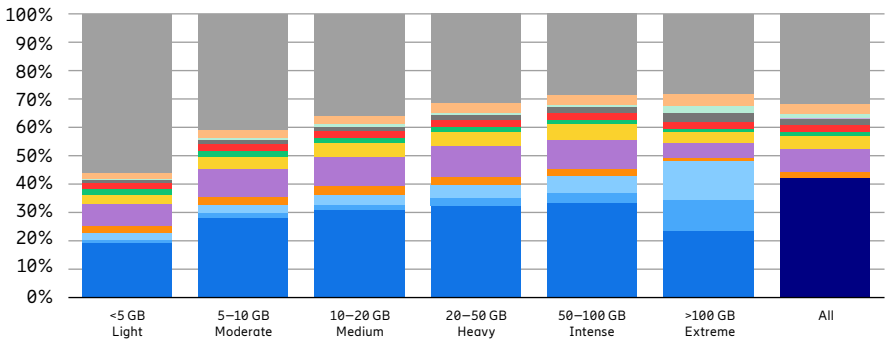


Figure 17: North American service provider: Traffic volume per application type of different subscriber clusters



[4] "Other" includes uncategorized traffic and traffic from services that have too small a share to be significant compared to the categorized segments in this figure. A large share of "Other" is presumably video traffic.

[5] "Unclassified" includes video traffic that was not possible to identify as a specific service or has too small a share to be significant compared to the specified services.

In both networks, the Netflix share of traffic goes from 1–5 percent share among light to intense users to make up around 13 percent of the video traffic among extreme subscribers (> 100 GB per month).

Facebook and YouTube have the highest video traffic share in both networks across all subscriber clusters, with a typical joint share of 50–60 percent of total traffic.

Across both networks, Facebook has a significant percentage of video traffic share for all subscriber clusters, but its share decreases significantly with increasing data consumption. The YouTube share of traffic displays a similar trend, while TikTok shows a trend toward an increasing share of traffic with increasing data consumption.

Conclusion

Video is having a significant influence on data consumption and traffic volumes in advanced mobile broadband markets. This trend is being driven by intense and extreme users, who have the highest percentages of video consumption. Video traffic share changes across subscriber clusters when going from light users to extreme users, with social media-generated video declining its share in favor of a higher share of VoD streaming services.

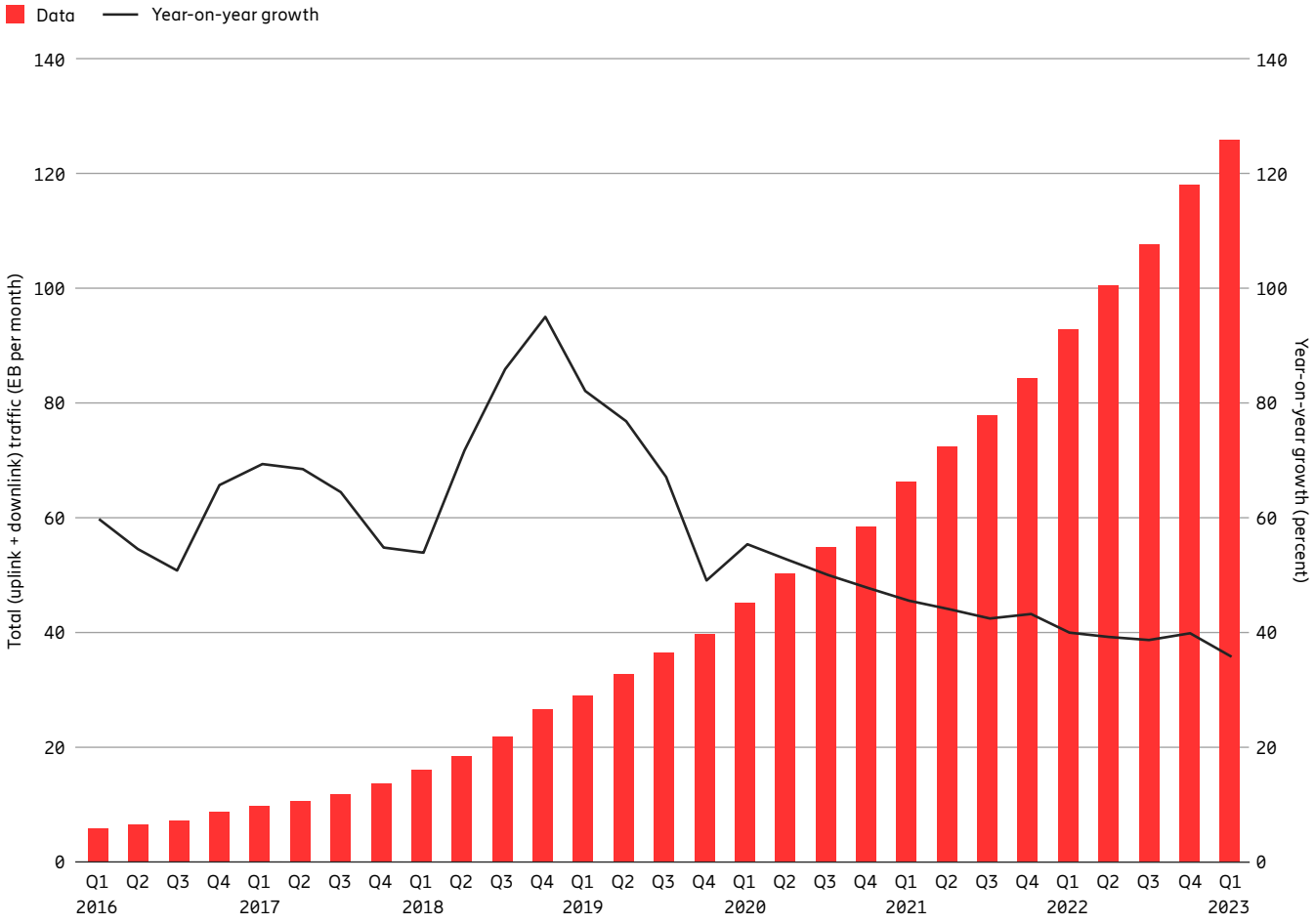
Mobile network traffic keeps doubling every two years

Mobile network data traffic grew 36 percent between Q1 2022 and Q1 2023

The quarter-on-quarter mobile network data traffic growth between Q4 2022 and Q1 2023 was around 7 percent. Total monthly global mobile network data traffic reached 126 EB. In absolute numbers, this means mobile network traffic has almost doubled in just 2 years, from 66 EB per month in Q1 2021.

Long-term traffic[1] growth is being driven by both rising smartphone subscriptions and increasing average data volume per subscription, fueled primarily by increased viewing of video content. Figure 18 shows the net addition and total global monthly network data traffic from Q1 2016 to Q1 2023, along with year-on-year percentage growth for mobile network data traffic.

Figure 18: Global mobile network data traffic and year-on-year growth (EB per month)



Source: Ericsson traffic measurements (Q1 2023).
Note: Mobile network data traffic also includes traffic generated by Fixed Wireless Access services.

[1] Traffic does not include DVB-H, Wi-Fi or Mobile WiMAX. VoIP is included.

5G to drive all mobile data growth within 5 years

In 2028, all growth in mobile data traffic will come from 5G, as 4G traffic is set to decline.

Total global mobile data traffic – excluding traffic generated by Fixed Wireless Access (FWA) – reached 93 EB per month at the end of 2022 and is projected to grow by a factor of 3.5 to reach 329 EB per month in 2028. When FWA is included, total mobile network traffic reached around 118 EB per month at the end of 2022 and is expected to reach 472 EB per month by the end of 2028. Predicted traffic growth up to 2028 includes an assumption that an initial uptake of XR-type services, including AR, VR and mixed reality (MR), will happen in the latter part of the forecast period. However, if adoption is stronger than expected, data traffic could increase significantly more than currently anticipated toward the end of the forecast period, particularly in the uplink. Currently, video traffic is estimated to account for 71 percent of all mobile data traffic, a share that is forecast to increase to 80 percent in 2028.

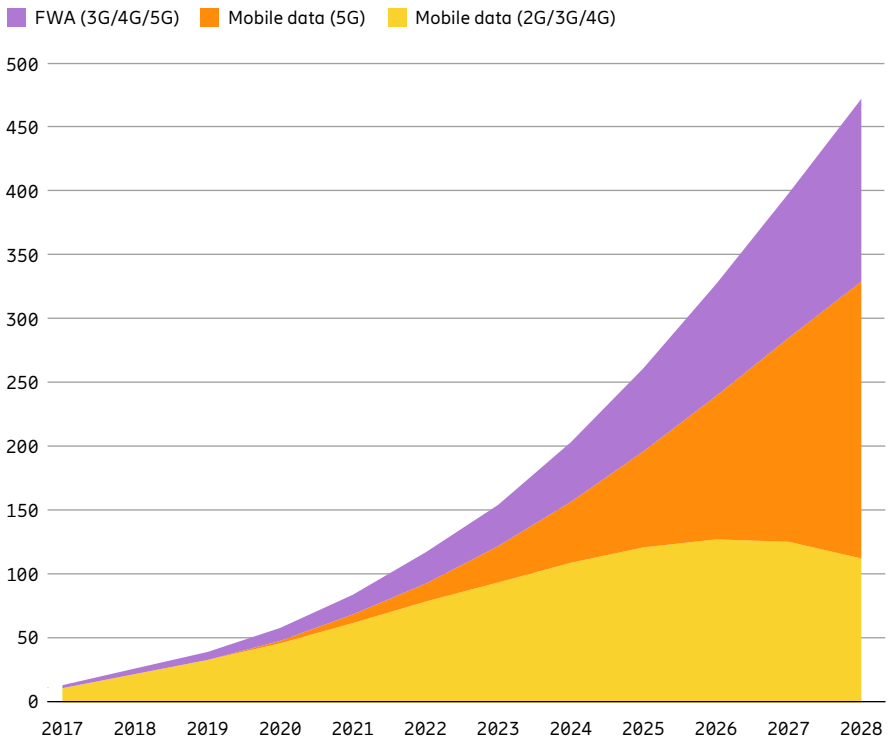
Populous markets that launch 5G early are likely to lead in terms of traffic growth over the forecast period. 5G's share of mobile data traffic was 15 percent at the end of 2022, an increase from 9 percent at the end of 2021. This share is forecast to grow to 66 percent in 2028. By then all growth in mobile data traffic will come from 5G.

Traffic growth varies across regions

Traffic growth can be highly volatile between years and can vary significantly between countries, depending on local market dynamics. Globally, the growth in mobile data traffic per smartphone can be attributed to three main drivers: improved device capabilities; an increase in data-intensive content; and growth in data consumption due to continued improvements in the performance of deployed networks.

An example of these differences can be seen in the contrast between the Sub-Saharan Africa region, where the average monthly mobile data usage per smartphone was 4.7 GB, and the Gulf Cooperation Council (GCC) countries which had 26 GB per smartphone at the end of 2022. The global monthly average usage per smartphone is anticipated to exceed 20 GB in 2023 and is forecast to reach 47 GB by the end of 2028.

Figure 19: Global mobile network data traffic (EB per month)

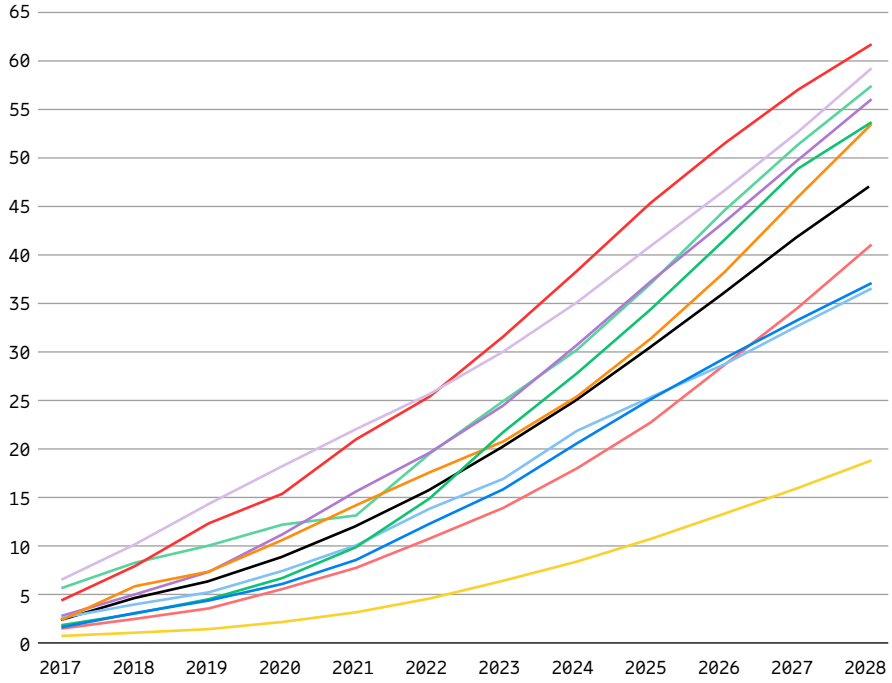


FWA affecting traffic patterns in North America

Average monthly mobile data usage per smartphone in North America is expected to reach 58 GB in 2028, as unlimited data plans and improved 5G network coverage and capacity increasingly attract new mobile and fixed 5G subscribers. The data traffic generated per minute of use will increase significantly in line with the expected uptake of gaming, XR and video-based apps. These experiences require higher video resolutions, increased uplink traffic, and more data from devices off-loaded to cloud computing resources to satisfy users. FWA has started to affect overall traffic patterns. In 2028, we predict that 5G subscription penetration in North America will be the highest of all regions, exceeding 90 percent.

In **Western Europe**, service usage and traffic growth are expected to follow similar patterns to those anticipated for North America. Although a more fragmented market situation has led to a later mass-market adoption of 5G, by 2028 traffic usage per smartphone is projected to reach 56 GB per month – close to the usage in North America at that time.

Figure 20: Mobile data traffic per smartphone (GB per month)



Regions	2022	2028	CAGR 2022–2028
India, Nepal, Bhutan	26	62	16%
GCC	26	59	15%
North America	20	58	20%
Western Europe	20	56	19%
North East Asia	18	54	20%
South East Asia and Oceania	15	54	24%
Global average	16	47	20%
Latin America	11	41	25%
Middle East and North Africa[1]	12	37	20%
Central and Eastern Europe	14	37	18%
Sub-Saharan Africa	4.7	19	26%

The **North East Asia** region's share of total global mobile data traffic is expected to be around 30 percent in 2028. In the region, 5G subscribers currently use, on average, 2–3 times more data than 4G subscribers. As more 4G subscribers migrate to 5G, average mobile data traffic per smartphone will increase and reach 54 GB per month in 2028. Video is the dominant traffic type. Additional traffic growth is expected with the introduction of new video services, for example high-definition video and XR services.

Sub-Saharan Africa is forecast to be the region with the highest growth in total mobile data traffic, rising by 37 percent annually between 2022 and 2028 as service providers across the continent continue to invest in 4G networks and migrate customers from 2G and 3G. This increase in data traffic will primarily be driven by a 4 times increase in smartphone traffic in the period, with average data per active smartphone settling at 19 GB per month in 2028.

In the **Middle East and North Africa** region, data traffic growth will similarly be driven as more subscribers are transitioned to 4G, and current momentum in 5G coverage increases uptake, in addition to attractive service offerings and more affordable smartphones. Total data traffic is forecast to rise by 27 percent annually between 2022 and 2028 with monthly data usage per smartphone at 37 GB at the end of the period. GCC countries will still experience growth in data traffic despite slow growth in total overall subscriptions, as data usage per smartphone rises by 15 percent annually between 2022 to 2028 to reach an average of 59 GB monthly. This will be driven by growing uptake of data-intensive services. Various industrial use cases for 5G will also contribute to a rise in total data traffic.

In **India, Nepal and Bhutan**, mobile networks continue to play a pivotal role in driving social and economic inclusion. In the case of India, enhanced mobile broadband is serving as the foundation for the government's "Digital India" vision, which seeks to transform the country into a digitally empowered society and knowledge economy.

Average data traffic per smartphone in the India region is the highest globally, together with GCC. It is projected to grow from 26 GB per month in 2022 to around 62 GB per month in 2028 – a CAGR of 16 percent. Total mobile data traffic is estimated to grow from 18 EB per month in 2022 to 58 EB per month in 2028, growing at a CAGR of 22 percent. This is driven by high growth in the number of smartphone users and increased average usage per smartphone.

Smartphone subscriptions in India as a percentage of total mobile subscriptions are expected to grow from 76 percent in 2022 to 93 percent in 2028.

Mobile data traffic per smartphone continues to grow strongly in **South East Asia and Oceania** and is expected to reach around 54 GB per month in 2028 – a CAGR of 24 percent.

In **Latin America** individual countries show very different growth rates for data traffic per smartphone. Traffic growth is driven by coverage build-out and continued strong adoption of 4G (and eventually 5G), linked to a rise in smartphone subscriptions and an increase in average data usage per smartphone. The average data traffic per smartphone is expected to reach 41 GB per month in 2028.

In **Central and Eastern Europe**, growth is fueled by the migration of 2G and 3G subscribers to 4G, up to 2024, which is when 5G is expected to overtake previous generations as the technology making the greatest contribution to subscriptions. Over the forecast period, monthly average data traffic per smartphone is expected to increase from 14 GB to around 37 GB per month.

It is important to bear in mind that there are significant variations in monthly data consumption within all regions, with some individual countries and service providers having considerably higher monthly consumption than any regional averages.

[1] All Middle East and North Africa figures include GCC countries.

5G population coverage has reached 35 percent

Globally, 5G mid-band population coverage has reached around 30 percent. However, excluding China it is just over 10 percent. There are large variations between regions, ranging from 7 percent to 90 percent.

4G population coverage surpassed 85 percent globally at the end of 2022 and is projected to reach over 95 percent in 2028. There are currently 816 4G networks deployed worldwide – 336 upgraded to LTE-Advanced, and 62 Gigabit enabled.[1]

The build-out of 5G continues, with 249 networks launched worldwide. Global 5G population coverage reached around 35 percent at the end of 2022 and is projected to increase to about 85 percent in 2028.

Large regional variations in 5G population coverage

Mid-band is a sweet spot for delivering the 5G experience, as it combines high capacity with good coverage and is available in most markets. Combined with a low-band FDD 5G carrier it can provide full coverage and mobility. While 5G mid-band population coverage reached 30 percent worldwide by the end of 2022, excluding China it is estimated to be just over 10 percent.

There are large regional variations in total 5G population coverage as well as mid-band coverage. Regions such as Latin America and Middle East and Africa have reached about 7 percent mid-band population coverage, with a similar total 5G population coverage of around 8 percent.

China has built 5G population coverage mainly on mid-band and has reached coverage of around 90 percent. Europe has large variation between 58 percent total 5G population and mid-band coverage of around 15 percent (both figures excluding Russia). This is due to the limited availability of mid-band spectrum in some countries, meaning deployments have been mainly in low band. North America has 5G deployments across low-, mid- and high-band frequencies. Several service providers have deployed 5G on low-band, covering around 95 percent. During recent years, mid-band has been rapidly deployed and has now reached around 80 percent.

Figure 21: World population and mid-band coverage split by region (end of 2022)

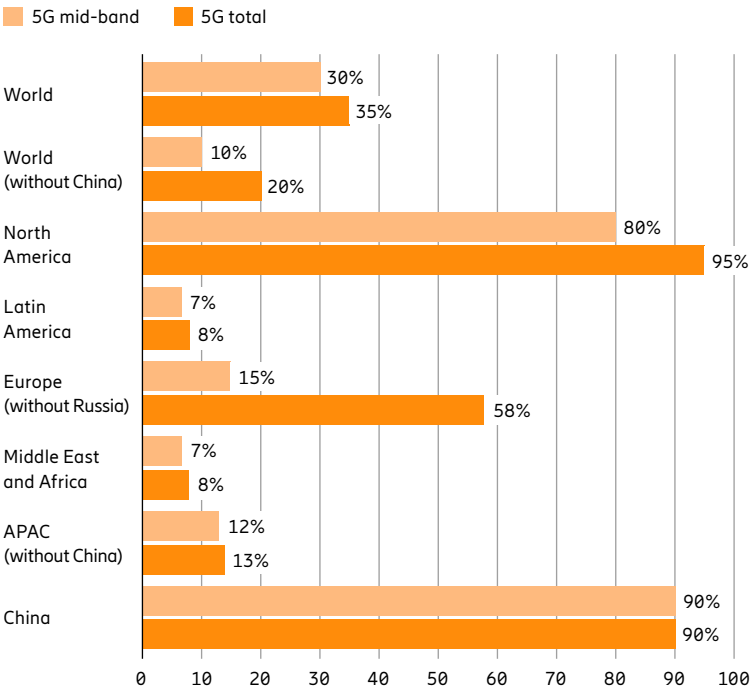
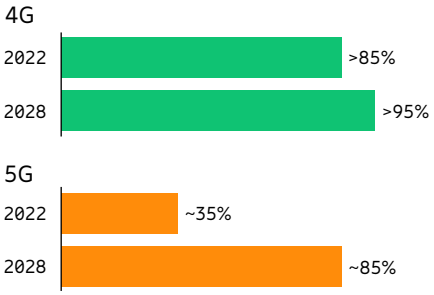


Figure 22: World population coverage by technology



Globally, 5G population coverage reached 35 percent at the end of 2022.

35%

Note: The figures in these graphs refer to coverage of each technology. The ability to utilize the technology is subject to factors such as access to devices and subscriptions.

[1] Ericsson and GSA (May 2023).

Data-hungry services such as AR, XR and network slicing are being introduced that will likely accelerate upward traffic trends. Ensuring these services are a success is a matter of preparing the networks for this increased demand, as well as ensuring they are viable and can be commercialized. Our articles focus on being prepared for this future demand, using modeled scenarios and real-life tests of such services, to discuss how service providers can meet both consumer demand and consumer expectations on service quality.

Traffic demand is up to 1,000 larger in dense urban than rural locations. Analysis of North American and European networks provides insights for service providers as to for how far they should consider the location, plus traffic consumption patterns, when designing networks.

Network slicing can be successfully monetized through offering premium services to 5G customers, as Singtel proved in a real trial at the Singapore Grand Prix. With Singtel, this article explores the future of differentiated services over 5G.

AR uptake, and therefore demand for network capacity, is predicted to accelerate in the coming years. In this article, a modeled scenario shows how AR demand is projected to outpace mobile broadband capacity growth, and discusses what additions will be needed to keep pace.

As consumer expectations on mobile QoE grow alongside the uptake of new services, the need to improve mobile network performance will also rise. Yet, traditional ways of measuring mobile QoE are limited in their usefulness, and new models must be developed.

Articles

Exploring how traffic patterns drive network evolution

In order to achieve optimum 5G performance, both coverage and capacity must be available throughout the network according to the location-specific needs.

Key insights

- The absolute traffic demand is up to 1,000 times larger in dense urban areas relative to rural areas.
- More uplink-centric services now require uplink performance to be considered. This becomes even more critical for new uplink-demanding services like XR.
- The 5G rollout is far from complete. 5G mid-band is only deployed in around 25 percent of 4G sites globally, with North America ahead and Europe behind.

Mobile networks must continuously evolve within the RAN domain, utilizing mid-band and mmWave to meet capacity and speed demands, but not all locations are equal. This is highlighted by a detailed analysis of data traffic growth and patterns across different locations in some North American and European networks, providing key insights and considerations for network evolution.

Methodology
In Western Europe, traffic data was retrieved from 4 networks, with 21 data sets from across 18 locations, collected in Q3 2021 and Q3 2022. In North America, 30 data sets were retrieved from three networks across 12 locations, collected in Q1 2022.

Traffic growth is not universal across locations

Variations in subscriber concentrations are clearly illustrated when traffic growth in several networks from Western Europe and North America are analyzed across different location types: dense urban, urban, suburban, and rural areas. The absolute traffic demand per location is 500 to 1,000 times higher in dense urban locations relative to more sparsely populated rural locations in both Western Europe and North America.

In Western Europe, relative growth in traffic during peak periods across the four different locations between 2021 and 2022 can be seen in Figure 23. Data for the most recent year shows that traffic growth per location is highest in dense urban and urban with up to 80 percent growth. But it has been much lower in rural areas with growth below 10 percent. The proportion of traffic on 5G in rural areas is lower due to reduced population coverage at the current stage of network deployment and also likely lower penetration of 5G devices.

When comparing North America with Western Europe, there are a couple of key differences that can be observed in the 2022 traffic. Firstly, traffic demand is higher in North America in both dense urban and urban locations. Secondly, in all locations, a greater proportion of traffic comes from 5G, which is likely a driving factor behind higher traffic volume in urban areas.

Traffic behavior drives different needs across locations

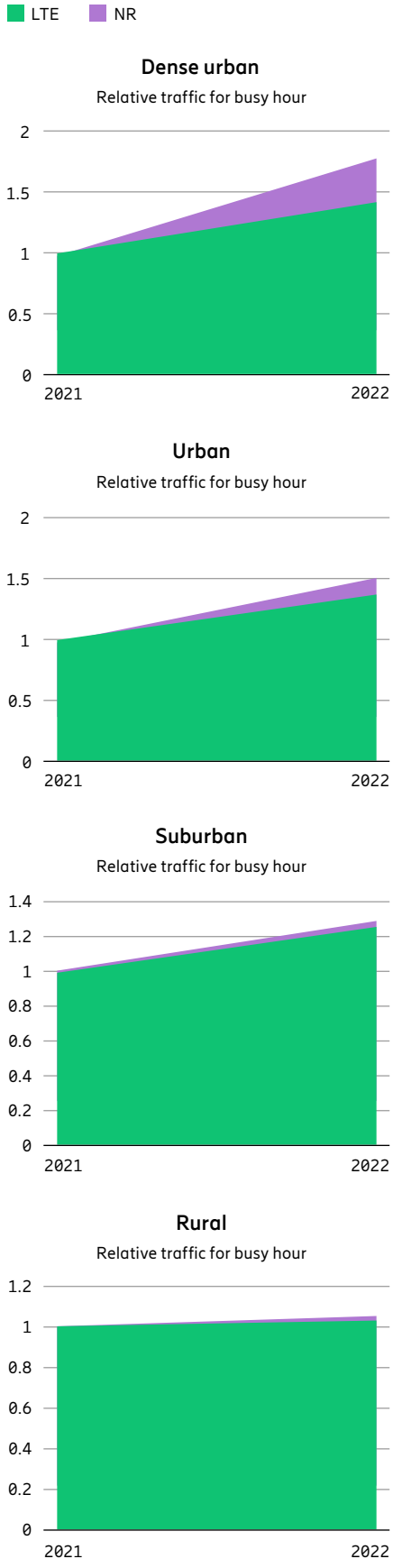
To support network evolution strategies, it is important to understand traffic patterns and behavior in more detail in different locations. Understanding daytime population density is very important, especially in dense urban-to-urban areas, since the highest traffic is in the middle of the day in both Western Europe and North America.

Figure 24 shows dense urban peak traffic period during the middle of the day, compared with the rural area, which has the peak traffic period during the evening. The rural areas are likely to be impacted by Fixed Wireless Access (FWA) subscriptions which have a significantly higher usage per subscription. North America follows a similar pattern, and in both regions urban and suburban traffic has a much flatter profile with the highest traffic levels more evenly distributed between the middle of the day and the late evening before traffic drops off.

Analysis of traffic by location shows a greater proportion of total traffic is uplink in dense urban locations in the peak period compared with other locations. In North America, dense urban uplink traffic is around 14 percent of total traffic compared with rural areas, where it is around 9 percent of total traffic. Traditionally for mobile broadband and FWA services uplink has had a smaller impact on overall user experience. However, with more uplink-centric services there is now also a need to consider uplink performance, especially in dense urban areas. This is also required to prepare for new uplink-demanding services like XR, which will place even more demanding requirements on networks.

Examination of the network data across the locations shows that although total traffic is significantly higher in urban locations, relative per-user traffic in peak periods is highest in suburban locations, with this difference being much more pronounced in Western Europe. This shows how the combination of population density and peak usage per user is important when considering network capacity requirements.

Figure 23: Relative traffic growth for peak period by location type in Western Europe



North America leads Europe with mid-band deployments

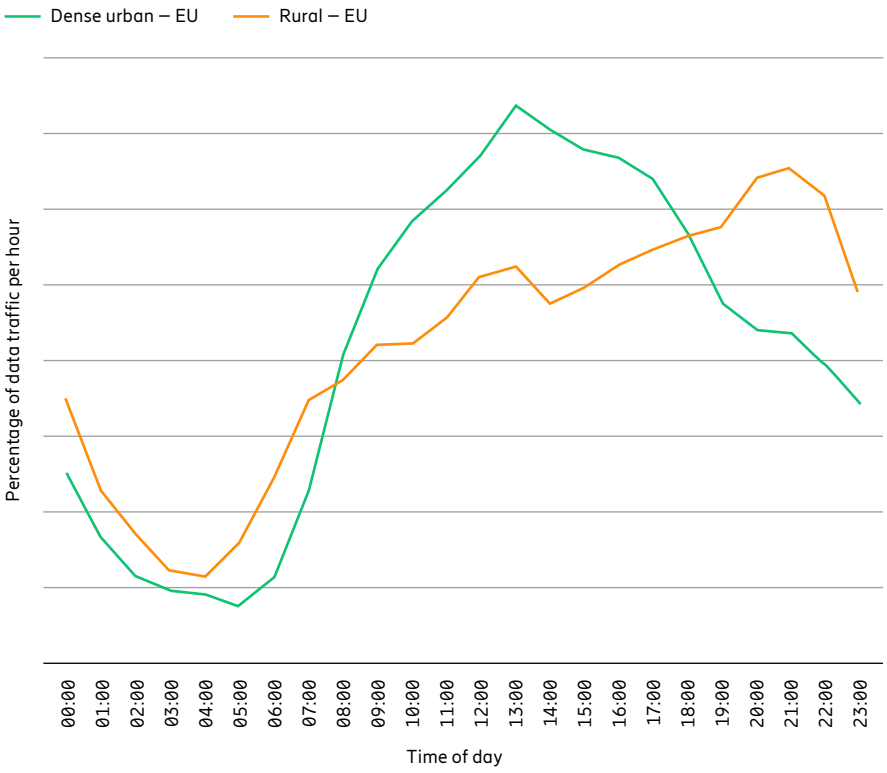
Globally, 5G population coverage reached 35 percent at the end of 2022. However, when looking into the mid-band deployments that bring the step change in network performance, only about 25 percent of 4G sites have been upgraded, and when China is excluded this drops to around 20 percent. There is a significant difference in the regions studied here, with North America at over 30 percent and Europe just above 10 percent.

Looking at the specific networks analyzed, 5G has been commercially deployed in Western Europe and North America since 2019, but rollout is far from complete. In Europe, some additional sites, totaling around 5 to 10 percent, have been added to suburban and rural areas to meet increased coverage expectations and license obligations. The focus on fulfilling coverage requirements is reflected in the much higher levels of New Radio (NR) frequency division duplex (FDD) sites deployed for coverage compared with mid-band time division duplex (TDD) sites for capacity in the networks analyzed from Western Europe.

The 5G deployments in Western Europe and North America for the locations sampled give a snapshot of the status of network deployment in the two regions, as illustrated in Figure 25. The figure shows the proportion of sites that have been upgraded to 5G NR FDD, compared to sites where 5G carriers have been added in either the mid-band TDD or with mmWave. Depending on the capacity demands of a particular site, mid-band TDD and mmWave carriers can be co-located at the same site. In Western Europe, it is notable that while the 5G NR FDD bar is as high as, or higher in certain cases, than in North America much of this has been achieved through spectrum sharing. This gives a high level of coverage but without the same levels of capacity, latency, or uplink capabilities.

In North America, there has been a focus on mid-band and mmWave from the early stages of 5G deployment to deliver higher capacity alongside coverage. mmWave is capable of supporting higher capacity in the network for dense urban and urban locations. It should be noted that since the data set was collected, the North American operators have continued deploying mid-band at pace, as reflected in the higher than global average number of sites deployed.

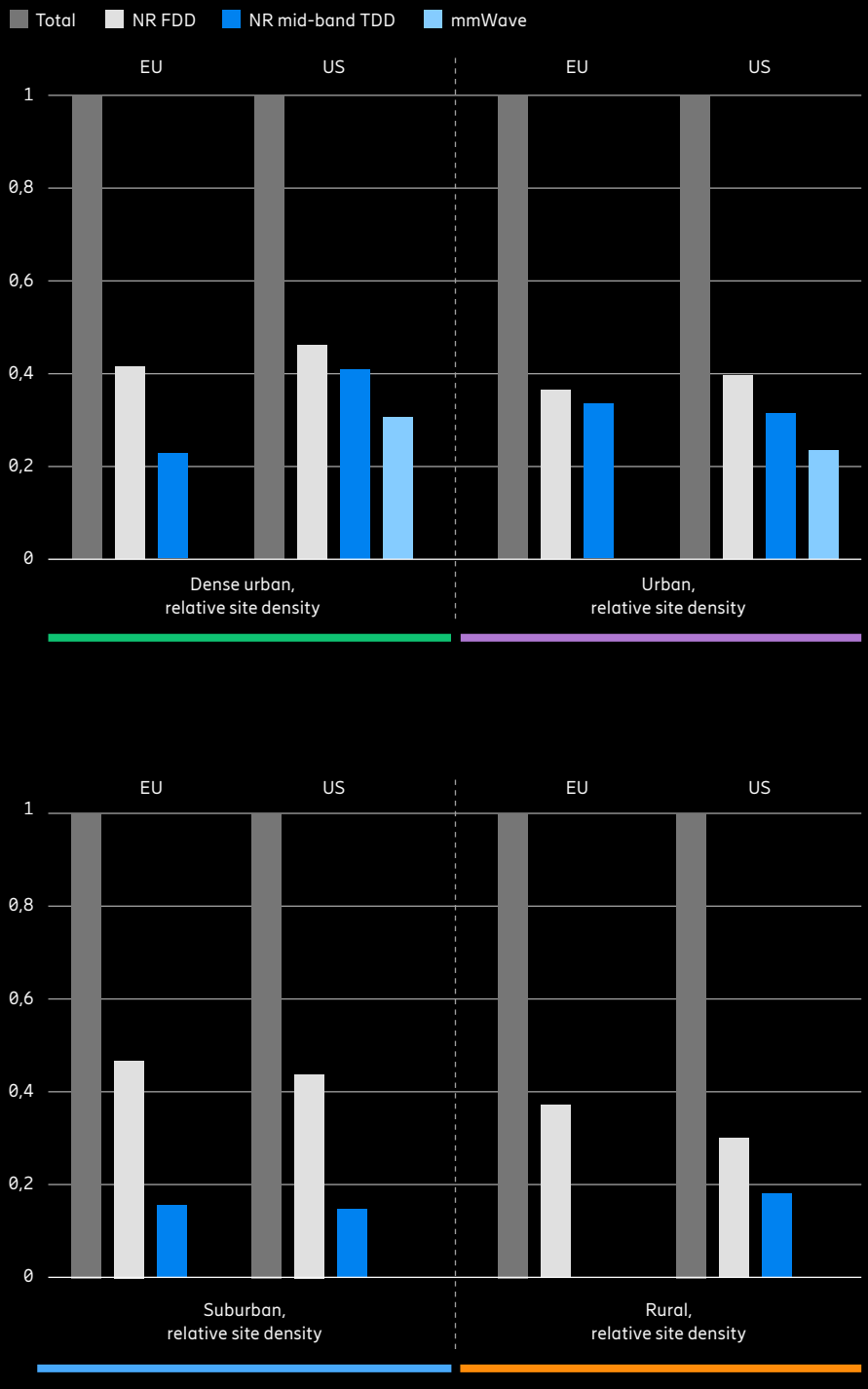
Figure 24: Western Europe hourly traffic over a typical 24 hours

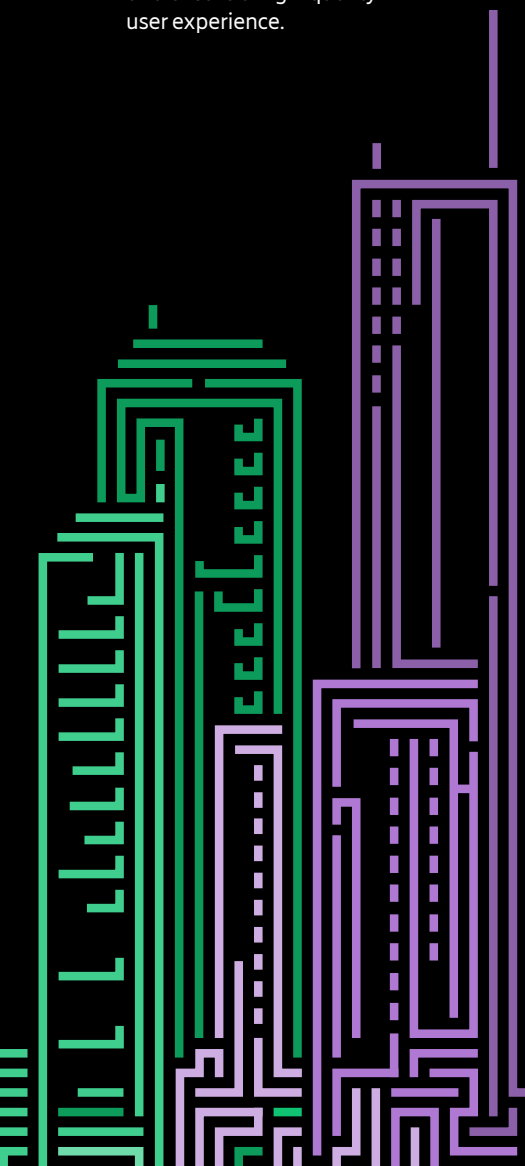


Rollout is far from complete

Network deployment comprises both coverage and capacity sites. Coverage sites provide basic geographical coverage while capacity sites add extra capacity where coverage is good and there is a high density of subscribers. To achieve optimum 5G performance, both coverage and capacity must be available throughout the network. Upgrading coverage sites with 5G enables coverage to be built out, but upgrades of capacity sites are also required to realize 5G services to most subscribers. Our analysis shows that firstly there are still existing sites without 5G, which need upgrading to 5G to enhance network coverage. Secondly, there are many sites without the additional capacity dimensions, and mid-band TDD deployments, needed to deliver the step change in 5G performance. Without network evolution, resource utilization will increase, resulting in poor user experience. Therefore, peak utilization must be maintained or, ideally, reduced over time to offer higher speeds and ensure a high-quality user experience.

Figure 25: Relative site density of 5G deployments





Exploring differentiated services with 5G networks

At the 2022 Singapore Grand Prix (GP), Singtel became the world's first service provider to deploy 5G network slicing at a major sporting event – and demonstrated the commercial opportunities of differentiated connectivity services.

Key insights

- Supported by network slicing, racing fans at the Singapore GP enjoyed high-quality video streams, taking their event experience to the next level.
- A consumer service based on 5G network slicing must be appealing, valuable and differentiated with clear benefits compared to a 4G service.
- Network slicing enables the introduction of new business models for different market segments.

Singapore is an island country, similar in size to New York City, with a population of around 6 million people. In July 2022, it became the first country in the world to be fully covered (95 percent) by 5G SA.

The Singaporean government's Infocomm Media Development Authority (IMDA)[1] is driving a national digital transformation plan, which emphasizes the importance of a world-class 5G infrastructure to enable innovative new use cases and transform industries. Among the initiatives are new policies to encourage and foster collaboration between industry players. Examples of such IMDA initiatives include partnering with:

- Building and Construction Authority (BCA) to develop a 5G-enabled Building Information Modeling (BIM) system that will improve productivity and safety in the construction industry
- Land Transport Authority (LTA) to explore the use of 5G in autonomous vehicle technology
- Energy Market Authority (EMA) to investigate the potential of 5G in smart grid technology
- a multinational automotive manufacturer deploying 5G-enabled robots that will help transport vehicle-manufacturing materials for the development of Singapore's first build-to-order (BTO) electric vehicle (EV) factory
- the healthcare sector as a key area for 5G implementation, with potential applications including remote healthcare monitoring and telemedicine

Singtel has launched a 5G network with an aim to support new digital growth opportunities within consumer, enterprise and public sector segments. Its 5G strategy includes a network evolution journey to a fully automated network with intelligent orchestration capabilities, enabling consumers and enterprises to subscribe on-demand to multiple products, services or use cases.

Deploying nationwide 5G SA coverage

In May 2021, Singtel launched the world´s first nationwide 5G SA network, despite the network roll-out challenges at the time due to the pandemic. It has currently achieved island-wide coverage of over 95 percent with 3.5 GHz TDD and 2.1 GHz spectrum bands. As of Q2 2022, 580,000 subscribers had signed up for 5G subscriptions. In terms of the top 10 most used applications, the behavior of 4G and 5G subscribers is largely similar with strong data usage across social media and video applications. This is expected to change as new applications that leverage 5G, such as AR and VR become more pervasive.

Already though, Singtel is seeing significantly higher data consumption among 5G customers. This is partly attributed to better video streaming experiences over its 5G network, which encourages subscribers to consume more rich media.

Challenges of implementing 5G in Singapore

Singtel considers extensive 5G SA coverage, combined with network slicing capabilities, to be key for unlocking new customer values. An essential part of its 5G SA deployment strategy includes extensive coverage for more than 700 indoor locations, in underground sites and along underground train lines where traffic demand is substantial. However, considering most of Singapore's geography consists of dense urban areas, ensuring coverage for high-rise buildings and underground areas has been a significant challenge.

Singtel

This article was written in collaboration with Singtel, a leading communications and digital services provider in Singapore aiming to capture untapped digital growth in the 5G era.

[1] www.imda.gov.sg/How-We-Can-Help/5G-Innovation

The main challenges Singtel had to overcome were:

- Line-of-sight obstruction: Obstacles such as walls, floors, and other structures present a significant challenge as they can cause signal interference, leading to poor coverage.
- Signal attenuation: High-rise buildings and underground areas often contain materials that absorb or reflect 5G signals, causing signal attenuation.
- Limited space: High-rise buildings and underground areas often have limited space, making it challenging to install 5G antennas or small cells.
- High-density areas: Singapore is a high-density city, prone to congestion, resulting in poorer customer experience.
- High costs: Deploying 5G infrastructure in high-rise buildings and underground areas can be costly due to the complex and challenging nature of the installation process.

To overcome these challenges, fundamental radio planning designs need to be sound, including the deployment of the right number of cell sites to ensure 5G coverage and use of all the available 5G spectrum bands in an optimal manner. With strong 5G traffic growth, the network needs to be able to handle demanding use cases and still be capable of serving casual users with internet traffic. Network technologies such as slicing, radio resource partitioning[2] and QoS features are increasingly important for managing different use cases and traffic demands efficiently.

Network slicing opens new opportunities

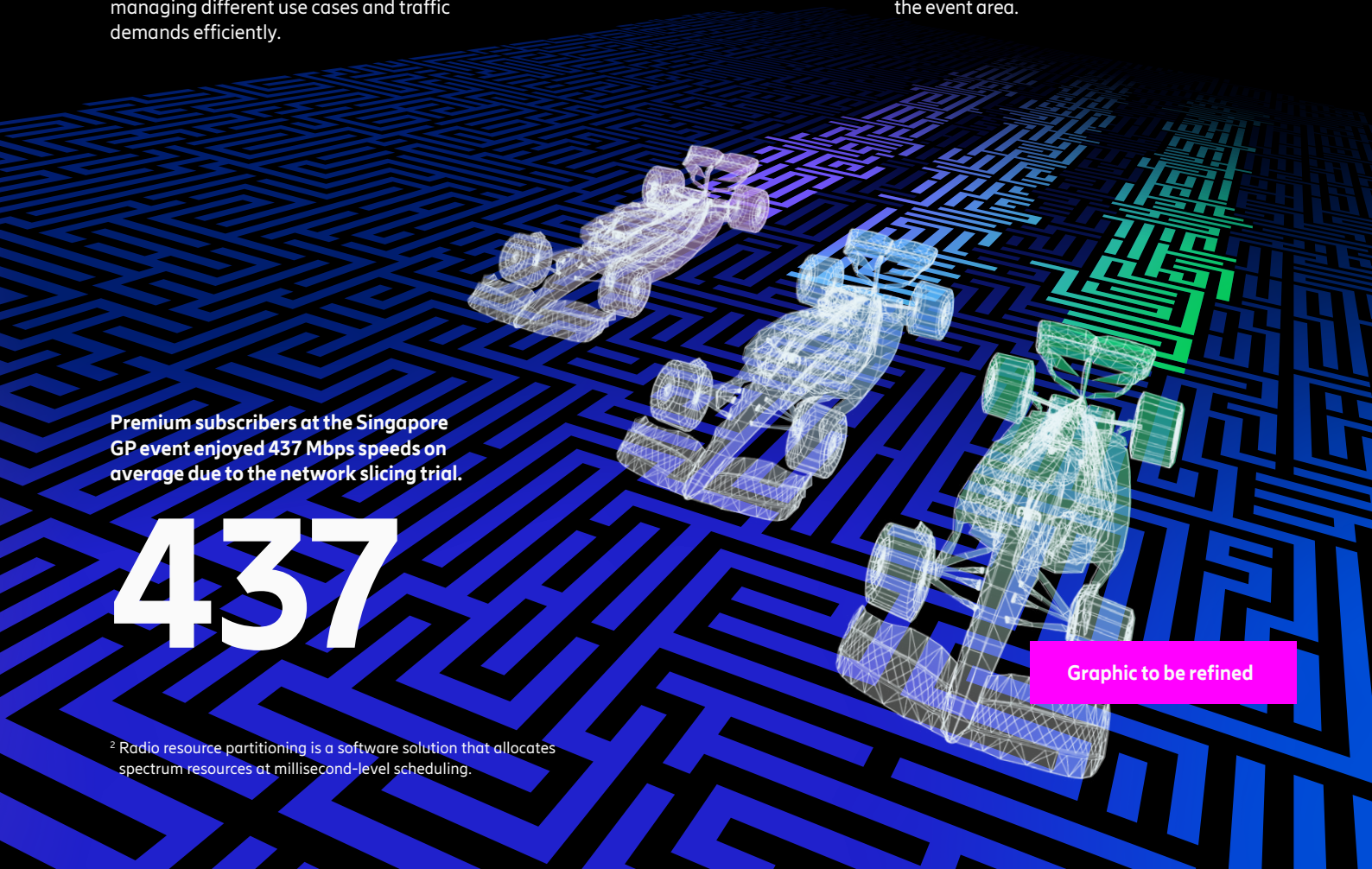
5G network slicing enables multiple independent logical networks to exist on the same physical network infrastructure. Each slice serves as an isolated end-to-end network accommodating different application requirements for security, reliability and performance. It enables service providers to go from providing one-size-fits-all wireless connectivity to services and customer-adapted network slices for specific use cases. As the capabilities of 5G networks evolve, slices will progress from being static (preconfigured) with basic functionality to being dynamically created, deployed, and modified as customer needs change (on-demand). The latter will enable on-time and fast delivery of slices with automated deployment and operations. For service providers, slice observability, orchestration, automation and service level agreement (SLA)-based charging are critical functionalities to both manage and monetize network slices.

Network slicing will play an instrumental role in supporting different QoS and service-based connectivity offerings. For most communications service providers, network slicing is currently about trialing, exploring and learning from such deployments.

Differentiating consumer offerings with network slicing

During 2022, Singtel applied a test-and-learn approach to ensure that network slicing was correctly implemented. Two excellent test case opportunities were the Singapore GP in October and the World Cup football tournament in December.

Singtel was the first service provider in the world to use radio resource partitioning to deliver end-to-end network slicing in a live 5G SA network for the Singapore GP. More than 300,000 spectators attended the event in the Marina Bay area, concentrated in small areas around the racetrack. Live streams of sports typically experience lag, jitter and other disturbances in busy and congested radio environments, which has a negative impact on the viewing experience. Along the track, there were two main zones, the fan zone and the stand area. In these zones, the user video streaming experience was expected to be poor due to high traffic demand from many smartphone users. This presented an excellent opportunity to test the capabilities of 5G network slicing, where a dedicated slice of Singtel's network was reserved for subscribers of Sports Plus, a service on Singtel's video streaming platform (CAST). The slice was designed and configured end-to-end in the core, transport, and radio networks to enable higher throughput and stable low latency. In addition, radio sites were allocated a radio resource partition to provide protection for radio resources in the event area.



Premium subscribers at the Singapore GP event enjoyed 437 Mbps speeds on average due to the network slicing trial.

437

Graphic to be refined

[2] Radio resource partitioning is a software solution that allocates spectrum resources at millisecond-level scheduling.

Figure 26: Network slicing use cases for the near to mid term

Segment	1–2 years	2–4 years
Consumer	Individual customized slices	Autonomous vehicles
	Smart home devices and appliances	Remote work and telecommuting
Enterprise	Logistics and transportation	Smart cities
	Smart factories and industrial IoT	Remote training and education
	Healthcare	
Public sector	Public safety and emergency	Smart energy grids
	Smart transportation infrastructure	Smart water management
	Public Wi-Fi networks	

5G subscribers who purchased the CAST Sports Plus could stream content by signing up to this package for SGD 9.90 during the race weekend and enjoy a good video experience everywhere along the racetrack area, compared to 4G subscribers. Users with a 4G subscription experienced lower video quality, due to low downlink throughput (on average 4.2 Mbps) because of high traffic congestion, while 5G premium package subscribers experienced a full high-definition quality stream due to a high downlink throughput (on average 437 Mbps). The value for the 5G network slicing users was the assurance of seamless video streaming under resource constraints.

The 5G network slicing was a "teaser" for Singtel to learn how to implement a network slice with the right parameter settings and radio resource management for this specific use case. Customers were not charged extra for the service. The network slices were manually preconfigured, with efforts being put into ensuring they were created homogeneously in each tracking area. Going forward, this process will be automated to increase efficiency and enable scaling. Network slice orchestration will be an integral aspect of this process, providing network slice management, including planning, lifecycle management and configuration. Another important aspect will be to implement slice observability solutions to provide real-time visibility into slice performance so that changes can be made on the fly in response to changes in traffic patterns.

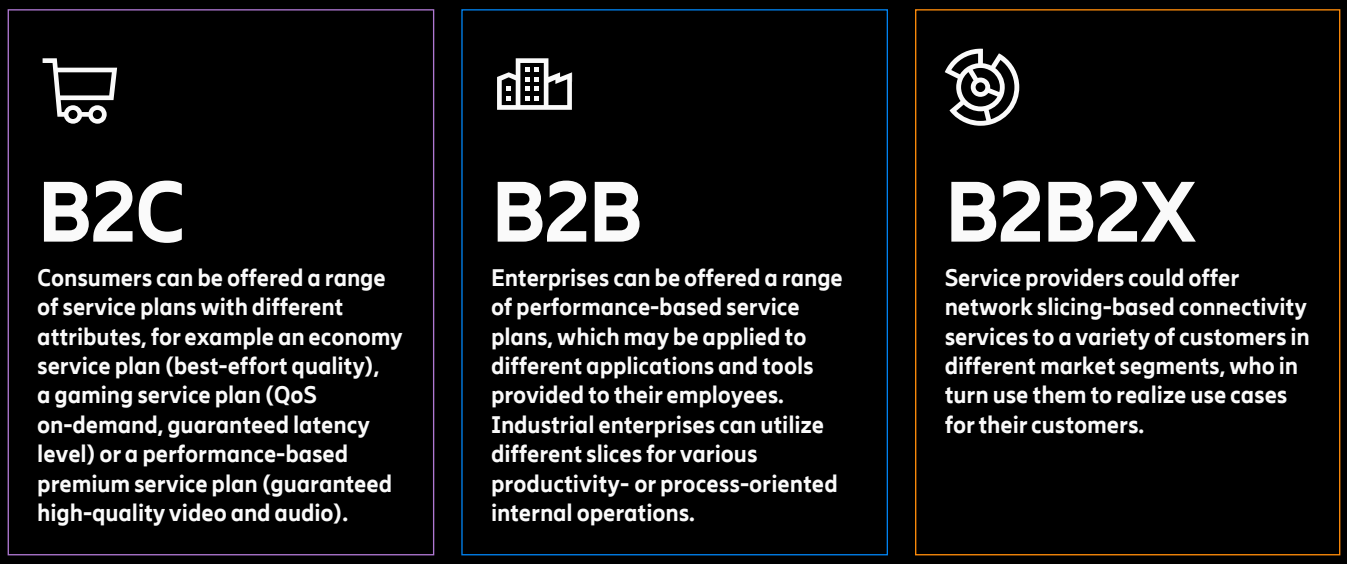
In a similar way, the expansion of 5G SA network slicing and radio resource partitioning across all of Singapore made it possible to offer full HD video streaming of World Cup football matches for 5G subscribers with a Singtel TV plan.

Learnings from the first network slicing implementations

By applying a test-and-learn approach, Singtel was able to better understand the behavior of network slicing and radio resource partition mechanisms. This will be relied on when designing the 5G network to meet more demanding use cases from both consumers and enterprises. It is also important to have worked out a good traffic forecast for the "slicing area" and not to under-dimension for both slice and non-slice users. There should be a distinct difference in experience for users of the generic service compared to users of the premium service enabled by network slicing. The implementation of radio resource partitioning in the live 5G network meant that engineers were better able to understand the behavior of the feature. For example, using radio partitioning for generic users as well as premium users resulted in unexpected results in certain test scenarios. Network slicing design was subsequently amended based on insights from the event. Another learning is the importance of having seamless service provisioning, making it easy and convenient for customers to subscribe to a service and immediately enjoy it.

Based on the Singapore GP experience, Singtel has recognized the business potential of deploying network slices to support new use cases in other geographically limited areas, such as shopping districts, convention centers, stadiums, school campuses, factories, airports and mines. Network slicing-based services could also be dynamically created and deployed in these limited geographical areas, fulfilling a specific need at the time it is required. In those areas, a range of customer segments that would benefit from differentiated service offerings could be identified by leveraging customer and market research and insights.

Figure 27: Market segment opportunities presented by network slicing



Opportunities for commercializing network slicing

Singtel aims to understand how to capture enterprise business requirements through market research and surveys, in order to then customize slice capabilities for current use and to build service evolution maps for the future. As new use cases and business models evolve, a better understanding will emerge of what 5G performance levels different customer segments prefer. It is therefore important to build a network slicing foundation that scales with new customer insights.

Network slicing enables the introduction of new business models for different market segments, see Figure 27.

New services that can be offered include customized subscriptions for specific services and geolocation-based subscriptions to satisfy specific customer needs, as below.

B2B needs:

- logistics management/port operations to ensure the service assurance for the operation of automated guided vehicles (AGV) remotely via 5G
- surveillance/security to ensure video feeds continually transmit via 5G with reliable upload speeds
- medical applications to ensure remote diagnostics can be performed via a stable 5G connection

B2C needs:

- app-based to differentiate user experience through different application subscriptions
- enhanced security for subscribers through network slicing
- priority access (location/geographical based) to provide differentiated user experiences by location, for example at gaming hotspots

Singtel considers security slices to be one of the early promising enterprise use cases. Figure 26 shows Singtel's view on network slicing use cases for the near to mid term.

Learnings from network slicing implementation

Network slicing is the starting point for traffic segregation in the connectivity layer. It will evolve into user equipment route selection priority (URSP) which enables dynamic slicing where traffic can be segregated by user application in the device itself. Close cooperation with device manufacturers is required to shape URSP's capabilities to market requirements.

The main go-to-market challenge for 5G network slicing for the consumer segment is creating appealing and valuable services that are differentiated from the current 4G offering. 5G SA and network slicing brings new capabilities, such as data prioritization, faster speeds and lower latency. However, these capabilities will require purposeful use cases to drive consumer adoption and a well-considered communications plan to explain the consumer benefits.

Singtel is constantly working to identify potential 5G use cases and migrating its non-5G customer base to 5G subscriptions so that they can enjoy the full benefits of 5G SA and network slicing-based services.

When designing network slices, the user experiences of prioritized and normal services need to be balanced within available network resources. For crowded events, a network slice with a QoS guarantee also has to function in a high radio noise environment. Therefore, an accurate forecast of traffic demands by users is required to balance resource allocation between priority and non-priority services. As customers expect their service experience quality to be premium, partnerships with over-the-top (OTT) service providers will be important to ensure the service is prioritized end to end.

More advanced network and service orchestration capabilities need to be implemented as demand for network slices increases. Service assurance will be important, especially for industries where mission-critical operations will require well-defined SLAs.

Meeting AR network requirements with sufficient radio network capacity

Video, messaging and multimedia services currently dominate mobile broadband network traffic, with most of this coming from video streaming. However, as augmented reality (AR) traffic grows, questions about network coverage, capacity and performance will need to be addressed.

Key insights

- Growth in devices and applications using AR in wide-area use cases is expected to accelerate in the latter part of this decade.
- Mobile networks will need to be re-dimensioned to handle the quantity of traffic and higher network requirements of these new real-time services.
- The solution will be a combination of additional spectrum and new functionality offering greater efficiencies, complemented with increased Radio Access Network (RAN) density.

AR enables users to experience information or digital objects overlaid onto views of the physical world. The level of augmentation can vary from a simple display of information to fully realized digital objects that adapt to the dynamic environment, moving as if they were physically present in it, with multiple users simultaneously interacting with them. These new services hold the promise of a leap forward in digitalization of industrial and business processes as well as offering new ways to communicate. Consumers will also benefit, as these technologies are applied to entertainment, gaming and social media.

The AR ecosystem is moving toward a tipping point when all the key elements are sufficiently developed to support services at scale, and this is expected in the latter part of this decade. Critical elements in the ecosystem include attractive devices and applications, enabled by computation offload to the edge cloud, which will need high-quality mobile connectivity.

Consequently, parameters have been defined to model a scenario which enables radio network capacity to be compared with expected traffic demand, and explores alternatives for increasing radio network capacity sufficiently to support the growth of AR services.

Methodology

Data from Los Angeles, a city dominated by a dense urban low-rise landscape, was used to simulate the network impact of combined mobile broadband and AR traffic. This was done under a range of assumptions around AR uptake through 2030. The aim was to explore the operating conditions under which mobile networks need to be prepared for increased requirements, and the additional radio network capacity that will be needed to handle the projected demand.

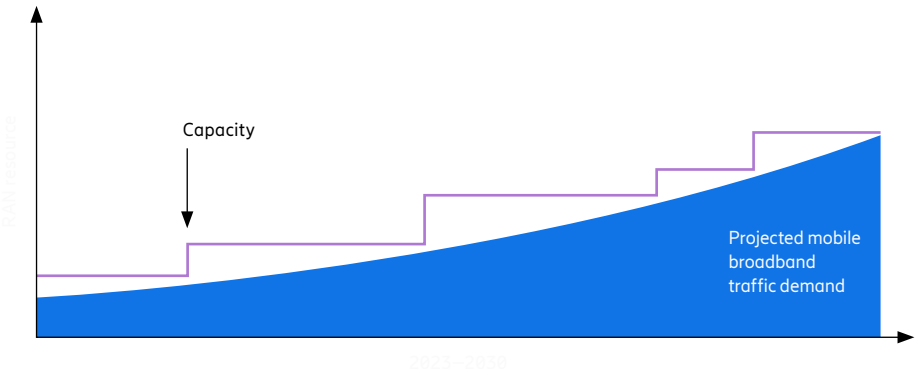
Mobile data traffic forecasts from the Ericsson Mobility Report were referenced to define growth rates, along with the AR traffic scenario. The forecasts project total mobile traffic in EB per month as well as average monthly mobile data traffic per device in GB.

Spectrum used in simulation:
- 2x20 MHz low-band FDD
- 2x40 MHz mid-band FDD
- 1x120 MHz mid-band TDD
- + mmWave

Ericsson simulations show that radio network capacity in areas like Los Angeles will narrowly meet mobile broadband traffic requirements around 2030. This assumes all currently available spectrum is deployed, and takes industry projected 5G performance evolution into consideration. In particular, uplink will face challenges in meeting the projected traffic demand. Already, there is a need for additional capacity, for example through additional mid-band spectrum.

Mobile broadband traffic and simulation parameters for 2030:
- subscriber density: ~10,000/km2
- number of subscribers constant over time
- average macro layer inter-site distance: 700 m
- total traffic demand (uplink and downlink): 63 GB per month
- uplink share of total traffic demand: 15 percent
- share of traffic during a busy hour: 10 percent
- busy hour uplink throughput per subscriber: 69 kbps

Figure 28: Mobile network traffic evolution



Given the development of the AR market, AR users are likely to demand radio network capacity in the same timeframe. Several scenarios could play out, each with different capacity requirements, above projected mobile broadband traffic demand. Projections of AR glasses' unit volume growth through 2030 show a ramp-up of sales to 20–35 million glasses by 2030 in North America. Assuming a renewal rate of around 30 percent, this could indicate an installed base of 30–50 million AR headsets by 2030 – equal to 10–15 percent smartphone subscription penetration.

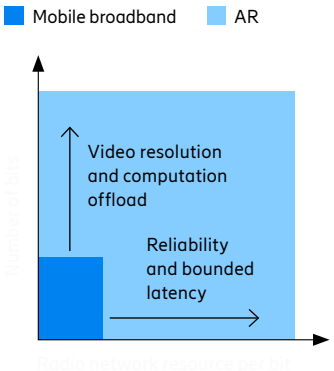
Mobile broadband and AR applications differ in the type of traffic they generate. AR uptake will drive significant capacity requirements in the radio network, depending on the level of cloud computation offload and usage. Relative to (best-effort) mobile broadband, an AR user will consume more bits due to continuous high-resolution video streams as well as edge cloud computation offload. In addition, AR drives higher radio network resource consumption per bit due to its stringent margins for the bounded latency and high reliability necessary to realize a good user experience. The difference between mobile broadband and AR traffic is especially significant for uplink traffic. Figure 29 illustrates the impact of an AR user, relative to a mobile broadband user, on mobile radio networks during the busy hours.

Traffic profiles were simulated in a computation offload scenario for AR (peak traffic speeds of 50 Mbps downlink and 10 Mbps uplink) with a traffic profile of heavy use for 2 hours per day. Bounded latency was set to 20 ms round trip time and reliability to 99 percent. The results were then compared with traffic projected for a mobile broadband user by 2030. Capacity requirements in this scenario increase significantly for both uplink and downlink, however as uplink is predicted to be the bottleneck, the results presented will focus on uplink.

In this scenario, the simulation indicated AR users would consume (in uplink) around three times the bits during the busy hour relative to a mobile broadband user. Each bit would require on average four times more radio network capacity relative to mobile broadband best-effort. This totals 12 times (3x4) more uplink radio network capacity requirements than a mobile broadband user in this timeframe.

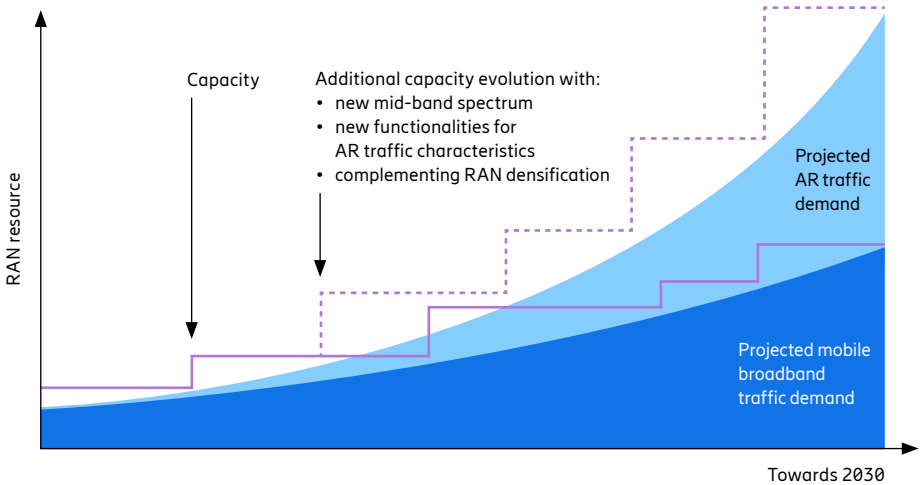
Consuming 12 times the capacity of mobile broadband users over a busy hour will put significant requirements on the network for a relatively low user penetration. With the 10–15 percent penetration range (taken from the estimated installed base of AR glasses above), we see a relative increase of more than double (2.1–2.7 times) the uplink traffic load compared to a network with only mobile broadband traffic. The increased traffic load puts additional requirements on network performance to be able to supply the extra capacity.

Figure 29: Resource consumption (busy hour)



Radio network resources
Stringent delay requirements (bounded latency) and limited packet loss (high reliability) are needed for emerging real-time applications such as AR. This can be achieved by adopting more conservative operating parameters in the RAN, in essence, using more network resource to deliver a given amount of traffic.

Figure 30: AR and mobile broadband traffic and capacity evolution

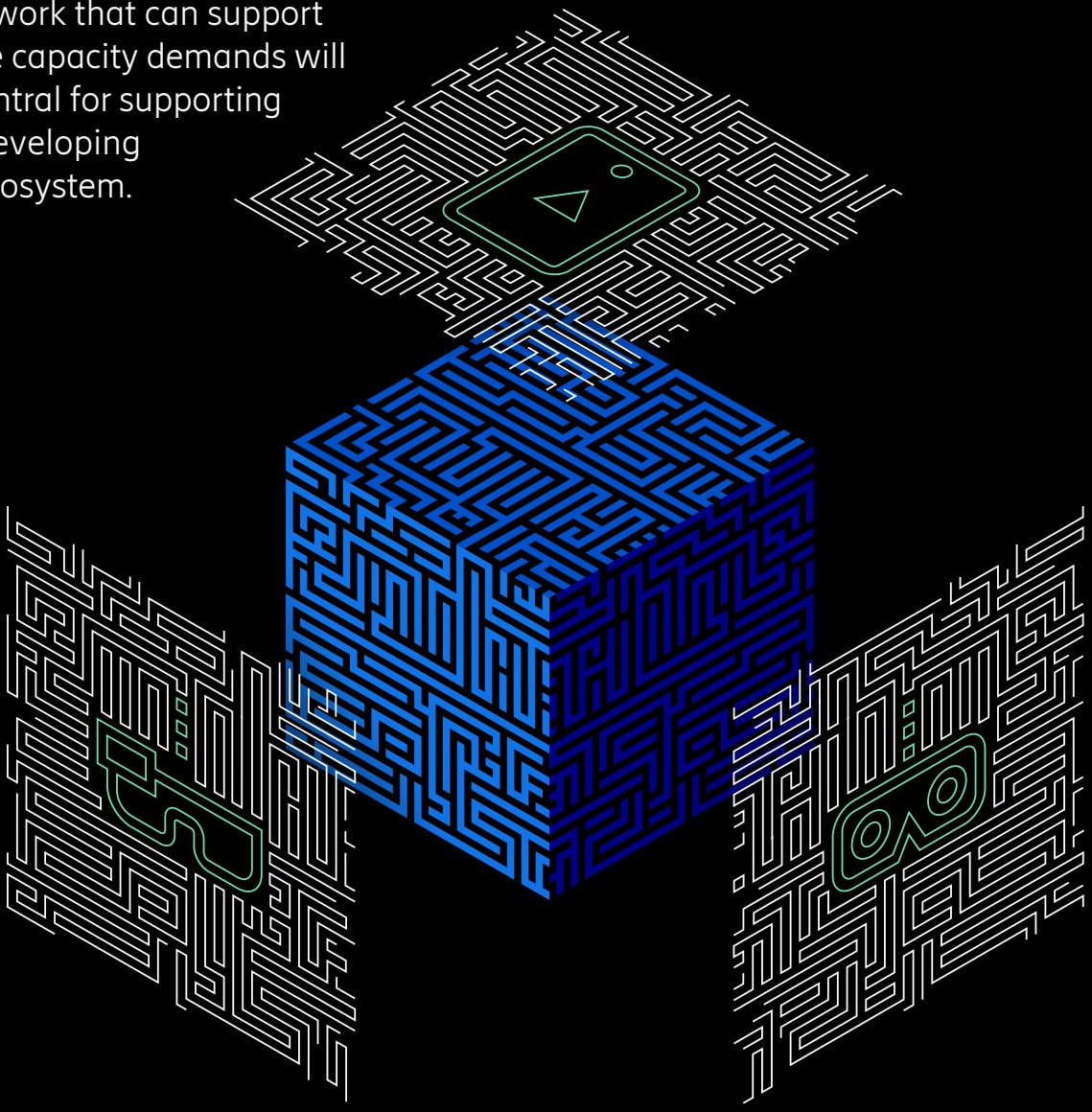


There are several solutions to address this:

- Additional mid-band spectrum will be needed for increased capacity. Depending on the country, additional mid bands may be within the 3.3–4.2 GHz, 4.4–5 GHz and 6.425–7.125 GHz. The 3.3–4.2 GHz and 4.4–5 GHz bands have already been licensed in many parts of the world and there is a device ecosystem with support for those bands. The 6.425–7.125 GHz band is currently under discussion for IMT identification at ITU World Radiocommunication Conference 2023 (WRC-23) and an ecosystem is under development, noting that the band is already included in 3GPP standards (3GPP n104). The 6.425–7.125 GHz band is a key opportunity for large-scale harmonization of wide-area licensed use and, in many cases, the last available mid-band resource.
- New functions to increase capacity and improve coverage are needed. One example is intelligent steering of traffic to spectrum bands based on both throughput and latency requirements. Another example is optimized scheduling to reduce latency and increase reliability by allowing additional retransmissions within a given latency budget.
- RAN densification will help – however, it is associated with high costs and long lead times.

None of these solutions will be sufficient on their own to address the capacity gap towards and beyond 2030 in the studied AR scenarios; a combination of all three will be needed to satisfy future network demands. Mobile broadband traffic, plus a scenario of high AR traffic uptake, combined with an assumed level of cloud computation offload indicates significant network load demand. Towards 2030, in dense urban low-rise landscapes such as Los Angeles, this demand will not feasibly be met by the available spectrum and 5G performance evolution on an existing site grid. Adding spectrum and functionality on existing sites would be the first steps, with network densification as a complement where and when needed. In the long term (2030 and beyond), the centimetric range 7–15 GHz will be essential to support AR uptake and more advanced use cases such as holographic communications.

A network that can support future capacity demands will be central for supporting the developing AR ecosystem.



Mobile quality of experience: Network readiness for new services

The next wave of 5G applications will bring new network requirement challenges. Service providers will have to apply new models for rating mobile quality of experience (QoE) to design networks that support performance needs of future applications.

Key insights

- Data captured from US networks shows that 5G substantially improves video streaming quality compared to 4G. The proportion of streams rated "excellent quality" increased from 58 percent (4G) to 72 percent (5G).
- Application developers and network planners need new models to rate QoE for new emerging mobile services.
- A need to continue improving mobile network performance capabilities to meet the requirements of new mobile experiences and rising user expectation of QoE will grow with uptake of new services.

The first wave of 5G primarily brought enhanced user experience for existing applications to smartphone users. New types of applications and use cases are expected in the next wave, bringing to networks new challenges in delivering sufficient mobile QoE to customers. Mobile user experience is a function of both application quality and network quality. Service providers need ways to rate experiences, and to become known in the market for delivering a mobile experience consumers and enterprises can rely on. Ultimately, this will impact how much customers are willing to pay for a service.

Models to predict the quality of mobile experiences

Traditional proxy measures for QoE are generic, and unrelated to a specific application and network combination. What users can expect from QoE in terms of the network is typically measured in three ways:

- population coverage (percentage with access to a specific cellular access technology (4G, 5G) in low- or mid-band spectrum)
- radio signal strength (measured on the device and presented as 1–4 bars)
- speed tests (user-initiated peak rate tests of throughput, at a given location during a defined time)

These measures indicate network fundamentals for users, but have limited value as input for planning networks for more advanced experiences. An alternative method is to calculate the quality of various mobile experiences using secondary data points retrieved from devices and analyzing by:

- uniformly capturing data across different service, equipment, measurement and device providers
- applying algorithms and standardized models, where a specific set of data points can be measured and correlated with the QoE for a specific service

ITU's Telecommunication Standardization Sector (ITU-T) set out to standardize and secure a broad anchoring for models to use. The ITU-T Rec. P.1203 is the world's first standard for measuring the QoE of video streaming services for longer viewing sessions and has been established for years. Models for measuring cloud gaming[1] and video telephony[2] QoE are under development. These will rely on a set of data points as input, with a known impact on the QoE, and a calculated overall rating as output.

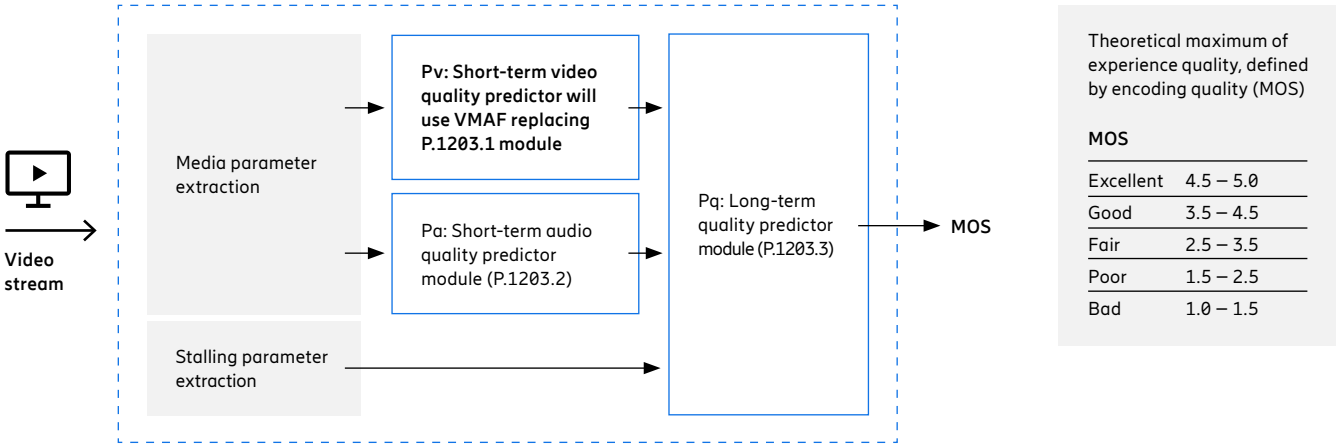
In collaboration with Ookla, Ericsson conducted a nationwide data-gathering project in the US during the first quarter of 2023. All data points were uniformly captured from smartphones across the three largest service providers' mobile networks, and were used to rate mobile QoE with the above-mentioned approach. The three experiences studied were video streaming (ranging in resolution from 144p to 4K), mobile gaming and video conferencing. All these services are mature and expected by customers to be delivered with excellent quality over a cellular network. The results indicate an ongoing need for network performance improvements to deliver a consistent QoE for these types of applications. General network readiness for delivering good QoE for cloud gaming and extended reality (XR) applications is still in its infancy.

Modeling mobile video streaming QoE

Video is the dominant traffic type in cellular networks, and its use continues to grow. A total of 80 percent of all data traffic in cellular networks is forecast to be video by 2028.[3] Video consumption has gradually shifted from broadcast to streaming, and mobile video quality evolves toward full-HD, 2K and 4K resolutions. However, user experience of mobile video depends on many different measurable aspects, like intrinsic encoding quality (affected by resolution, frame rate and codec) and dynamic quality effects (such as time-to-content, rebufferings and resolution adaptation to channel capacity). Video QoE is well-researched

[1] ITU-T work item P.BBQCG, www.itu.int/ITU-T/workprog/wp_item.aspx?isn=17809.
[2] G.CMVTQS, www.itu.int/ITU-T/workprog/wp_item.aspx?isn=17785. Note: Video telephony is not the same as video conferencing, but still similar to a two-party video conference call.
[3] Ericsson Mobility Report (November 2022).

Figure 31: Video streaming quality model



and relies on models that were standardized before 5G was introduced, such as the ITU-T P.1203 standard.[4] This includes modules for estimating short-term video (P.1203.1) and audio (P.1203.2) quality, and an integration module (P.1203.3) estimating the final session quality due to adaptation and stalling. The short-term video quality scores are fed into the integration module and the final quality score is then presented as a single mean opinion score (MOS) ranged 1–5 for the whole experience. This is an objective model designed to mimic the behaviour and perception of humans, producing the MOS values that would result from running a subjective video quality test with a group of individuals in a laboratory environment.

In this study, Ericsson replaced the P.1203.1 module with the open source-based Video Multimethod Fusion Approach (VMAF) algorithm, as P.1203.1 does not support some commonly-used codecs.[5] Since the test video is known, and pre-encoded, VMAF could be used offline to assess the video encoding quality for the resolutions utilized, while P.1203.3 was used to add the dynamic effects of time-to-content, rebufferings and resolution adaptation. The resulting QoE measure (output) from the model is presented as a single mean opinion score (MOS) in a range of 1–5 for the whole experience (see Figure 31). This figure shows the P.1203 architecture, with P.1203.1 exchanged to VMAF.

The model relies on a theoretical maximum value defined by the resolution, where standard definition (SD) is the lowest possible resolution that gives a good experience (MOS 3.5–4.5) on a smartphone, and excellent experience (MOS 4.5–5) requires at least full HD (see Figure 32).

Insights into mobile video streaming QoE

When applying the model (Figure 31) to mobile video streaming deliveries over commercial networks in the US, it was found that:

- Excellent quality (MOS 4.5–5) was achieved by 61 percent of the mobile video streams measured. The measurements varied between 44–72 percent across the three large service providers. The differences between service providers relate to spectrum used and network rollout strategies. The premium resolution samples were limited and represented only 12 percent (2K) and 4 percent (4K) of all measured streams.
- Only 13 percent of the streams measured were less-than-good (below 3.5 MOS). Poor radio conditions were the root cause for 40 percent of the less-than-good experiences, with either poor radio frequency (RF) strength, poor RF quality, or a combination of both.
- 5G increases video streaming quality compared to 4G and Wi-Fi. The proportion of streams with excellent quality increased from 58 percent (4G) to 72 percent (5G). The QoE gap compared to Wi-Fi decreased from 22 percent to 8 percent. 5G has significantly reduced Wi-Fi's previous streaming quality advantage.

Insights into mobile gaming QoE

Two-thirds of mobile app revenues come from mobile games,[6] and we are at the beginning of the fourth gaming wave (after console, PC, and mobile games) with cloud gaming increasingly offered by service providers. The transition from mobile app games, studied here, to mobile cloud games will materially change network performance requirements. For mobile games executed in an app[7] on a smartphone or tablet, the QoE depends on latency, packet loss and jitter. A simple evaluation model was applied to the captured data for these parameters to rate the QoE:

- 57 percent of the mobile gaming experiences measured were of excellent quality. Mobile app-based gaming is latency-sensitive. However, the differences in latency between service

Figure 32: Maximum possible MOS for video streaming to smartphones

[4] Ericsson, Video QoE, leveraging standards to meet rising user expectations (June 2017).
[5] VMAF, Video Multi-Method Assessment Fusion.
[6] Data.ai, State of Mobile 2023, (January 11, 2023).
[7] No video component is transmitted, only metadata in the uplink and downlink.

providers was limited, and all three Tier-1 providers fall within the 54–58 percent bracket for an excellent QoE. The shift from 4G to 5G increased gaming sessions with excellent QoE by 6 percent.
- Server locations influence mobile gaming QoE, due to longer delays. There is a difference in mobile gaming QoE between servers located in the US (82 percent providing excellent quality) and elsewhere (38 percent providing excellent quality).

In this case, a simple evaluation model was used to rate the QoE. More work is needed to develop a deeper understanding of what parameters influence the perceived QoE for mobile gaming.

Insights into mobile video conferencing QoE

COVID-19 led to 2D video conferencing being universally adopted in home offices. Not only is it here to stay in the hybrid workplace, but it will evolve toward immersive 3D communication. While PCs presently dominate as the platform for video conference calls at work and home, mobile devices are growing in importance in the workplace and when commuting. The QoE for mobile video conferencing is dependent on video resolution and round-trip delays. A few aspects make mobile video conferencing different to using a fixed network connection. The high-end resolutions of 4K and 2K are typically not used, and the usage of Full HD (1080p) and lower resolutions vary somewhat between different video conferencing services. Video conferencing is inherently latency-sensitive, but material drops in quality do not occur until after about 100 ms in round-trip delay.

In anticipation of a standardized model, we have used the same resolution base as for video streaming (see Figure 32). The resolution estimate comes from the available bit rate at the initiation of the video conferencing service. The impact of network delays leverages the ITU-T G.107 model, initially defined for voice quality predictions, as users tend to be more sensitive to audio delays, than video delays. The key results were:
- 58 percent of mobile video conferencing experiences (4G) were of excellent quality, with both throughput and latency variables meeting the threshold for excellent quality
- 88 percent of mobile video conference experiences (5G) were of excellent quality – a significant leap upward by 30 percentage points from the 58 percent for 4G
- 5G emerged as the best network, even 3 points ahead of Wi-Fi, for overall QoE of mobile video conferencing

Network readiness for new types of mobile experiences

The most significant value of the approach described in this article will be for new types of experiences, for which both application developers and network planners need new tools to rate QoE. However, QoE models are experience-specific and need to be standardized for new types of experiences like cloud gaming and XR.

As part of the analysis, the capabilities of existing networks to meet quality thresholds on downlink, uplink and latency for these types of services were examined. 5G connectivity requirements vary for mobile cloud gaming and AR use cases:
- mobile cloud gaming:[8] 10 Mbps downlink, 5–9 Mbps uplink, and 30–75 ms round trip latency
- AR:[9] 2–60 Mbps downlink, 2–20 Mbps uplink, and 5–50 ms round-trip latency

Through modeling of measured downlink throughput and round-trip delays, network readiness for these types of services were measured as follows, as a percentage of modeled service access attempts:
- mobile cloud gaming: 40 percent of measured throughput and latency values meet requirements
- AR: 3–32 percent of measured throughput and latency values meet minimum requirements

The large spread in network readiness values for AR depends on the "flavor" of AR in play, and where in the requirement span each flavor falls. The location of servers required for remote rendering have a high impact on the results for data points collection coupled to latency. As AR flavors, server locations, model development and data point collection mature, the initial spread in network readiness will be replaced by specific values.

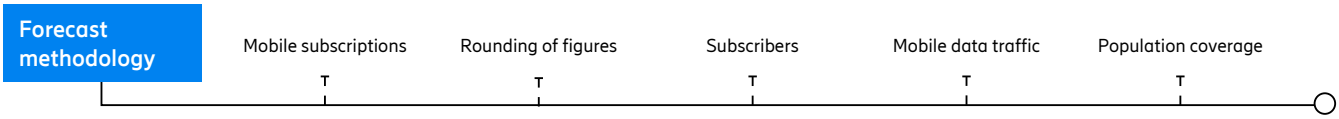
The difference between the high percentage (61 percent) of mobile video streaming experiences rated "excellent quality" and the low percentage for meeting the minimum network requirements of mobile cloud gaming (40 percent), AR (3–32 percent) experiences points to a need for continued 5G network evolution. This will be necessary to meet a large variety of requirements of new types of services, with higher demands on network performance.

Performance capabilities need further improvements

The work to define QoE rating models for new experiences with high network performance requirements is still to be undertaken. However, the work to define the models and the job of capturing datapoints for predicting quality for an experience can happen in parallel, so that both models and robust data sets can guide network evolution plans before standards are complete. A need to continue improving mobile network performance capabilities to meet the requirements of new mobile experiences, and rising user expectation on QoE, will grow with uptake of new services.

[8] Xbox gamepass requirements, Microsoft.
[9] "XR and 5G: Extended reality at scale with time-critical communication" (August 24, 2021)

Methodology



Forecast methodology
Ericsson makes forecasts on a regular basis to support internal decisions and planning, as well as market communications. The forecast time in the Mobility Report is six years and this moves forward one year in the November report each year. The subscription and traffic forecast baseline is established using historical data from various sources, validated with Ericsson internal data, including measurements in customer networks. Future developments are estimated based on macroeconomic trends, user trends, market maturity and technological advances. Other sources include industry analyst reports, together with internal assumptions and analyses.

Historical data may be revised if the underlying data changes – for example, if service providers report updated subscription figures.

Mobile subscriptions
Mobile subscriptions include all mobile technologies. Subscriptions are defined by the most advanced technology that the mobile phone and network are capable of. Our mobile subscriptions by technology findings divide subscriptions according to the highest-enabled technology they can be used for. LTE (4G) subscriptions, in most cases, also include the possibility for the subscription to access 3G (WCDMA/HSPA) and 2G (GSM or CDMA in some markets) networks. A 5G subscription is counted as such when associated with a device that supports New Radio as specified in 3GPP Release 15, and connected to a 5G-enabled network. Mobile broadband includes radio access technologies HSPA (3G), LTE (4G), 5G, CDMA2000 EV-DO, TD-SCDMA and Mobile WiMAX. WCDMA without HSPA and GPRS/EDGE are not included.
FWA is defined as a connection that provides broadband access through mobile network enabled customer premises equipment (CPE). This includes both indoor (desktop and window-mounted) and outdoor (rooftop and wall-mounted) CPE. It does not include portable battery-based Wi-Fi routers or dongles.

Rounding of figures
As figures are rounded, summing up data may result in slight differences from the actual totals. In tables with key figures, subscriptions have been rounded to the nearest 10th of a million. However, when used in highlights in the articles, subscriptions are usually expressed in full billions or to one decimal place. Compound annual growth rate (CAGR) is calculated on the underlying, unrounded numbers and is then rounded to the nearest full percentage figure. Traffic volumes are expressed to two significant figures.

Subscribers
There is a large difference between the numbers of subscriptions and subscribers. This is because many subscribers have several subscriptions. Reasons for this could include users lowering traffic costs by using optimized subscriptions for different types of calls, maximizing coverage and having different subscriptions for mobile PCs/tablets and mobile phones. In addition, it takes time before inactive subscriptions are removed from service provider databases. Consequently, subscription penetration can be above 100 percent, which is the case in many countries today. However, in some developing regions, it is common for several people to share one subscription, for example via a family- or community-shared phone.

Mobile network traffic
Ericsson regularly performs traffic measurements in over 100 live networks covering all major regions of the world. These measurements form a representative base for calculating worldwide total mobile network traffic. Mobile network data traffic also includes traffic generated by FWA services. More detailed measurements are made in a select number of commercial networks with the purpose of understanding how mobile data traffic evolves. No subscriber data is included in these measurements. Please note that the Ericsson Mobility Report data traffic forecast, both global and regional, represents the estimated traffic volume in all networks over the duration of a month. Traffic (in terms of throughput) in high-traffic areas will be much higher than the average traffic.

Population coverage
Population coverage is estimated using a database of regional population and territory distribution, based on population density. This is then combined with proprietary data on the installed base of radio base stations (RBS), together with estimated coverage per RBS for each of six population density categories (from metro to wilderness). Based on this, the portion of each area that is covered by a certain technology can be estimated, as well as the percentage of the population it represents. By aggregating these areas, world population coverage per technology can be calculated.

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Explore actual and forecast data from the Mobility Report in our interactive web application. It contains a range of data types, including mobile subscriptions, mobile broadband subscriptions, mobile data traffic, traffic per application type, VoLTE statistics, monthly data usage per device and an IoT connected device forecast. Data can be exported and charts generated for publication subject to the inclusion of an Ericsson source attribution.

Find out more
Scan the QR code, or visit
ericsson.com/mobility-visualizer

Glossary

2CC: Two component carrier

2G: 2nd generation mobile networks (GSM, CDMA 1x)

3CC: Three component carrier

3G: 3rd generation mobile networks (WCDMA/HSPA, TD-SCDMA, CDMA EV-DO, Mobile WiMAX)

3GPP: 3rd Generation Partnership Project

4CC: Four component carrier

4G: 4th generation mobile networks (LTE, LTE-A)

4K: In video, a horizontal display resolution of approximately 4,000 pixels. A resolution of 3840 × 2160 (4K UHD) is used in television and consumer media. In the movie projection industry, 4096 × 2160 (DCI 4K) is dominant

5G: 5th generation mobile networks (IMT-2020)

AI: Artificial intelligence

AR: Augmented reality. An interactive experience of a real-world environment whereby the objects that reside in the real world are "augmented" by computer-generated information

ARPU: Average revenue per user

CAGR: Compound annual growth rate

Cat-M1: A 3GPP standardized low-power wide-area (LPWA) cellular technology for IoT connectivity

CDMA: Code-division multiple access

dB: In radio transmission, a decibel is a logarithmic unit that can be used to sum up total signal gains or losses from a transmitter to a receiver

EB: Exabyte, 10^{18} bytes

EN-DC: EUTRA-NR Dual connectivity

FDD: Frequency division duplex

FWA: Fixed wireless access

GB: Gigabyte, 10^{9} bytes

Gbps: Gigabits per second

GHz: Gigahertz, 10^{9} hertz (unit of frequency)

GSA: Global mobile Suppliers Association

GSM: Global System for Mobile Communications

GSMA: GSM Association

HSPA: High speed packet access

IoT: Internet of Things

Kbps: Kilobits per second

LTE: Long-Term Evolution

MB: Megabyte, 10^{6} bytes

Mbps: Megabits per second

MHz: Megahertz, 10^{6} hertz (unit of frequency)

MIMO: Multiple Input Multiple Output is the use of multiple transmitters and receivers (multiple antennas) on wireless devices for improved performance

mmWave: Millimeter waves are radio frequency waves in the extremely high frequency range (30–300GHz) with wavelengths between 10mm and 1mm. In a 5G context, millimeter waves refer to frequencies between 24 and 71GHz (the two frequency ranges 26GHz and 28GHz are included in millimeter range by convention)

Mobile broadband: Mobile data service using radio access technologies including 5G, LTE, HSPA, CDMA2000 EV-DO, Mobile WiMAX and TD-SCDMA

Mobile PC: Defined as laptop or desktop PC devices with built-in cellular modem or external USB dongle

Mobile router: A device with a cellular network connection to the internet and Wi-Fi or Ethernet connection to one or several clients (such as PCs or tablets)

MOCN: Multi-operator core network

MORAN: Multi-operator Radio Access Network

MR: Mixed reality. Immersive technology in which elements from both the real world and a virtual environment are fully interactive with each other

NB-IoT: A 3GPP standardized low-power wide-area (LPWA) cellular technology for IoT connectivity

Net Zero: Defined in ITU standards as a future state where all emissions that can be reduced are reduced, with like-for-like or permanent removals applied by carbon-removal technologies to balance the remaining emissions

NR: New Radio as defined by 3GPP Release 15

NR-DC: NR-NR Dual connectivity

NSA 5G: Non-standalone 5G is a 5G Radio Access Network (RAN) that operates on a legacy 4G/LTE core

PB: Petabyte, 10^{15} bytes

RedCap: Reduced capability

SA: Standalone

Short-range IoT: Segment that largely consists of devices connected by unlicensed radio technologies, with a typical range of up to 100 meters, such as Wi-Fi, Bluetooth and Zigbee

Sunsetting: The process of closing down older mobile technologies

TD-SCDMA: Time division-synchronous code-division multiple access

TDD: Time division duplex

VoIP: Voice over IP (Internet Protocol)

VoLTE: Voice over LTE as defined by GSMA IR.92 specification

VR: Virtual reality

WCDMA: Wideband code-division multiple access

Wide-area IoT: Segment made up of devices using cellular connections or unlicensed low-power technologies like Sigfox and LoRa

XR: Extended reality. An umbrella category for virtual or combined real/virtual environments, which includes AR, VR and MR

Key figures

Global key figures

Mobile subscriptions	2021	2022	Forecast 2028	CAGR* 2022–2028	Unit
Worldwide mobile subscriptions	8,200	8,260	9,100	2%	million
• Smartphone subscriptions	6,160	6,420	7,740	3%	million
• Mobile PC, tablet and mobile router subscriptions	390	410	660	8%	million
• Mobile broadband subscriptions	6,770	7,030	8,490	3%	million
• Mobile subscriptions, GSM/EDGE-only	1,290	1,100	440	-14%	million
• Mobile subscriptions, WCDMA/HSPA	1,330	1,030	220	-22%	million
• Mobile subscriptions, LTE	5,050	5,160	3,800	-5%	million
• Mobile subscriptions, 5G	510	950	4,620	30%	million
• Fixed wireless access connections	88	107	300	19%	million
Fixed broadband connections	**1,360**	**1,450**	**1,800**	**4%**	**million**
Mobile data traffic					
• Data traffic per smartphone	12.2	16	47	20%	GB/month
• Data traffic per mobile PC	17	20	30	7%	GB/month
• Data traffic per tablet	9.5	11.2	27	16%	GB/month
Total data traffic**					
Mobile data traffic	69	93	329	23%	EB/month
• Smartphones	66	90	320	24%	EB/month
• Mobile PCs and routers	0.6	0.8	2.1	17%	EB/month
• Tablets	2.1	2.4	6.7	18%	EB/month
Fixed wireless access	15.6	24	143	34%	EB/month
Total mobile network traffic	84	118	472	26%	EB/month
Total fixed data traffic	220	270	600	14%	EB/month

Regional key figures

Mobile subscriptions	2021	2022	Forecast 2028	CAGR* 2022–2028	Unit
North America	400	410	450	2%	million
Latin America	700	710	790	2%	million
Western Europe	540	540	560	0%	million
Central and Eastern Europe	570	570	560	0%	million
North East Asia	2,110	2,160	2,270	1%	million
China[1]	1,640	1,680	1,740	1%	million
South East Asia and Oceania	1,150	1,140	1,290	2%	million
India, Nepal and Bhutan	1,140	1,110	1,230	2%	million
Middle East and North Africa	750	730	880	3%	million
Gulf Cooperation Council (GCC)[2]	74	75	80	1%	million
Sub-Saharan Africa	860	900	1,070	3%	million

Smartphone subscriptions	2021	2022	Forecast 2028	CAGR* 2022–2028	Unit
North America	310	320	340	1%	million
Latin America	550	560	670	3%	million
Western Europe	400	420	450	1%	million
Central and Eastern Europe	380	390	430	2%	million
North East Asia	1,900	1,970	2,130	1%	million
China[1]	1,500	1,560	1,650	1%	million
South East Asia and Oceania	890	930	1,120	3%	million
India, Nepal and Bhutan	800	840	1,140	5%	million
Middle East and North Africa	550	560	800	6%	million
GCC[2]	61	63	71	2%	million
Sub-Saharan Africa	370	410	690	9%	million

Regional key figures

LTE subscriptions	2021	2022	Forecast 2028	CAGR* 2022–2028	Unit
North America	320	230	40	-25%	million
Latin America	460	520	360	-6%	million
Western Europe	440	430	60	-27%	million
Central and Eastern Europe	350	410	330	-4%	million
North East Asia	1,590	1,420	630	-13%	million
China[1]	1,200	1,050	480	-12%	million
South East Asia and Oceania	560	640	770	3%	million
India, Nepal and Bhutan	780	820	500	-8%	million
Middle East and North Africa	370	420	520	4%	million
GCC[2]	58	55	7	-29%	million
Sub-Saharan Africa	183	270	590	14%	million

5G subscriptions	2021	2022	Forecast 2028	CAGR* 2022–2028	Unit
North America	55	166	410	16%	million
Latin America	3	7	330	N/A	million
Western Europe	32	69	490	39%	million
Central and Eastern Europe	1	5	230	N/A	million
North East Asia	397	637	1,610	17%	million
China[1]	353	560	1,310	15%	million
South East Asia and Oceania	9	25	430	N/A	million
India, Nepal and Bhutan	0	10	700	N/A	million
Middle East and North Africa	11	22	290	N/A	million
GCC[2]	6	13	70	31%	million
Sub-Saharan Africa	1	3	140	N/A	million

Data traffic per smartphone	2021	2022	Forecast 2028	CAGR* 2022–2028	Unit
North America	13	20	58	20%	GB/month
Latin America	7.8	10.9	41	25%	GB/month
Western Europe	16	20	56	19%	GB/month
Central and Eastern Europe	10.2	14	37	18%	GB/month
North East Asia	14	18	54	20%	GB/month
China[1]	15	18	47	17%	GB/month
South East Asia and Oceania	10	15	54	24%	GB/month
India, Nepal and Bhutan	21	26	62	16%	GB/month
Middle East and North Africa	8.7	12	37	20%	GB/month
GCC[2]	22	26	59	15%	GB/month
Sub-Saharan Africa	3.3	4.7	19	26%	GB/month

Total mobile data traffic	2021	2022	Forecast 2028	CAGR* 2022–2028	Unit
North America	4.6	6.7	21	21%	EB/month
Latin America	3.8	5.3	24	28%	EB/month
Western Europe	6.0	8.0	23	20%	EB/month
Central and Eastern Europe	3.1	4.3	12	19%	EB/month
North East Asia	23	30	97	22%	EB/month
China[1]	20	26	84	22%	EB/month
South East Asia and Oceania	8.3	12.8	55	27%	EB/month
India, Nepal and Bhutan	14.1	18	58	22%	EB/month
Middle East and North Africa	4.3	6.2	27	27%	EB/month
GCC[2]	1.1	1.3	3.3	17%	EB/month
Sub-Saharan Africa	1.08	1.7	11.4	37%	EB/month

[1] These figures are also included in the figures for North East Asia.
[2] These figures are also included in the figures for Middle East and North Africa.

* CAGR is calculated on unrounded figures.
** Figures are rounded (see methodology) and therefore summing up of rounded data may result in slight differences from the actual total.

About Ericsson

Ericsson enables communications service providers and enterprises to capture the full value of connectivity. The company's portfolio spans the following business areas: Networks, Cloud Software and Services, Enterprise Wireless Solutions, Global Communications Platform, and Technologies and New Businesses. It is designed to help our customers go digital, increase efficiency and find new revenue streams. Ericsson's innovation investments have delivered the benefits of mobility and mobile broadband to billions of people globally. Ericsson stock is listed on Nasdaq Stockholm and on Nasdaq New York.

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