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Ericsson Mobility Report

June 2021

Letter from the publisher

5G on the road to mass market

For more than 18 months now, the world has faced a crisis on a scale that defies belief. As countries around the world deal with different phases of the COVID-19 pandemic, it is clear that technology, and specifically connectivity, increasingly supports many aspects of our everyday lives.

The resilience and diligence of our industry continues to be evidenced by the striking numbers in this edition of the Ericsson Mobility Report. The speed of 5G uptake is far higher than it was for 4G, let alone 3G, and it is one more sign of an industry that tirelessly continues to drive innovation and bring new technology to the market.

So far, more than 160 communications service providers have launched 5G services and over 300 5G smartphone models have been announced or launched commercially. Before the end of this year, we will have surpassed half a billion 5G users in the world.

However, the picture becomes a bit different when looking at the development on a regional level, where it is clear that it will take longer in some regions for 5G to be deployed and ready for mass-adoption. Nevertheless, whether it's 4G or 5G, the need for good, high-speed connectivity is virtually limitless. The fact that more than 70 percent of all service providers are now offering fixed wireless access (FWA) services speaks to this need.

As societies plan a return to a more normal situation after the pandemic, the need to secure and invest in high-quality digital infrastructure should be on everyone's agenda as a key component of economic recovery. It's a good thing, then, that the industry able to deliver on that need is already on its way to doing so.

We hope you find the report engaging and useful!

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70%

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46%

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Mobile subscriptions shifting towards 5G

By the end of 2021, 5G subscriptions are expected to reach 580 million.

Despite the uncertainty caused by COVID-19, service providers continue to switch on 5G and more than 160 have launched commercial 5G services.[1]

5G subscriptions with a 5G-capable device grew by 70 million during the first quarter, to reach around 290 million. We estimate close to 580 million 5G subscriptions[2] by the end of 2021. Currently, North East Asia has the highest 5G subscription penetration, followed by North America, Gulf Cooperation Council countries and Western Europe. In 2026, it is projected that North America will have the highest share of 5G subscriptions of all regions at 84 percent.

5G subscription uptake is expected to be faster than that of 4G following its launch in 2009. 5G subscriptions are estimated to reach 1 billion 2 years earlier than 4G. Key factors include China's earlier engagement with 5G compared to 4G, as well as the timely availability of devices from several vendors. By the end of 2026, we forecast 3.5 billion 5G subscriptions globally, accounting for around 40 percent of all mobile subscriptions at that time.

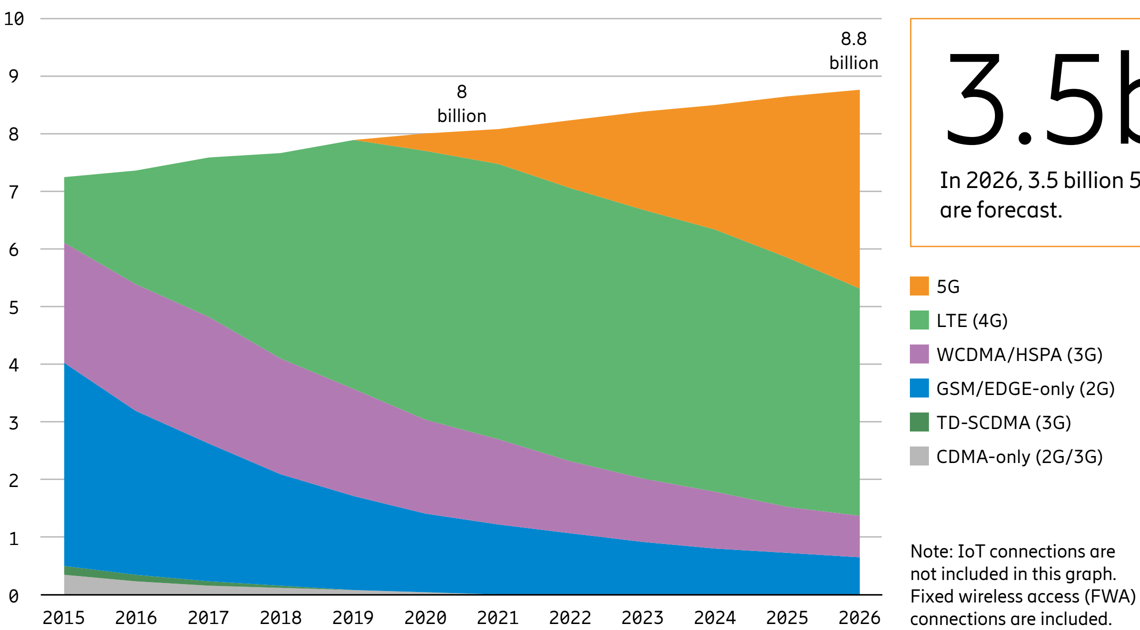
4G will remain the dominant mobile access technology by subscription over the forecast period. During Q1 2021, 4G subscriptions increased by approximately 100 million, exceeding 4.6 billion, equaling 58 percent of all mobile subscriptions. It is projected to peak during the year at 4.8 billion subscriptions before declining to around 3.9 billion subscriptions by the end of 2026 as more subscribers migrate to 5G.

The net addition of mobile subscriptions was quite low during Q1 2021, at 59 million. This is likely due to the pandemic and associated lockdown restrictions. India had the most net additions (+26 million), followed by China (+6 million) and Nigeria (+3 million).

Service package trends

Service providers are continuously adapting their service packaging towards consumers. In addition to offering significantly higher speeds, 5G subscriptions often contain larger buckets or even unlimited data. As this drives up usage, service providers are also including limitations, albeit soft ones, as a means to improve monetization. Daily allowances for unlimited packages are appearing, with an option to increase the allowance in steps of a few GB without cost, using a simple text message each time.

Figure 1: Mobile subscriptions by technology (billion)



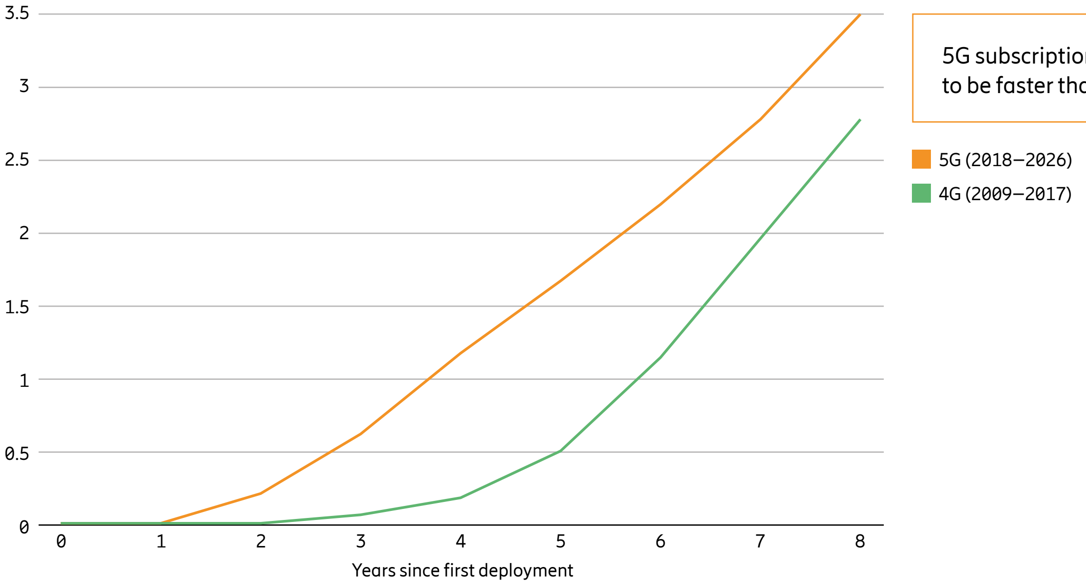
Note: IoT connections are not included in this graph. Fixed wireless access (FWA) connections are included.

3.5bn

In 2026, 3.5 billion 5G subscriptions are forecast.

[1] GSA (April 2021).
[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.

Figure 2: Comparison of 5G and 4G subscription uptake in the first years of deployment (billion)



5G subscription uptake is expected to be faster than for 4G.

Many service providers are also introducing terms and conditions against the use of various IoT devices together with these packages, as well as capping usage within family and share plans. Service-based packages, such as music and video passes, have been steadily growing in numbers over the past few years. A new addition in this segment is the arrival of gaming passes. These packages, sold as add-ons to regular buckets, are appealing to gamers by promoting 5G and low-latency experiences. Either the traffic is zero-rated or a certain number of hours of use or amount of GB are set aside for the packages.

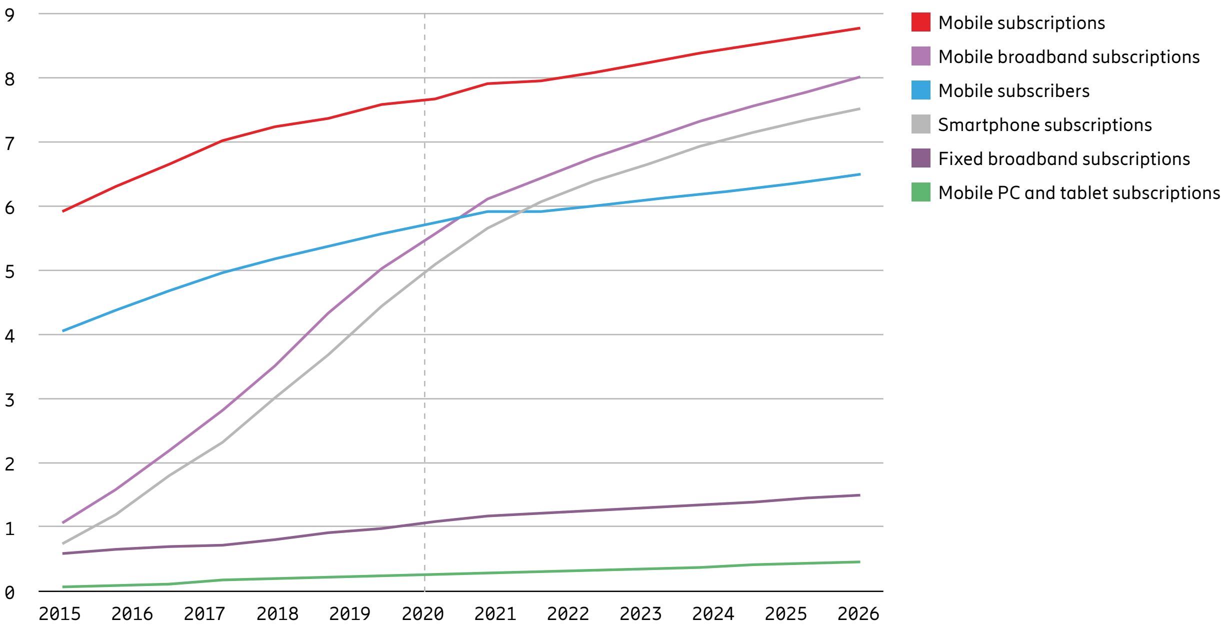
Mobile broadband subscriptions on the rise

Today, there are around 8 billion mobile subscriptions. We estimate that this figure will increase to 8.8 billion by the end of 2026, of which 91 percent will be for mobile broadband. The number of unique mobile subscribers is projected to grow from 5.9 billion in Q1 2021 to 6.5 billion by the end of the forecast period.

Smartphone penetration continues to rise, and subscriptions associated with smartphones account for about 76 percent of all mobile phone subscriptions.

At the end of 2020, there were 6 billion smartphone subscriptions. This number is forecast to reach 7.7 billion in 2026, which will account for around 88 percent of all mobile subscriptions at that time. Subscriptions for fixed broadband are expected to grow around 4 percent annually through 2026.[3] FWA connections are anticipated to show strong growth of about 20 percent annually through 2026. Subscriptions for mobile PCs and tablets are expected to show moderate growth, reaching around 450 million in 2026.

Figure 3: Subscriptions and subscribers (billion)

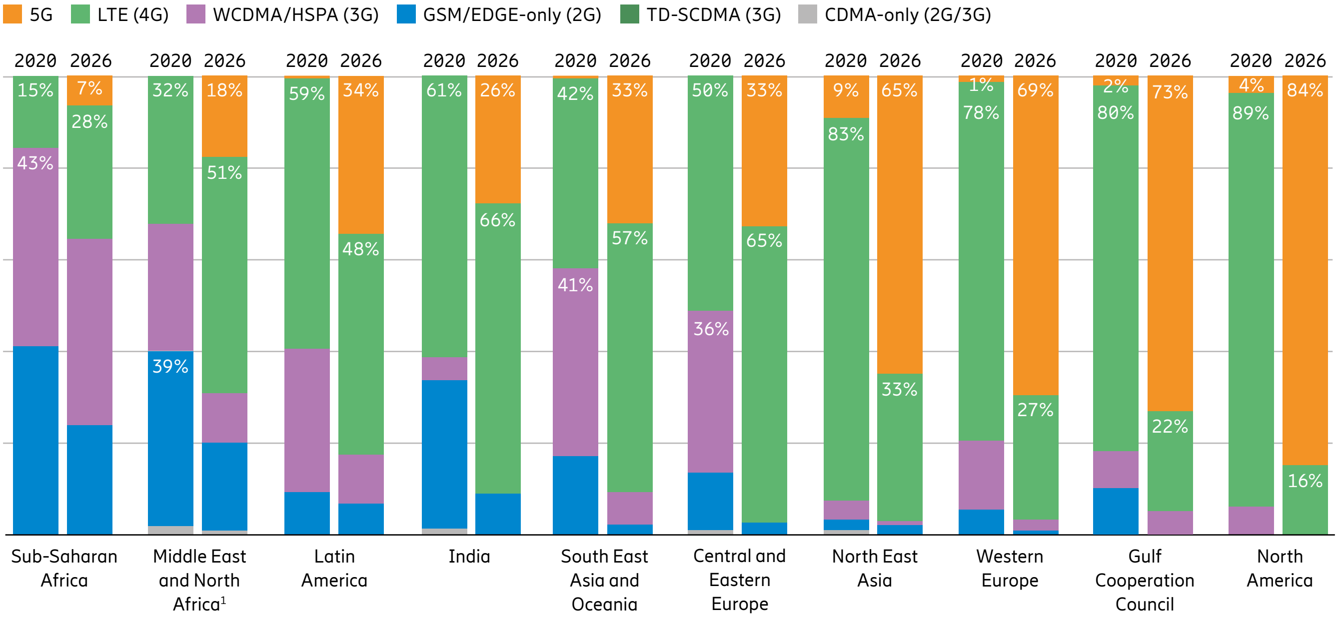


[3] The number of fixed broadband users is at least three times the number of fixed broadband connections due to shared subscriptions in households, enterprises and public access spots. It is the opposite for mobile phones, where subscription numbers exceed user numbers.

5G set to penetrate every region by 2026

Mobile broadband subscriptions currently make up 83 percent of all mobile subscriptions.

Figure 4: Mobile subscriptions by region and technology (percent)



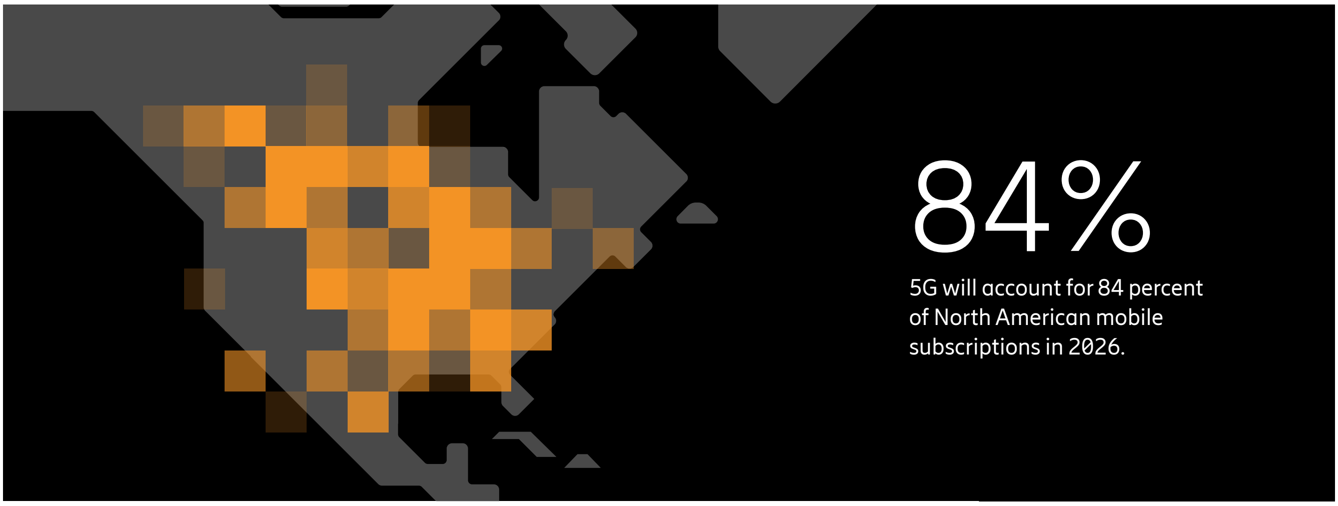
Note: Technologies with less than 1 percent of subscriptions are not shown in the graph.

Sub-Saharan Africa
In Sub-Saharan Africa, mobile subscriptions will continue to grow over the forecast period as mobile penetration is less than the global average. In the first quarter of 2021, more than 20 percent of the global net additions were recorded in Africa, with Nigeria having the third-highest numbers globally of net adds. 4G accounted for around 15 percent of subscriptions at the end of 2020. Over the forecast period mobile broadband[2] subscriptions are predicted to increase, reaching 76 percent of mobile subscriptions. While 5G and 4G subscriptions will continue to grow over the next 6 years, HSPA will remain the dominant technology with a share of over 40 percent in 2026. Driving factors behind the growth of mobile broadband subscriptions include a young, growing population with increasing digital skills and more affordable smartphones. Over the forecast period, discernible volumes of 5G subscriptions are expected from 2022, reaching 7 percent in 2026.

Middle East and North Africa
In the Middle East and North Africa region, around 32 percent of mobile subscriptions were for 4G at the end of 2020. The region is anticipated to evolve over the forecast period, and by 2026 about 80 percent of subscriptions are expected to be for mobile broadband, 4G being the dominant technology with more than 50 percent of subscriptions. Commercial 5G deployments with leading service providers have taken place and 5G subscriptions exceeded 1 million at the end of 2020. Significant 5G volumes are expected in 2021 and the region is likely to reach around 150 million 5G subscriptions in 2026, representing 18 percent of total mobile subscriptions.

Gulf Cooperation Council (GCC)
The GCC countries, part of the Middle East and North Africa region, are among the most advanced ICT markets in the world – over 90 percent of mobile subscriptions were for mobile broadband at the end of 2020 and this is estimated to reach 95 percent in 2026. 4G is the dominant technology, accounting for about 80 percent of the subscriptions at the end of 2020. However, with 5G adoption accelerating in the forecast period, the majority of mobile subscriptions are anticipated to be for 5G at over 62 million in 2026, representing about 73 percent of total mobile subscriptions. This will make the GCC the region with the second-highest 5G penetration at that time.

[1] Includes GCC countries.
[2] Mobile broadband includes radio access technologies HSPA (3G), LTE (4G), 5G, CDMA2000 EV-DO, TD-SCDMA and Mobile WiMAX.



Latin America
In Latin America, 4G remains the dominant radio access technology during the forecast period, accounting for 59 percent of subscriptions at the end of 2020 and a predicted 48 percent in 2026. A steady decline in WCDMA/HSPA is forecast as users migrate to 4G and 5G, falling from 30 to 11 percent. To date, Brazil and Colombia have launched commercial 5G services, and other countries such as Argentina, Chile and Mexico are investing in and deploying 5G. By the end of 2026, 5G is set to make up 34 percent of mobile subscriptions.

India
In the India region, 4G subscriptions are forecast to rise from 680 million in 2020 to 830 million in 2026, increasing at a CAGR of 3 percent. 4G remained the dominant technology in 2020, accounting for 61 percent of mobile subscriptions. The technology will continue to be dominant, representing 66 percent of mobile subscriptions in 2026, with 3G being phased out by that time. 5G will represent around 26 percent of mobile subscriptions in India at the end of 2026, estimated at about 330 million subscriptions. The number of smartphone subscriptions was 810 million in 2020 and is expected to grow at a CAGR of 7 percent, reaching over 1.2 billion by 2026. Smartphone subscriptions accounted for 72 percent of total mobile subscriptions in 2020 and are projected to constitute over 98 percent in 2026, driven by rapid smartphone adoption in the country.

South East Asia and Oceania
Mobile subscriptions in the region have now exceeded 1.1 billion, with Indonesia being among the top 5 countries globally when it comes to net additions. 5G subscriptions now sit just below the 2 million mark in the region but will grow strongly over the next few years with a forecast total of about 400 million by 2026. Key achievements in 5G continue to be observed in the region's most developed markets. Carrier aggregation trials have been gathering momentum with a world-first combination of 5G FDD 2.1GHz and 5G TDD 3.5GHz spectrum in Australia. Earlier in the year, Australia saw the launch of a capacity-enhancing 2.3GHz and 3.5GHz TDD dual band network, also using carrier aggregation techniques. In Singapore, several 5G standalone (SA) sites are being deployed in preparation for a launch that would complement current 5G non-standalone (NSA) commercial offerings in the country.

Central and Eastern Europe
In Central and Eastern Europe, 4G is the dominant technology and now accounts for 50 percent of all subscriptions. In 2026, 4G will remain the dominant technology and is expected to account for 65 percent of mobile subscriptions, while 5G subscriptions are forecast to make up 33 percent. During the forecast period, there will continue to be a significant decline in WCDMA/HSPA, from 36 percent to virtually zero, as users migrate to 4G and 5G.

To date, around 20 5G networks have been commercially launched across the region. Further spectrum auctions in the key frequency bands like 700MHz and 3.4–3.8GHz were planned for the end of 2020 and the beginning of 2021, some of which were delayed. This will have a short-term impact on 5G deployment in affected countries.

North East Asia
In North East Asia, service providers continue to invest in 5G deployments to further fuel 5G subscription growth. A current focus area for service providers is to improve nationwide coverage. Meanwhile, the rapid growth of 5G subscriptions, supported by an increased number of available 5G-device models have had a positive impact on services providers' financial performance. Major service providers in leading 5G markets, such as China and South Korea, have reported a positive impact of 5G subscribers on mobile service revenues and ARPU in 2020.

At the close of the forecast period, the region is anticipated to have more than 1.4 billion 5G subscriptions, equaling a 5G subscription penetration of 65 percent.

Western Europe
In Western Europe, 4G is the dominant access technology, accounting for 78 percent of all subscriptions. 4G is predicted to decline to 27 percent and WCDMA/HSPA to only 3 percent of subscriptions in 2026 as subscribers migrate to 5G. More than 60 service providers have launched 5G services across the region. Further spectrum auctions in the 700MHz and 3.4–3.8GHz bands were planned during 2020, but some were delayed, which will have a short-term impact on the deployment and coverage of 5G in the region. 5G subscription penetration is projected to reach 69 percent by the end of 2026.

North America
In North America, 5G commercialization is moving at a rapid pace. Service providers have launched commercial 5G services, with a focus on mobile broadband and fixed wireless access (FWA). The introduction of 5G smartphones supporting all three spectrum bands has already made 2021 an eventful year for early 5G adopters. FWA will play a key role in closing the digital divide where the pandemic has exposed large gaps for education, remote working and small businesses. By 2026, more than 360 million 5G subscriptions are anticipated in the region, accounting for 84 percent of mobile subscriptions.

5G commercial launches drive FWA offerings

Over 70 percent of all service providers are now offering fixed wireless access (FWA) services. Connections are forecast to exceed 180 million by the end of 2026, accounting for more than 20 percent of total mobile network data traffic globally.

More than 70 percent of all service providers are now offering FWA
The COVID-19 pandemic is accelerating digitalization, as well as increasing the importance of, and need for, fast and reliable home broadband connectivity. FWA is, in many cases, the quickest alternative to meet this demand.

In April 2021, Ericsson, for the fifth time, updated its study of retail packages offered by service providers worldwide. Out of the 311 service providers studied, 224 had an FWA offering, which represents an average of 72 percent globally. Service providers' adoption of FWA offerings has increased by 12 percentage points during the last six months, and more than doubled since the first measurements in December 2018.

~90%

Almost 90 percent of service providers that have launched 5G also have an FWA offering (4G and/or 5G).

Figure 5: Global number of service providers offering FWA

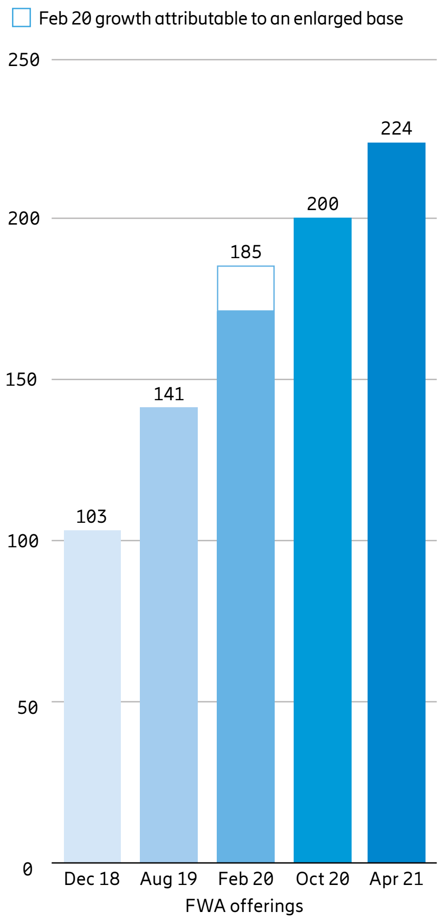


Figure 6: Regional percentage of service providers offering FWA

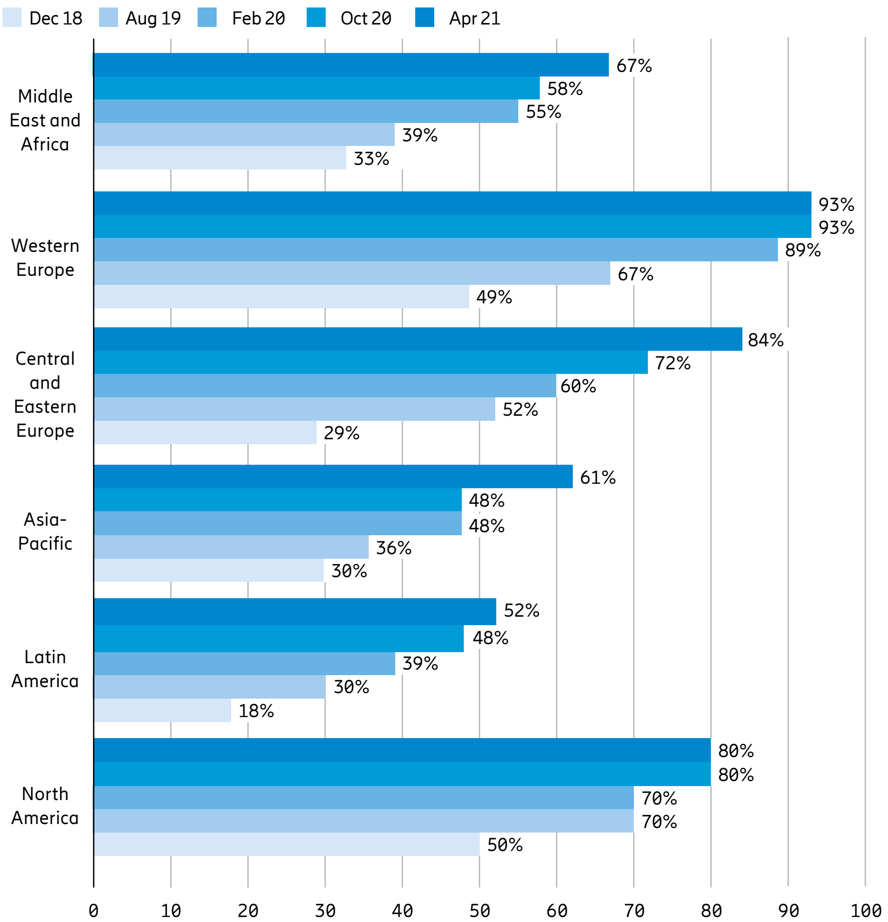
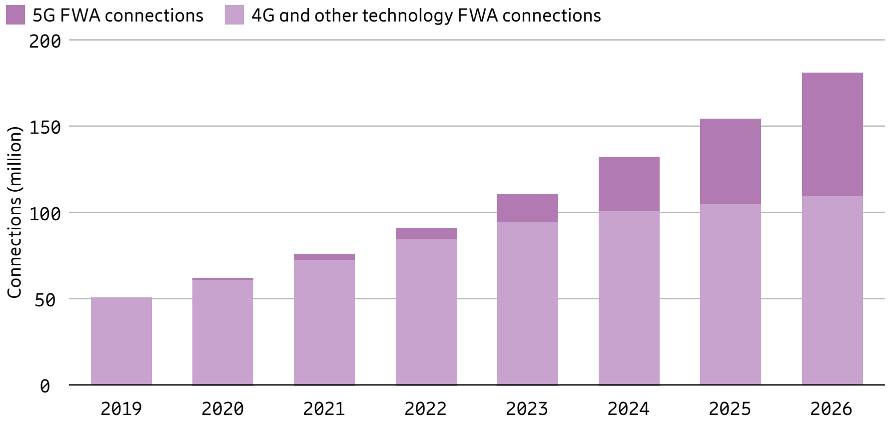
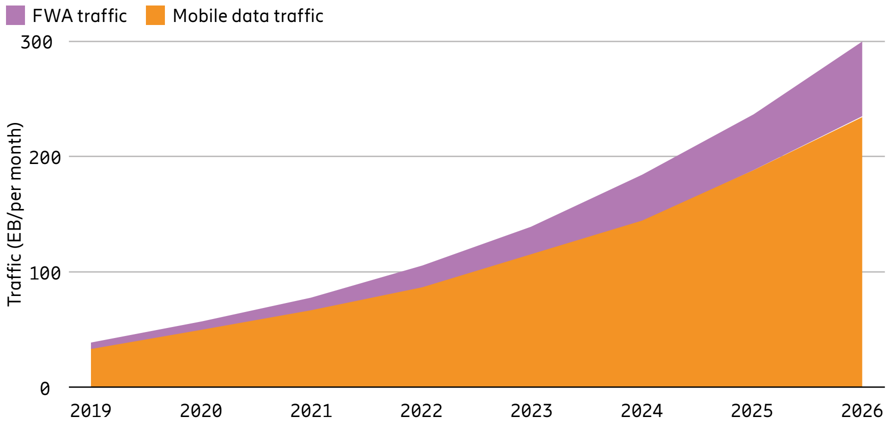


Figure 7: FWA connections



Definition of FWA
A connection that provides primary broadband access through wireless wide area mobile network enabled customer premises equipment (CPE). This includes various form factors of CPEs, 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 8: Mobile data and FWA traffic



Over half of service providers in every region now offer FWA

According to the regional breakdowns, more than 50 percent of service providers in every region are offering FWA. The highest growth during the last six months has been in regions with the lowest fixed broadband penetration – that is, Middle East and Africa, Central and Eastern Europe, Asia-Pacific and Central and Latin America. These regions grew between 4–13 percentage points. Central and Eastern Europe has had a growth of almost 25 percentage points since the start of the pandemic in February 2020. Globally, they now have the second highest adoption at 84 percent, while Western Europe have the highest FWA adoption at 93 percent.

5G service providers at the forefront of FWA adoption

Almost 90 percent (87 percent) of service providers that have launched 5G also have an FWA offering (4G and/or 5G). This is a substantially higher adoption of FWA compared to service providers that have not yet launched 5G (62 percent). The high adoption rate of FWA is also prevalent in countries with a high fiber penetration.

FWA global connections uptake

In addition to the need driven by the pandemic, there are three main factors that drive FWA growth. First, demand from consumers and businesses for broadband connectivity continues. Second, FWA is an increasingly cost-efficient alternative compared to fixed services such as DSL, cable and fiber. Increasing capacity, allowed by greater spectrum allocations and technological advancements, is driving higher network efficiency in terms of the cost per delivered gigabyte. In addition, innovations within 5G mmWave have extended the range of mmWave spectrum from a few hundred meters to over 7km coverage radius. This offers new opportunities to use the current network infrastructure grid, making 5G a future-proof technology for large scale FWA deployments. Third, governments are fueling broadband connectivity through programs and subsidies, as it is considered vital for digitalization efforts and economic growth.

The limited reporting of FWA connections, combined with varying FWA definitions, results in differences in the reported number of connections globally. However, we estimated that there were more than 60 million FWA connections by the end of 2020. This number is forecast to grow more than threefold through 2026, reaching over 180 million. Out of these, 5G FWA connections are expected to grow to more than 70 million by 2026, representing around 40 percent of total FWA connections.

FWA data traffic represented around 15 percent of global mobile network data traffic by the end of 2020. This is projected to grow 7 times to reach 64EB in 2026, accounting for more than 20 percent of total mobile network data traffic globally.

FWA in the broadband context

There are approximately 2 billion households in the world. By the end of 2020, approximately 1.2 billion (60 percent) had a fixed broadband connection, and by the end of 2026 this will reach approximately 1.5 billion (around 70 percent). FWA will then represent 12 percent of all fixed broadband connections. However, it is worth mentioning that FWA is also seen as a replacement option for 250 million existing DSL connections.

The FWA impact in society is larger than the number of FWA connections, as it brings connectivity to three to five people in a household depending on regional demographics. The forecast of over 180 million FWA connections by the end of 2026 represents approximately 650 million individuals having access to a wireless broadband connection.

Consumers continue to embrace 5G devices

The introduction of New Radio (NR) functionality maintains momentum.

The 5G device ecosystem continues to evolve rapidly and outpace historical developments in previous cellular technology generations.

5G adoption is growing in momentum for both the network and device domains:
- over 300 5G smartphone models announced or launched commercially
- global smartphone shipments are expected to grow 7 percent year-on-year in 2021, despite a temporary shortage of semiconductors
- 5G device pricing continues to decline, with retail prices supporting low and medium frequency bands under USD 250 outside China and USD 400 for devices with mmWave support in the US
- 5G standalone (SA) continues to evolve as more markets enable it with:
  - 5G-native voice over NR (VoNR) services
  - support for network slicing
  - dual connectivity using an NR anchor carrier (NR-DC), allowing use of mmWave spectrum in SA networks
- the first chipsets and devices with NR carrier aggregation (CA) capability available from Q2
- new device chipsets for mmWave spectrum bands will lower the price points for these devices during 2021

Semiconductor crunch

The device industry has navigated the effects of COVID-19 on semiconductor availability fairly well so far, despite worries due to the significant impact the shortage had on the automotive industry in 2020. Most vendors have been able to secure their share of baseband and radio frequency (RF) components, indicating that any impact on the device industry will be limited and the projection of approximately 500 million 5G-capable devices could be delivered in 2021. This is equivalent to 35–45 percent of all devices shipped globally being 5G-capable, albeit with strong regional differences.

Standalone making new strides

With the basic 5G capabilities in place, the focus has shifted to SA deployments. China and North America have been in the lead, and now there are signs of SA momentum in other markets like Europe as well.

Chipsets have had SA capabilities for some time, however, enabling those capabilities on devices outside China and North America has been dependent on operator launch plans. In the second half of 2021, we anticipate the introduction of commercial 5G-native VoNR services in networks and devices, and the inclusion of mmWave support on the chipset level for SA mode.

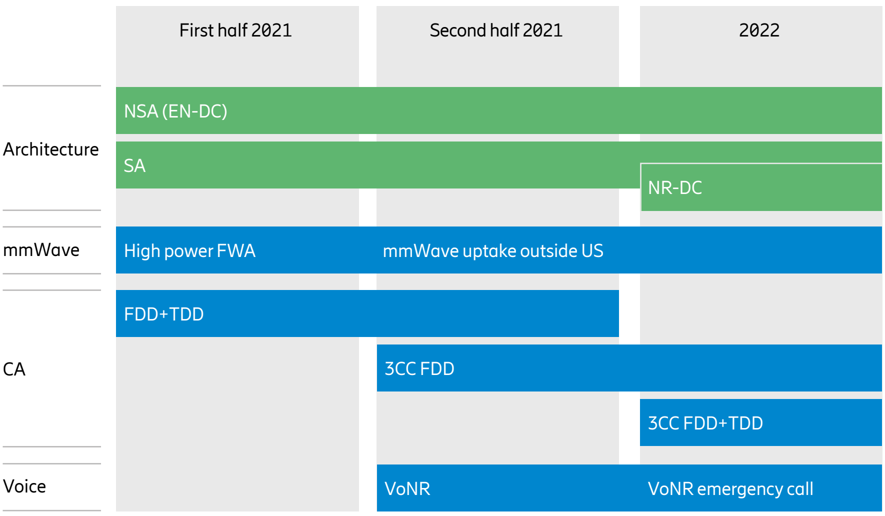
Carrier aggregation deployment

Wide-scale deployment of NR CA in live networks has been somewhat slower than expected, with only a few markets launching this in 2020. As more devices and networks are being readied for commercial services, we expect to see many more devices supporting NR CA in the second half of 2021. This will serve to extend coverage of TDD spectrum and increase peak data rates. First, two NR carriers will be aggregated and then during 2022, three-carrier options will be supported by the ecosystem.

Enter mmWave

As competition picks up, we expect more chipset brands to enter the mmWave space and the price of mmWave-capable devices to continue to decrease. At least 12 smartphone vendors now offer mmWave-capable phones. Additionally, fixed wireless access (FWA) continues to evolve with further coverage enhancements in mmWave, enabled by new features on both devices and networks.

Figure 9: 5G technology market readiness



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

Broadband IoT set to overtake 2G and 3G

During 2021, broadband IoT (4G/5G) will overtake 2G and 3G as the segment that enables the biggest share of IoT applications.

The Massive IoT technologies NB-IoT and Cat-M[1] continue to be rolled out around the world, with the number of connections expected to increase by almost 80 percent during 2021 to reach close to 330 million. In 2026, these technologies are forecast to make up 46 percent of all cellular IoT connections.

Massive IoT primarily consists of wide-area use cases, connecting large numbers of low-complexity, low-cost devices with long battery life and relatively low throughput. About 120 service providers have commercially launched NB-IoT and 55 have launched Cat-M. NB-IoT and Cat-M technologies complement each other, and approximately 40 service providers have launched both technologies.

Cat-M and NB-IoT follow a smooth evolution path into 5G networks and can continue to be deployed in the same bands as today, even when 5G is introduced. Today's most commonly deployed Massive IoT devices include various types of meters, sensors and tracking devices, as these and corresponding applications (smart metering, asset tracking) are easy to integrate and deploy end-to-end.

Broadband IoT mainly includes wide-area use cases that require higher throughput, lower latency and larger data volumes than Massive IoT technologies can support. 4G is already supporting many use cases in this segment. By the end of 2026, 44 percent of cellular IoT connections will be broadband IoT, with 4G connecting the majority. With the introduction of 5G New Radio (NR) in old and new spectrum, throughput data rates will increase substantially for this segment.

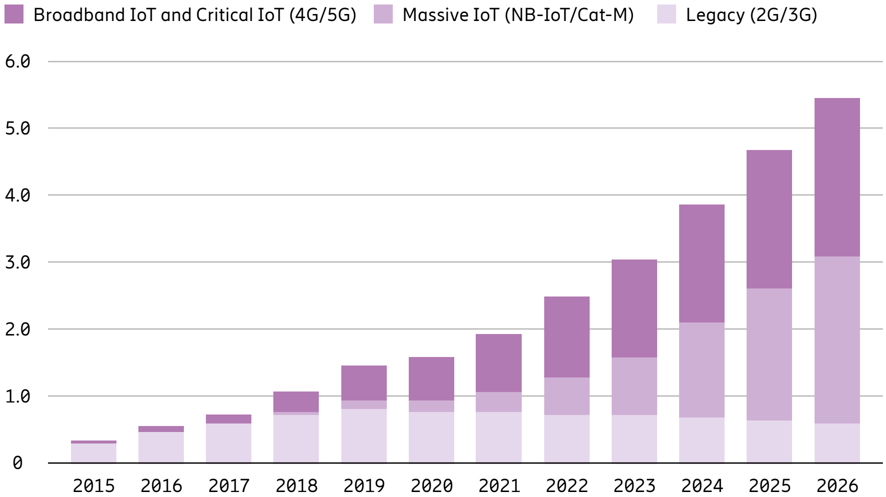
Critical IoT is intended for time-critical communications in both wide- and local-area use cases that require guaranteed data delivery with specified latency targets. Critical IoT will be introduced in 5G networks with the advanced time-critical communication capabilities of 5G NR. It will enable a wide range of time-critical services for consumers, enterprises and public institutions across various sectors. Typical use cases include cloud-based AR/VR, remote control of machines and vehicles, cloud robotics, advanced cloud gaming and real-time coordination and control of machines and processes. Deployment of the first commercial devices supporting time-critical communications is expected during 2022.

The removal of inactive cellular IoT connections in China indicates a substantial share of inactive connections, leading us to revise our estimate for 2020 from 1.7 billion to 1.6 billion cellular IoT connections and adjust the overall forecast accordingly.

IoT devices

The first IoT devices to leverage 5G capability have been industry routers and vehicles. The IoT devices released in 2020 were limited to supporting 5G non-standalone (NSA) architecture. In the first half of 2021, we have seen the first IoT devices with 5G standalone (SA) capability. 5G SA-capable modules from a few vendors are already available, and additional module vendors are expected to fuel the IoT ecosystem. We expect to see 5G extend its reach to more IoT device types during the second half of 2021, such as cameras, VR headsets and unmanned aerial vehicles (UAVs). Some of these use cases are expected to evolve with time critical communication capabilities during 2022.

Figure 10: Cellular IoT connections by segment and technology (billion)



[1] Cat-M includes both Cat-M1 and Cat-M2. Only Cat-M1 is being supported today.
[2] These figures are also included in the figures for wide-area IoT.

Figure 11: IoT connections (billion)

IoT	2020	2026	CAGR
Wide-area IoT	1.7	5.8	23%
Cellular IoT[2]	1.6	5.4	23%
Short-range IoT	10.7	20.6	12%
Total	**12.4**	**26.4**	**13%**

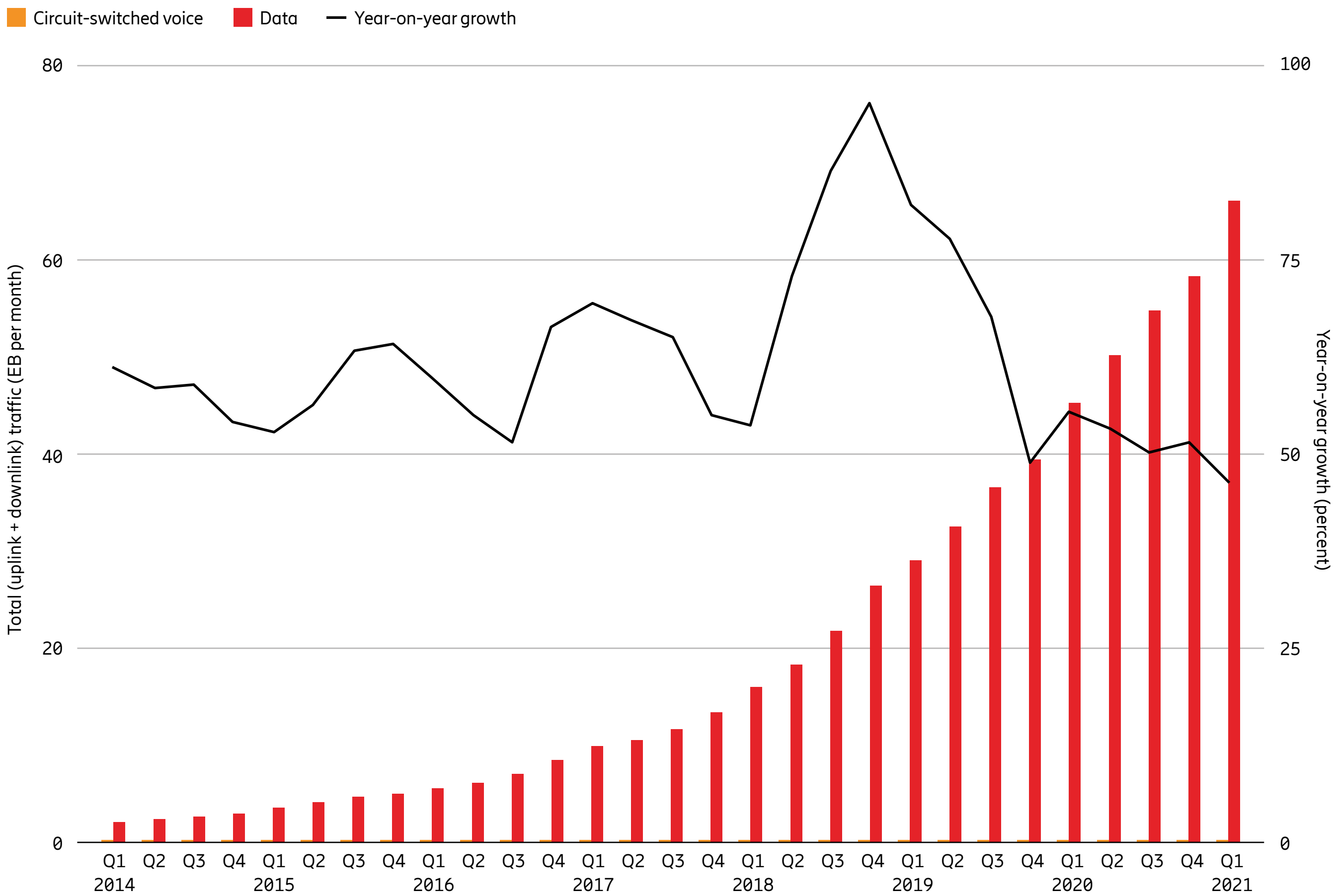
Mobile network traffic growth remains steady

Mobile network data traffic grew 46 percent between Q1 2020 and Q1 2021.

As in the previous quarters during 2020, the year-on-year traffic growth rate remained at a more normal level – around 46 percent – compared to the extraordinary peak in 2018 and the first part of 2019. The quarter-on-quarter growth was 13 percent, and total monthly mobile network data traffic in Q1 2021 exceeded 66EB.

Over the long term, traffic[1] growth is driven by both the rising number of smartphone subscriptions and an increasing average data volume per subscription, fueled primarily by more viewing of video content. Figure 12 shows total global monthly network data and voice traffic from Q1 2014 to Q1 2021, along with the year-on-year percentage change for mobile network data traffic.

Figure 12: Global mobile network data traffic and year-on-year growth (EB per month)



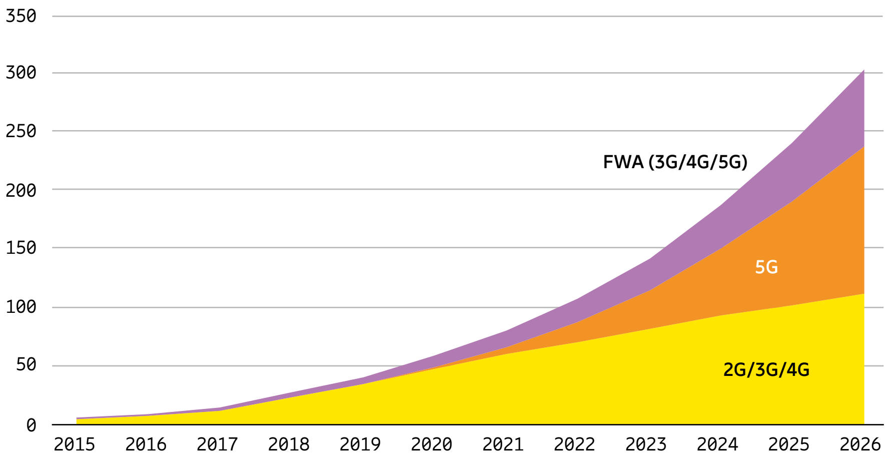
Note: Mobile network data traffic also includes traffic generated by fixed wireless access (FWA) services.

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

Smartphones and video driving up mobile data traffic

In 2026, 5G networks will carry more than half of the world's smartphone traffic.

Figure 13: Global mobile network data traffic (EB per month)



10GB

Globally, the average usage per smartphone now exceeds 10GB.

Total global mobile data traffic – excluding traffic generated by fixed wireless access (FWA) – reached 49EB per month at the end of 2020 and is projected to grow by a factor of close to 5 to reach 237EB per month in 2026. Including FWA traffic took the total mobile network traffic to 58EB per month at the end of last year. The total mobile network traffic is forecast to exceed 300EB per month in 2026.

The monthly global average usage per smartphone now exceeds 10GB, and is forecast to reach 35GB by the end of 2026.

Video traffic currently accounts for 66 percent of all mobile data traffic, a share that is forecast to increase to 77 percent in 2026.

Smartphones continue to be at the epicenter of this development as they generate most of the mobile data traffic – about 95 percent – today, a share that is projected to increase throughout the forecast period.

Populous markets that launch 5G early are likely to lead traffic growth over the forecast period. By 2026, we expect that 5G networks will carry 53 percent of total mobile data traffic.

Large variations in traffic growth across regions

Traffic growth can be very volatile between years and can also vary significantly between countries, depending on local market dynamics. We have increased our forecasts for South East Asia and Oceania, as well as for India, with India remaining a region with one of the highest monthly usage per smartphone rates, at around 15GB at the end of 2020.

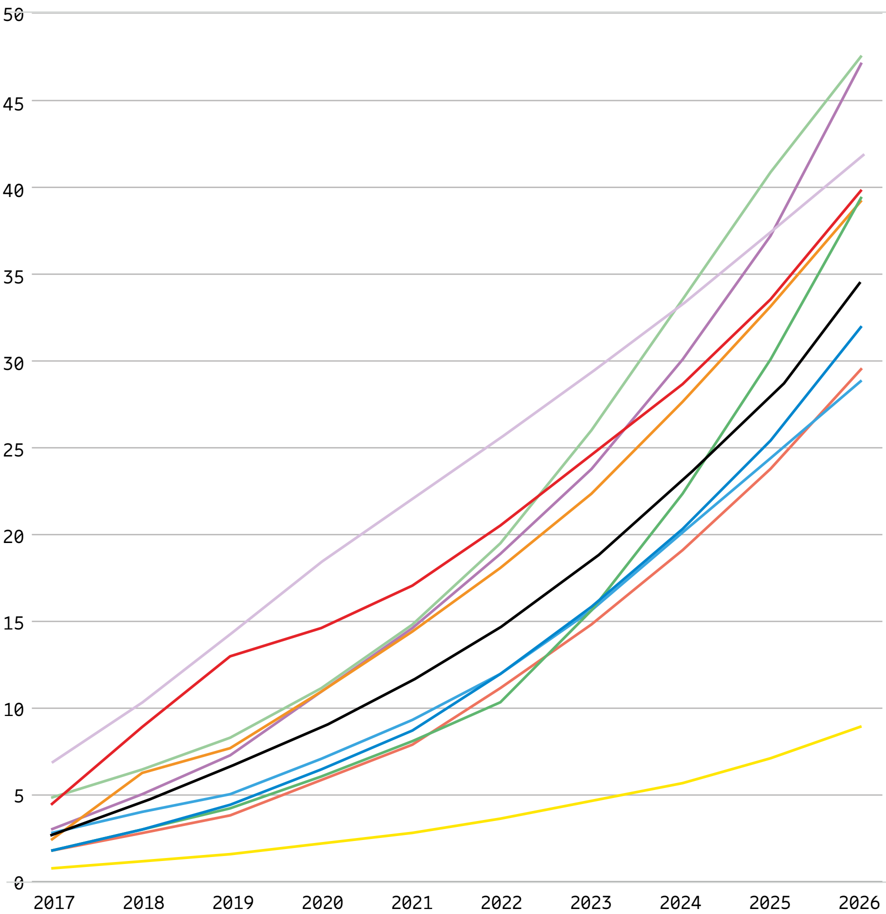
Globally, the growth in mobile data traffic per smartphone can be attributed to three main drivers: improved device capabilities, an increase in data-intensive content and more and more data consumption due to continued improvements in performance of deployed networks.

Over 1.2 billion smartphone subscriptions in India region in 2026

COVID-19 has accelerated India's digital transformation as more and more consumers rely on digital services – be it digital payments, remote health consultations, online retail or video conferencing – to fulfill their business or personal needs. Accordingly, the average monthly mobile data usage per smartphone continues to show robust growth, boosted by people increasing their smartphone usage while staying at home. The reliance of people on their mobile networks to stay connected as well as work from home has contributed to the average traffic per smartphone user increasing from 13GB per month in 2019 to 14.6GB per month in 2020. The average traffic per smartphone in the India region stands second highest globally and is projected to grow to around 40GB per month in 2026. Competitive pricing by service providers for subscription packages, affordable smartphones and increased time spent online all contribute to monthly usage growth in the region.

Total mobile data traffic in India has grown from 6.9EB/month to 9.5EB/month in 2020 and is projected to increase by more than four times to reach 41EB/month in 2026. This is driven by two factors: high growth in the number of smartphone users, including growth in rural areas, and an increase in average usage per smartphone. An additional 430 million smartphone subscriptions are expected in India during the forecast period, taking the total to over 1.2 billion in 2026.

Figure 14: Mobile data traffic per smartphone (GB per month)



Regions	2020	2026	CAGR 2020–2026
North America	11.1	48	27%
Western Europe	11	47	28%
GCC	18.4	42	xx%
India	14.6	40	18%
South East Asia and Oceania	6.2	39	36%
North East Asia	10.9	39	24%
Global average	9	35	25%
Middle East and North Africa	6.5	32	30%
Latin America	5.9	30	31%
Central and Eastern Europe	7.2	29	26%
Sub-Saharan Africa	2.2	9	26%

In North America, future monthly GB growth depends on 5G service adoption

The monthly average usage of mobile data in North America is expected to reach 48GB per smartphone, per month, in 2026. A smartphone-savvy consumer base and video-rich applications in combination with large data plans will drive traffic growth. While there may be strong growth in traffic per smartphone in the near term, the adoption of immersive consumer services using AR/VR is expected to lead to an even higher growth in the long term. In 2026, 5G subscription penetration in North America is set to be the highest of all regions at 84 percent.

Western Europe traffic growth follows a similar pattern to that expected in North America. The more fragmented market situation is anticipated to lead to later mass-market adoption of 5G, but in 2026 the traffic usage per smartphone is expected to be 47GB per month, which will be very close to the usage in North America at that time.

5G growth in monthly mobile data usage continues in North East Asia

Video consumption, remote working, mobile gaming and new types of streaming such as AR/VR drive up mobile data usage in the region. Monthly usage per smartphone is estimated to reach 14.5GB by the end of 2021, increasing from 10.9GB at the end of 2020. As a leading 5G market, the region is expected to continue its high growth and the data traffic per smartphone is forecast to reach 39GB per month in 2026.

The **Middle East and North Africa** region is expected to have the second highest growth rate during the forecast period, increasing total mobile data traffic by a factor of almost 7 between 2020 and 2026. The average data per smartphone is expected to reach 32GB per month in 2026. Looking more closely at the **Gulf Cooperation Council (GCC)** countries, data traffic per smartphone was the highest globally at the end of 2020, exceeding 18GB per month. By the end of the forecast period, it is expected to reach an average of 42GB per month.

Sub-Saharan Africa also has a very high growth rate, but from a relatively small base, with total mobile data traffic increasing from 0.87EB per month in 2020 to 5.9EB in 2026. Average traffic per smartphone is expected to reach 9GB per month over the forecast period.

South East Asia and Oceania will see data traffic per smartphone growing at the fastest rate globally, reaching 39GB/month by 2026 – a CAGR of 36 percent. Total mobile data traffic will grow accordingly, with a CAGR of 42 percent, reaching 39EB/month driven by continued growth in 4G subscriptions and 5G uptake in those markets where 5G has already been launched.

Latin America is expected to follow a similar trend as South East Asia over the forecast period on a regional level, while individual countries can show very different growth rates for traffic per smartphone. Traffic growth is driven by coverage build-out and continued adoption of 4G (and eventually 5G), linked to a rise in smartphone subscriptions and increases in average data usage per smartphone. The data traffic per smartphone is expected to reach 30GB per month in 2026.

In **Central and Eastern Europe**, growth is also fueled by 4G and 5G adoption. Over the forecast period, the monthly traffic per smartphone is expected to increase from 7.2GB to 29GB per month.

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

5G network coverage rising faster than 4G

5G is expected to be the fastest deployed mobile communication technology in history, and is forecast to cover about 60 percent of the world's population in 2026.

Global 4G population coverage was over 80 percent at the end of 2020 and is forecast to reach around 95 percent in 2026. 4G networks are evolving to deliver increased network capacity and faster data speeds. There are currently 809 commercial 4G networks deployed. Of these, 328 have been upgraded to LTE-Advanced, and 42 Gigabit LTE networks have been commercially launched.

5G covered over 1 billion people at the end of 2020
The estimated population coverage at the end of 2020 was approximately 15 percent, equivalent to over 1 billion people. The build-out of 5G networks is continuing to accelerate and, to date, there have been more than 160 commercial launches across the world.

5G coverage build-out can be divided into three broad deployments:
1. New bands in the sub-6GHz range
2. mmWave frequency bands
3. Existing 4G bands

There are big differences between countries in how service providers have started to deploy 5G. In the US, all three of these categories have been used, resulting in 5G coverage for a large part of the population. In Europe, countries such as Germany and Spain have deployed in existing bands to create substantial coverage. New bands in the sub-6GHz range – often referred to as mid-bands – are available in many markets, offering a good mix of network coverage, capacity, and speed. China is one example where service providers have deployed a substantial number of base stations in mid-bands.

Network sunsets will have no negative impact on global network coverage
Service providers are continuously seeking alternatives to increase coverage and capacity by using newer-generation technologies. One option is to "sunset", or shut down, one legacy technology – that is, 2G or 3G – which are often deployed in low- to mid-bands that are ideal for creating large network coverage with 4G and 5G.

A further driver of network shutdowns is to reduce network complexity and operational expenditure. However, there are several considerations to be made, such as device fleet capability and the IoT installed base. There are also regulatory requirements; for instance, as of March 30, 2018, EU regulations require motor vehicles to be fitted with the ability to make 112-based emergency calls. Many of these are limited to 2G and 3G technologies. Sunsetting plans and trends look very different across regions and countries, with shutdowns already taking place in developed countries. This is enabled by the device mix; for instance, in North America, the 2G/3G share of subscriptions is only 7 percent, compared to Sub Saharan Africa, where the share is currently 70–80 percent.

Coverage and capacity gains in low- to mid-bands can be achieved without, or with gradual, sunsetting – for example with the use of spectrum sharing. Also, if a legacy technology is shut down, the corresponding spectrum band will be used for a newer 3GPP technology, and have no negative impact on network coverage.

Figure 15: World population coverage by technology[1]

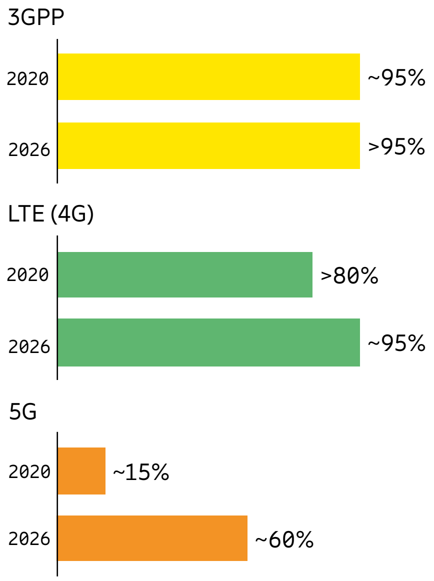
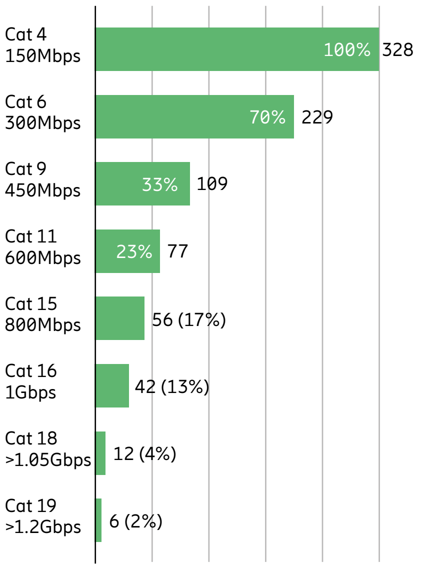


Figure 16: Percentage and number of LTE-Advanced networks supporting various categories of devices



Source: Ericsson and GSA (May 2021)

[1] The figures refer to coverage of each technology. The ability to utilize the technology is subject to factors such as access to devices and subscriptions.

The Gulf Cooperation Council countries: a deep dive

Initiatives to diversify the Gulf Cooperation Council (GCC) countries' economies into new industries have accelerated both technological innovation and forecasted 5G uptake.

This is the premiere issue of the Mobility Report to break out statistics for the GCC countries from the Middle East and North Africa regional key figures. The statistics and forecasts include various figures for mobile subscriptions and traffic (see pages 34–35).

Service providers in the GCC were among the first in the world to launch 5G, with commercial services available in most of the member states during 2019. In performance measurements from Ookla, 5G networks throughout the region have downlink throughput 6–10 times greater than 4G. Smartphone penetration was 82 percent at the end of 2020, second place to North East Asia and comparable to North America. Monthly data traffic per smartphone was the highest globally at the end of 2020, exceeding 18GB.

In aggregate, the GCC is forecast to have 62 million 5G mobile subscriptions by the end of 2026, accounting for nearly three-quarters of all mobile subscriptions in the Gulf region at that time.

Service providers are using 5G network performance as a key to differentiation in a highly competitive market. This is positioning the GCC countries to be second only to North America for 5G subscription penetration by the end of 2026. But the significance of 5G in this region goes beyond the number of subscriptions for consumers. 5G will also bring new capabilities allowing operators to develop innovative applications, services, and revenue streams for the enterprise market. New 5G applications and services are expected to have a profound impact on a range of industry verticals.

The GCC countries' economies have been highly dependent on petroleum and related services. However, due to price volatility and in anticipation of peak oil, in recent years there has been a growing governmental focus on diversifying economies to reduce oil dependence.

A consequence of this is the prevalence of government-sponsored digital initiatives aimed at promoting technological innovation.

- The **Kingdom of Saudi Arabia (KSA)** – one of the strongest regional economies – has a number of high-profile digital initiatives which it administrates under its Vision 2030 initiative. Key themes include Creating a Vibrant Society, Building a Thriving Economy and Fueling an Ambitious Nation.
- A similar plan was announced by the **United Arab Emirates (UAE)**, where the goal of the Smart Dubai Vision is to make the city completely paperless, ensuring all government transactions are 100 percent digitized.
- **Qatar** aims to transform itself into an advanced nation, capable of sustaining its development and providing a high standard of living for its people. To this end, its Vision 2030 has four pillars focusing on human, social, environmental and economic development.
- **Oman** has a strategy, Oman Digital 2030, which aims to prepare its workforce – both private and government – for the effects of technology and digital transformation, with a special focus on AI.
- In **Bahrain**, emerging technologies such as AI, biotechnology, material sciences and robotics have been identified as particularly promising areas to drive economic growth, and the focus has been on creating an effective ecosystem to foster innovation through those technologies.
- **Kuwait's** National Development Plan (2035 Vision) focuses on building a diversified and sustainable economy based on a digital infrastructure. Its goal is to transform Kuwait into a regional and global hub for both finance and trade.

73%

5G will account for nearly three-quarters of all mobile subscriptions in the GCC countries by the end of 2026.

18GB

At the end of 2002, the region had the highest monthly data traffic per smartphone in the world, exceeding 18GB.

In a business environment infused with such initiatives, service providers are incentivized to keep up with the latest technologies and meet the projected demand from tech-savvy consumers. This is bringing monetization opportunities for service providers when it comes to entertainment, lifestyle, tourism, education and the workplace.

Ambitious plans for digital transformation are apparent in the number of high visibility sporting and cultural events to be hosted by GCC countries over the next three years. These include Expo 2020 (to take place in the UAE from October 2021 through March 2022) and a 2022 international football tournament in Qatar.

Figure 17: The Gulf Cooperation Council countries

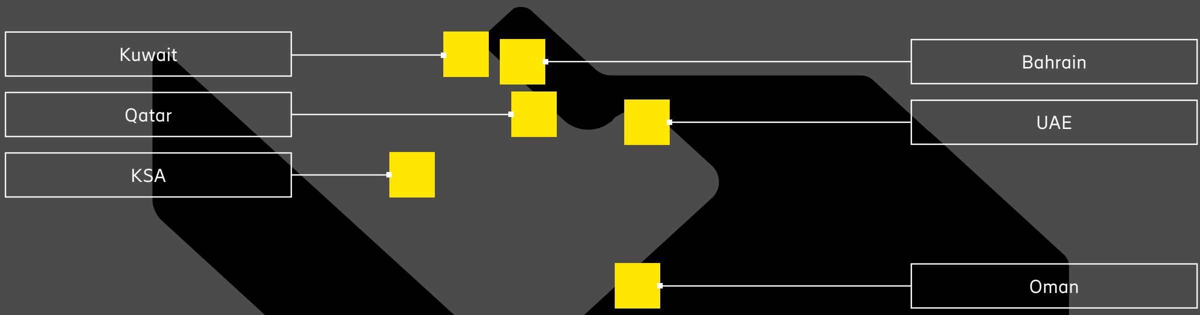
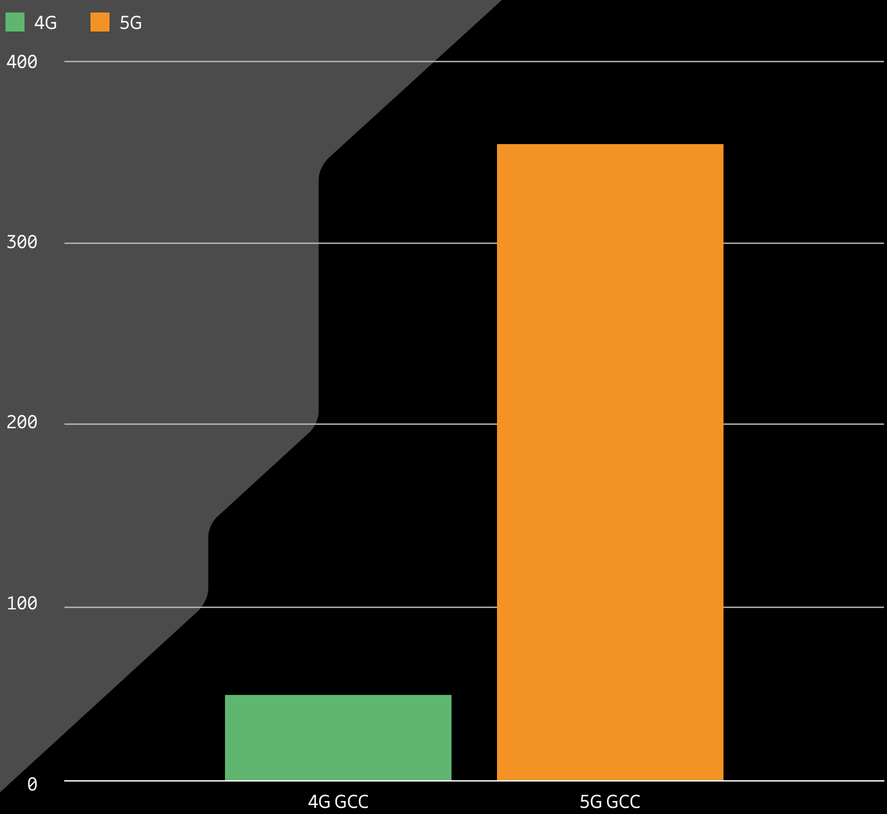


Figure 18: GCC aggregate downlink (January – April 2021)



An analysis of Speedtest® measurements collected during January through April 2021 indicate an aggregate median downlink throughput for 5G that is higher than 4G by a factor of 7, uplink throughput by a factor of 2 and latency that is nearly one third lower.

Source: Ericsson analysis on Speedtest Intelligence® data from Ookla®.

Note: This is Ericsson's analysis of Speedtest® measurement samples aggregated over the first four months of 2021. It is the median of downlink throughput samples that have been filtered and aggregated.

T-Mobile pursues a multi-band 5G spectrum strategy

By deploying a 5G network across all three types of spectrum bands – low, mid and high – service providers can unlock a wider range of use case possibilities.

The architecture and technology choices in a 5G network are about delivering the right connectivity where users need it, while maximizing the available spectrum assets. Most service providers around the globe initially launched 5G networks using mid-band spectrum, as it provides a balance between coverage and capacity for initial 5G use cases and deployment scenarios. A few service providers have already deployed their 5G networks in more than one spectrum band.

Understanding different spectrum bands' characteristics and roles in carrying 5G services can be a challenge for consumers and businesses. This is partly because most existing 4G services perform well for both outdoor and indoor scenarios in fewer spectrum bands. 5G technologies use more spectrum bands, compared to 4G, to deliver a broader range of services with different network performance requirements.

Eventually, all three major spectrum bands will power the world's 5G networks, but some service providers are already leading the way. This article examines the 5G deployment strategy of T-Mobile in the US, currently deploying a network on all three band types. For more information on 5G spectrum, see page 21.

T-Mobile's strategy for 5G deployments

T-Mobile is deploying 5G on dedicated low-band spectrum (600MHz) as a base layer for coverage, which allowed it to launch the country´s first nationwide 5G network at the end of 2019. The target is to cover 300 million people (90 percent of people in the US) by the end of 2021 and 97 percent of the population in 2022.

T-Mobile has dedicated mid-band spectrum (2.5GHz), from its merger with Sprint, on which deployments started in mid-2020 and are ongoing. Mid-band spectrum can deliver more capacity and speed than low-band, with better reach and building penetration capabilities than high-band spectrum. The build-out of population coverage on this band reached 140 million (over 40 percent of people in the US) in early 2021, and is planned to grow to reach 200 million this year. This is the largest mid-band deployment to date in the US, with a target of reaching 300 million people (90 percent) by the end of 2023. In addition, acquired C-band spectrum will be used for deployment where helpful in urban areas, complementing the 2.5GHz layer.

The use of 5G mid-band spectrum, in proximity to mid-band spectrum for existing 4G services, allows for a network realization characterized by:

- urban and suburban coverage and capacity across large metropolitan areas
- networks leveraging existing 4G macro radio sites
- Massive MIMO radios at each site, software configurable to support the full spectrum available
- increases in coverage and capacity for mid-band services, when mid-band downlinks are combined with uplinks in low-band spectrum (inter-band carrier aggregation)
- significant performance increase for mid-band versus low-band services
- upgrade of backhaul capacity to support the leap in capacity enabled by powerful radios

This article was written in cooperation with T-Mobile, a market-leading service provider in the US, deploying a nationwide 5G network on multiple spectrum bands to unlock a wide range of use cases.

The third part of T-Mobile US´s 5G deployment strategy is high-band spectrum (mmWave), where deployments started in parts of large metropolitan areas in the middle of 2019.

The combination of low- and mid-band spectrum delivers significant improvements over the 4G/5G average downlink speeds, as measured in drivetests performed by Umlaut (see Figure 19).

Network quality and differentiated services

T-Mobile's 5G network build-out across all spectrum bands is expected to increase the available network capacity by a factor of 14 over the next few years, compared to the capacity in 2019. T-Mobile's multi-layer 5G network will be fit for a range of services and applications that demand wide area network coverage and mobility, enabling an increase in service revenue through customer adoption of multiple services.

Enhanced mobile broadband (eMBB) delivers the higher peak rates and low latencies required for rich media experiences. The tectonic shift in the entertainment sector towards streaming of video, music and games is exciting for mobile service providers to tap into. The targeted increase in network capacity through 2024 is the foundation to meet a growing demand for higher quality video services, AR/VR, cloud gaming and connected consumer wearables.

Fixed wireless access (FWA) is an attractive proposition where the business case for fiber is weak compared to the limited incremental investments needed to deploy FWA. T-Mobile targets the home broadband market with FWA over 5G as an alternative to older generations of copper, coax and non-cellular wireless network technologies. A dual play broadband offer, FWA and mobile broadband, is attractive for residential users, for meeting both private and remote working needs. According to the Organisation for Economic Cooperation and Development (OECD), 16.5 percent of US residential broadband connections were fiber-based by mid-2020. Providing 4G- and 5G-based home broadband is a fast way to secure digital inclusion for education and work. T-Mobile aims to serve 7–8 million customers by 2025.

The pandemic has also shown the potential for 5G in serving small and medium-sized businesses (SMBs) by connecting business locations with FWA for primary or secondary access. Fiber connections to large commercial buildings are well underway in the US, but only 12.8 percent of small commercial buildings were fiber-connected at the end of 2020. 5G has an important role to play in connecting SMBs in urban, suburban and rural areas.

Smaller markets and rural areas in the US are made up of 50 million households that are home to 130 million people, making it the largest geographic segment of the consumer market. T-Mobile wants to expand its addressable market by targeting this segment with fixed wireless and mobile broadband offerings.

Figure 19: Customer experience, average downlink comparison 5G mid-band versus 4G/5G

Source: Umlaut (February 2021).
Note: Drivetest, T-Mobile network.

Eventually, all three major spectrum bands will power the world's 5G networks.

Network architectural considerations to secure mid-band performance

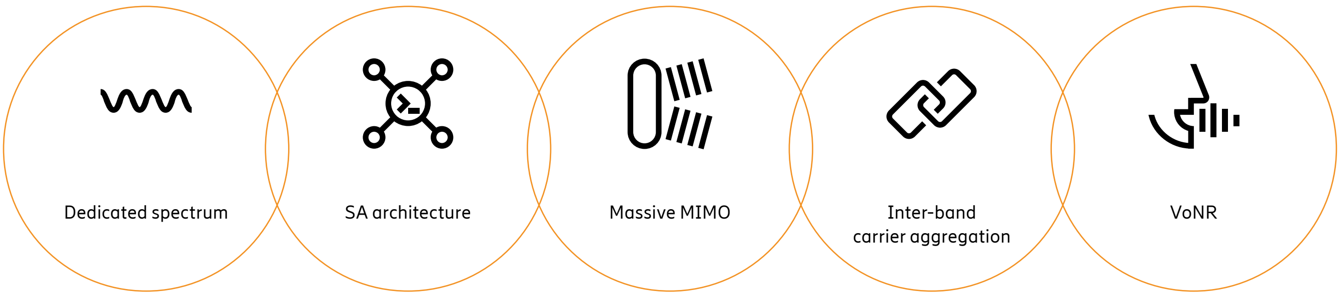
The architecture and technology choices in a 5G network are about delivering the right connectivity where users need it, while maximizing the available spectrum assets.

- T-Mobile's strategy relies on using dedicated spectrum for 5G services, in all three band types, while keeping its 4G services in existing bands.
- T-Mobile decided to adopt 5G standalone (SA) architecture when introducing 5G in the low-band spectrum to expand 5G coverage to areas with a low-band only signal. This decision was made to secure the integration from low- and mid-band services on the target architecture from the start. 5G SA brings significant benefits, with a simplified architecture, providing opportunities for a better end-user experiences and enabling new use cases with low-latency requirements compared to non-standalone (NSA) architecture. It is also the only way to deploy 5G without dependencies on 4G coverage.
- Massive MIMO 64x64 deployed on mid-band spectrum (2.5GHz) further increases capacity and extends the cell edge, providing an improved user experience, as the performance in each sector can be maximized.
- The introduction of inter-band carrier aggregation allows T-Mobile to combine high-capacity downlinks in the mid-band spectrum with an uplink in the low-band to extend the mid-band coverage by up to 30 percent in suburban and rural areas. This combination is one of many examples of how additional 5G performance values are unlocked when using multiple spectrum bands together. This is also applicable for aggregating 5G high-band with low-band FDD, which can increase the high-band cell coverage area more than threefold. Carrier aggregation can also improve in-building performance in urban areas.
- Voice services will remain central in mobile networks. By introducing Voice over NR (VoNR), T-Mobile can ensure users stay in the 5G domain as long as there is coverage, and only fall back on 4G when outside of 5G coverage.

T-Mobile's strategy to build out 5G across all three bands exemplifies how to build a target architecture that unlocks a wide range of 5G use case possibilities, as well as how different 5G technologies can interwork to improve network performance.

Eventually, most 5G networks in the world will utilize low-, mid- and high-band spectrum to deliver the required network performance in different geographical areas, and to serve the evolving needs of consumers, society and businesses.

Figure 20: Key architecture and technology choices



Diving into 5G spectrum

Different 5G spectrum bands provide different capabilities:

- Low-band 5G spectrum comes from a mix of re-farmed spectrum from early mobile generations (1G, 2G) and previously unused bands. This type of spectrum is suitable for building out a foundation for 5G coverage.
- Mid-band spectrum covers the 1–6GHz bands and includes existing 3G/4G bands, as well as new spectrum licensed for mobile services. The increase in capacity comes from the use of wider bands, and higher 5G coverage and capacity per band are enabled by new radio technologies.
- High-band spectrum is completely new for 5G and enables the launch of services with high performance in dedicated zones. The coverage for 5G services in this spectrum band is less than the coverage provided by low- and mid-band spectrum, but serves larger zones than Wi-Fi hotspots.

Services on low- and mid-bands can be delivered from existing macro towers and can also serve indoor environments from outdoor radios. Delivering services on high-bands relies on a combination of radios on towers and small cell poles to cover outdoor areas, while indoor coverage is achieved by deploying indoor small cell solutions. 5G services will be seamlessly delivered over all three bands as they become increasingly available over time.

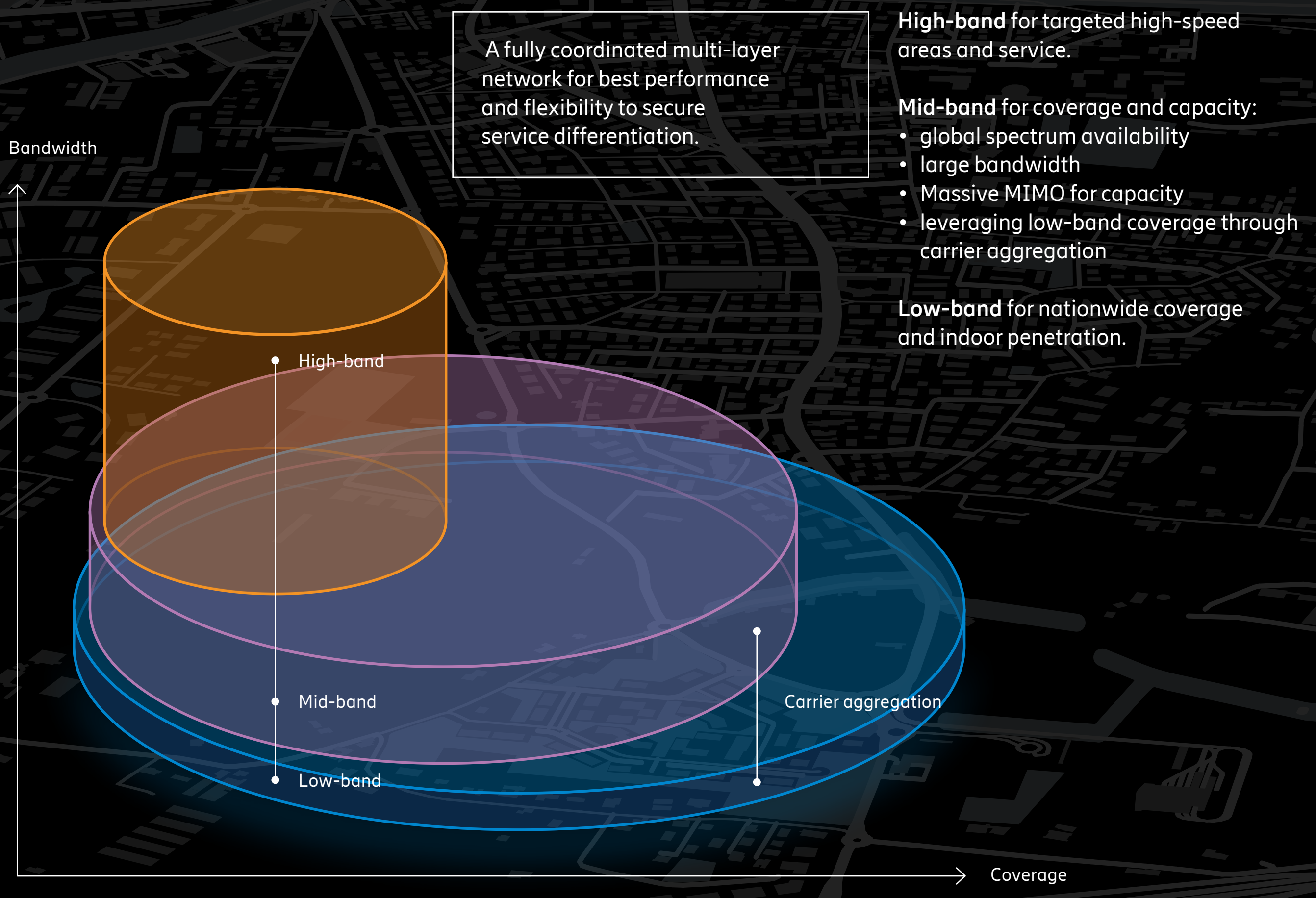
Flavors of mid-band spectrum in the US

Spectrum allocation differs in the US from the rest of the world. The early spectrum auctions for 5G focused on providing high- and low-band spectrum to service providers. Three flavors of the mid-band spectrum are now through the auctioning phase and a fourth is coming up in the second half of 2021.

- **2.496–2.690GHz:** Broadband Radio Service/Educational Broadband Service (BRS/EBS) is a pure licensed spectrum band with 194MHz allocated to serve both 4G (band 41) and 5G NR (band n41). The proximity to frequently used 4G bands makes it attractive for capacity expansion for both mobile and fixed wireless broadband.
- **3.55–3.70GHz:** Citizens Broadband Radio Service (CBRS) consists of a mix of 80MHz of shared and 70MHz of licensed spectrum. The reach of CBRS is shorter as the power allowed is lower than licensed spectrum bands. CBRS spectrum can serve both 4G and 5G services.
- **3.70–3.98GHz:** C-band is the most recently added spectrum in the largest auction in US history. The Federal Communications Commission (FCC) auctioned 280MHz of spectrum, with clearing to take place in two steps, the first by the end of 2021 and the second at the end of 2023.
- **3.45-3.55GHz:** The next mid-band spectrum band to be auctioned in the US in 2021.

In addition, earlier licensed mid-band spectrum that today serves 3G and 4G services, can potentially be re-farmed for 5G services later.

Figure 21: A complete 5G network for all use cases – three layers of spectrum



Businesses build 5G on wireless WAN foundation

Cellular networking's well-established role at the edge of enterprise architecture is poised to expand, with the latency, bandwidth, and density improvements 5G offers.

Amid the many conversations taking place about 5G and its deployment pace, lies a quiet, albeit rising, wave of innovation at the edge of the enterprise wide-area network (WAN) space – at the edge of corporate networks. It's where the rapidly evolving needs of businesses intersect next-generation networking and cellular technology.

Take healthcare, for example. Globally, healthcare delivery is changing rapidly. This has been accelerated by COVID-19, but the seeds were planted long before. Vacant buildings, arenas and parking lots must be instantly convertible into testing or distribution centers and wards. Additionally, healthcare organizations have to figure out how to leverage IoT technologies, to send patients home faster while providing continuous monitoring and care. These changes have resulted in a more agile healthcare response to crises, as well as better patient outcomes and lower care costs.

From distribution, manufacturing and construction sites, to the "customer edge" where retail outlets, healthcare, first responder agencies and blue light emergency services are prevalent, the current and planned roles of 4G and 5G cellular at the WAN edge are expanding.

This new wave of WAN transformation, which mirrors business transformation, is called wireless WAN (WWAN). It is already underway, using today's fast, reliable 4G cellular networks to expand connectivity and enable new ways of doing business, more streamlined business operations, and an improved customer experience. 5G is already becoming a catalyst, expanding use cases and unlocking even more intelligence and capabilities at the edge.

WWAN is essential infrastructure for enterprises

Enterprise WANs have come a long way since their brick-and-mortar connectivity roots. The rapid rise of cloud, mobile and IoT technologies have enabled new business automation and applications, forcing the enterprise WAN to go beyond fixed sites,and beyond wires. This shift puts tremendous pressure on connectivity at the WAN edge. While enterprises still need to connect fixed sites, such as plants, offices and stores, they also now have a plethora of other business-critical WAN connections, including temporary locations and pop-up sites, sensors, surveillance cameras, kiosks, digital signage, vehicles and even robots. In fact, according to results from a recent online survey of 499 IT decision-makers in the US, Canada and the UK, 40 percent of organizations already have branch locations, vehicles, and IoT devices connected via their WAN.[1]

With WANs taxed by continually increasing variety and velocity of connected devices, they need network connectivity at the edge that is agile, flexible, reliable, secure and performant. It also needs to be cost-effective and simple to manage at scale.

Enter, WWAN. Whether used as the primary or secondary link to connect fixed locations or the sole connection for IoT devices or a fleet vehicle, 4G and 5G cellular broadband at the WAN edge has become essential infrastructure for modern business operations.

cradlepoint

This article was written in cooperation with Cradlepoint, a global leader in cloud-delivered 4G and 5G wireless network edge solutions. Cradlepoint works with service providers around the world to unlock the power of cellular technology for enterprise and public sector customers.

Cradlepoint became an independent part of Ericsson in Q4 2020.

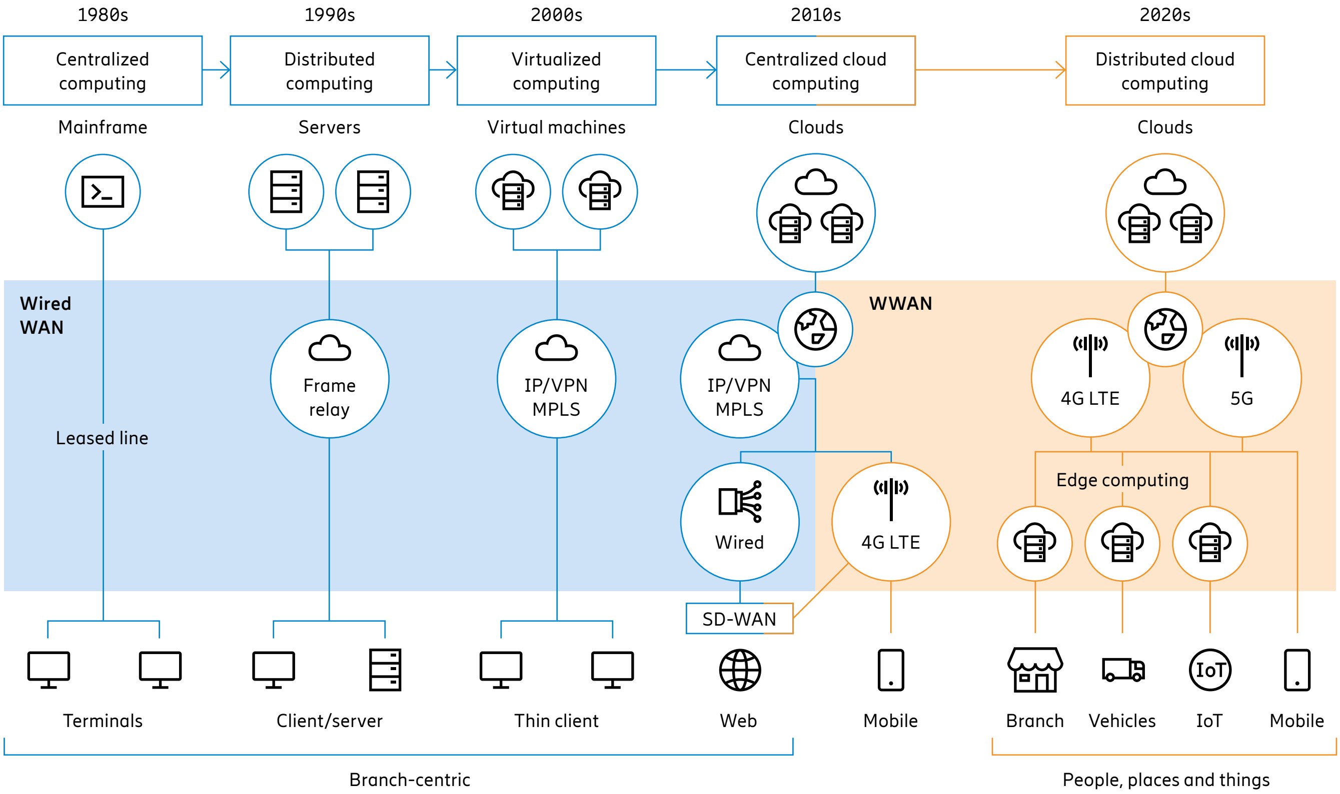
WWAN improves connection flexibility and expedites deployment

WWAN owes much of its popularity to the need for flexibility, as mobility becomes increasingly important at the edge. Customers are demanding that retailers bring their goods and services to where they live, work and play, rather than the other way around. Citizens are requesting similar service from their government agencies. Healthcare providers are using new technologies to close access gaps and patient care inefficiencies. First responders are leveraging connected technology to help keep their people safer and more productive, while serving the real-time information needs of their communities. All of these shifts in business activity and customer preferences require new forms of connectivity.

So, it stands to reason that the primary driver for IT decision makers (51 percent) to increase their use of cellular as a WAN link is to introduce new services.[2] Business transformation and technology innovations are driving the need to connect new people, places and things to the enterprise WAN as quickly and easily as possible.

[1] Cradlepoint and IDG, "The State of Wireless WAN 2020" (2020).
[2] Cradlepoint and IDG.

Figure 22: Evolution from centralized computing to WWAN



Few businesses can afford to delay opening new locations or rolling out Critical IoT applications while waiting on unpredictable fiber installations, which can take weeks or even months. In a recent study,[3] based on interviews with technology leaders at 12 companies across a range of industries[4] in the US and Australia that use 4G services for their WWAN solutions, it was found that they averaged about 35 days waiting for wired links to come online, as opposed to an average of 26 minutes to set up a 4G or 5G solution to provide initial "day one" network connectivity at a new location. In addition, the study showed that WWAN was a more reliable and cost-effective solution compared to wired connectivity.

WWAN minimizes network downtime

Over-the-air links such as 4G or 5G are natural back-ups to, or replacements for, in-the-ground wired lines. These are susceptible to costly internet outages. The businesses interviewed in the aforementioned study stated that at least 90 percent of their sites using WWAN as the primary link reduced their average mean downtime by 88 percent. Businesses with at least 90 percent of locations using WWAN for failover experienced a 62 percent reduction.

WWAN reduces overall costs

While cellular broadband may not be the best fit in every scenario, often it is the most cost-effective choice in the long term.

Companies that have switched from legacy links to WWAN report that their monthly per-site broadband costs were reduced by half and their per-Mbps costs were reduced by 90 percent.[5] They also reported spending less time and resources troubleshooting WAN issues and managing internet service provider (ISP) contracts, which can prove unwieldy when dealing with hundreds of regionally-based wired vendors. WWAN usually involves just one or two nationwide network operator contracts.

What shifting from 4G to 5G looks like

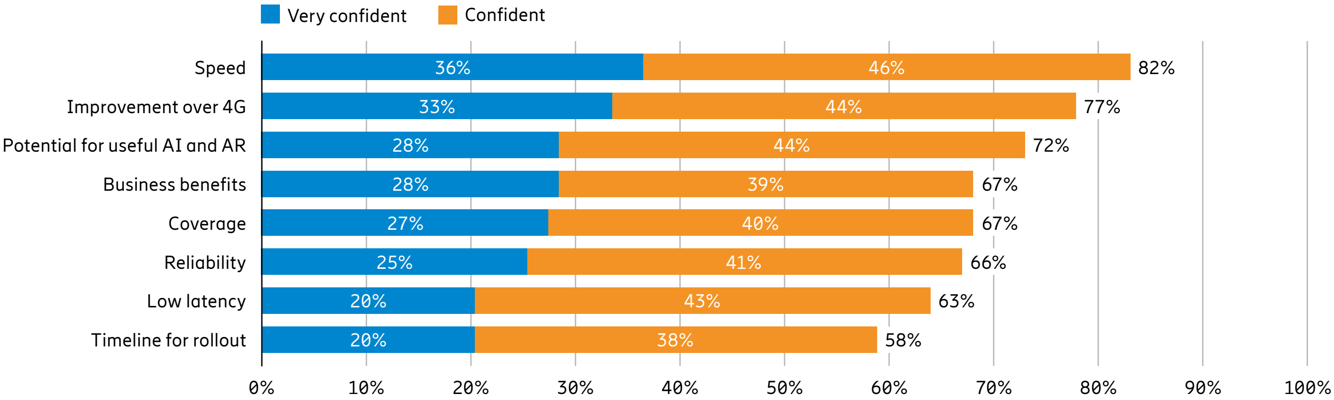
4G has long been considered an ideal connectivity option for business continuity and mobility. The network performance improvements (speed, reliability, and capacity) provided by the latest generations of cellular technology, Gigabit LTE and 5G, are now making wireless an increasingly popular primary connectivity choice for stores, clinics and other fixed sites – which until now have mainly been dominated by wired networks.

With 5G technology improving speed, latency, and connection density, network administrators and IT managers are identifying edge use cases that can be drastically expanded as old barriers to WWAN disappear.

In industries such as retail, healthcare, and law enforcement, opportunities abound for organizations to take WWAN to new heights – with 5G as the driving force. The online survey visualized in Figure 23 reveals high confidence among IT decision makers that 5G will provide enhanced capabilities, such as increased speed, better coverage and improved reliability compared to 4G. Bandwidth improvement was cited as a top driver for 5G adoption (60 percent) and many anticipate 5G to be an enabler for the introduction of new services (51 percent). As an example, 72 percent of the respondents are either confident or very confident that 5G is an enabler for useful AI and AR services. Sixty-seven percent of the respondents are either confident or very confident that 5G will deliver the promised business benefits within the next year.

[3] Nemertes, "The viability of Wireless WAN for Business" (December 2020).
[4] This includes large companies in retail, healthcare, professional services, logistics and a government agency. Three-quarters have revenues exceeding USD 1 billion, two-thirds have more than 2,500 employees and 58 percent have over 500 network sites in their wide-area network.
[5] Nemertes.

Figure 23: High confidence in 5G capabilities, today and tomorrow



Soure: Cradlepoint and IDG, "The State of Wireless WAN 2020" (2020).

Retail: 5G for expanding footprints and enhanced customer experience

The overarching popularity of online shopping has changed how and where consumers expect to be served. What's more, customers who still choose to visit stores want a much richer and immersive experience than ever before. Beacon-based systems[6] for personalized marketing in stores provide one such tool. Half of those surveyed for RIS News' Smart Store of the Future report[7] say they either have up-to-date beacon technology in place, or plan to integrate it within two years.

Heightened expectations also mean diminished tolerance for disruptions to the shopping experience. 4G has long been the best, most flexible option for ensuring WAN uptime. WWAN-enabled solutions help keep essential traffic at retail locations, such as credit card processing, connected and flowing. However, the amount of business-critical retail store systems and data that requires nonstop availability is growing rapidly.

5G solutions provide the flexible and resilient bandwidth needed to ensure nonstop uptime for all in-store traffic. Additionally, 5G ensures that customer-focused services, such as guest Wi-Fi, surveillance cameras for security and wayfinders, are always operational.

The ability to expand their footprint deeper into communities and other places where their customers congregate is another benefit of wireless broadband for retailers. 4G, and now 5G, are the networks of choice for many companies as they expand their reach with kiosks, digital signs, contactless technologies, seasonal storefronts and pop-up venues.

5G brings new cellular network capabilities and attributes, such as low latency and increased bandwidth, that enable immersive technologies such as AI and VR. For the first time, a retailer can use WWAN to implement a virtual dressing room or live teleconferencing between a shopper and a remote fashion consultant, from anywhere.

Private 5G networks have the potential to transform wireless broadband's role in retail, too. A large warehouse on a private cellular network could provide low-latency, secure and scalable "wide area LAN" connectivity for everything from order-gathering robots to autonomous vehicles and surveillance cameras.

Healthcare: 5G for enhanced remote care

Like shoppers, patients now expect more convenience, flexible service delivery and better outcomes from healthcare. Connected technologies including telehealth, IoT-enabled care at home, proactive video access to doctors and critical-care personnel for patients on hospital-bound ambulances, mobile testing vehicles and pop-up temporary care sites, make medical services abundantly accessible.

Telehealth may be the biggest tech trend in healthcare today. It has captured the world's attention during the COVID-19 pandemic. Live video consultations and other services bring quality care directly to those who need it, regardless of location. As a result, healthcare organizations have begun equipping their doctors and care providers with wireless broadband solutions to ensure secure, compliant and reliable telehealth services can be dispensed from anywhere.

Many healthcare providers already use 4G-enabled IoT devices and applications in their clinics. Doctors and patients no longer have to be in the same place to gain access to real-time data from connected diagnostic and medical devices such as stethoscopes, otoscopes, vital sign monitors, ultrasound devices, blood glucose monitors, and ECG machines.

5G could further improve remote healthcare. For example, a doctor can use specially designed haptic gloves and VR equipment to perform procedures remotely through robotic machinery.

The use of emergency vehicles is evolving too. Most ambulances in the US are already equipped with cellular in-vehicle networks to support computer-aided dispatch, mobile data terminals (MDTs), automated external defibrillators (AEDs), live video streaming and connected medical devices. These technologies enable the communication of critical patient information between the field and the hospital and help saves lives.

Many of these ambulatory capabilities are being deployed over 4G today. However, the low latency, high bandwidth and security aspects of 5G are essential for mainstream adoption.

[6] Beacons are small, wireless transmitters that use Bluetooth to broadcast information to other smart devices nearby.
[7] risnews.com/preparing-smart-store-future

Law enforcement: 5G for live HD video during emergencies
Reliable, go-anywhere connectivity is the minimum needed by today's law enforcement agencies. In the US, wireless roadband, together with Wi-Fi, ethernet, serial and other connections, have turned cruisers into roving communication hubs. Each in-vehicle network connects a plethora of IoT devices and sensors, from vehicle-mounted and body-worn cameras, notebooks and tablets, to critical backend systems at headquarters and in the cloud. Critical applications like computer-aided dispatch and fleet management are always connected and leverage real-time location data to keep officers safe and productive, and to ensure assets are maintained.

As 5G adoption spreads, the benefits of connected technologies to law enforcement, and the communities they serve, grows significantly. With 5G, officers can stream HD video from the scene to commanding officers in real time. It also enables the use of advanced recognition technologies, improved situational awareness via access to citywide surveillance cameras, and greater utilization of drones and robots. All of this keeps officers safer and better prepared, and makes information more readily available to the community.

Implications for service providers
While WWAN has the power to enable businesses and entire industries to transform, its impact on service providers is equally compelling.

Where 4G networks fueled the consumer mobility app revolution, 5G is ideally suited to enable the hyper-connected enterprise. As consumer net adds and ARPU are flat-to-declining in mature markets, 5G enables service providers to offer compelling and differentiated network solutions to B2B customers. Not only are these services stickier and deliver higher ARPU, they provide the foundation for additional services.

Taylor Construction builds future with 5G as backbone

By the time Telstra introduced Australia's first 5G service plan for business, Taylor Construction had already been using WWAN solutions in its building site administrative trailers for years. Wired broadband takes too long to deploy, is complicated to decommission, and is difficult to relocate, whereas cellular broadband offered the flexibility to commence operations immediately.

The company had a model that worked: using all-in-one edge routers to connect laptops, tablets, printers, and architectural printers via Wi-Fi for the LAN and 4G as the WAN link. But Taylor Construction recognized that 4G soon wouldn't be sufficient for its on-site administrative trailers – not with the variety of next-generation applications it was planning.

These technologies included:

- **Holographic building visualization** in which employees and customers use Microsoft HoloLens for mixed-reality visualization of virtual building models and schematics
- **Wide-area safety scanning** uses 360-degree 8K streaming and QR code scanning from wireless video cameras to track who has completed safety training
- **IoT structural sensing** is when smart sensors that aggregate and send data to the cloud are affixed to rebar and embedded in concrete
- **Real-time design display** enables real-time visibility into digital blueprint adjustments
- **Large-site failover** involves replacing expensive back-up fiber line with 5G, gaining fiber-like speeds with the diversity of a wireless connection

Taylor Construction decided to trial Telstra's 5G service plan through a solution that included 5G-optimized routers and cloud-based network management.

With a flexible 5G for business solution in place, the company quickly began seeing the WAN speeds and coverage necessary to support bandwidth-heavy connected devices and applications. These improvements will drive superior cost efficiency and client satisfaction on construction sites for years to come.

5G enables Taylor Construction to adopt innovative on-site use cases.

AI: enhancing customer experience in a complex 5G world

Reinforcement learning (RL) – a branch of machine learning – enables a network to continuously learn from observations and experiences, maintaining an optimized customer experience in a dynamic environment, as validated in two live networks.

Children soon learn that certain behaviors earn rewards, and these rewards inform their future behavior. This is the basis of RL. Rather than following manually programmed behaviors, AI agents instead focus on goal states, enabling them to learn and even optimize complex processes entirely autonomously. Testing and learning behaviors with digital twins takes the risk out of this approach.

AI applied in telecoms

The expanding scope of 5G applications puts numerous demands on networks, such as high availability, ultra-reliability, low latency and high security. This growing complexity is driving a need for more automation. Intelligent agents capable of handling complex processes are needed to optimize trade-offs between long-term benefits of the agent's behavior and short-term benefits from the immediate steps to be taken; for example, how to optimize a network in multiple steps. These processes need to be learned autonomously, without the intervention of a human domain expert. RL is the specialized area of machine learning that is well suited for this challenge.

RL delivers long-term rewards in dynamic environments

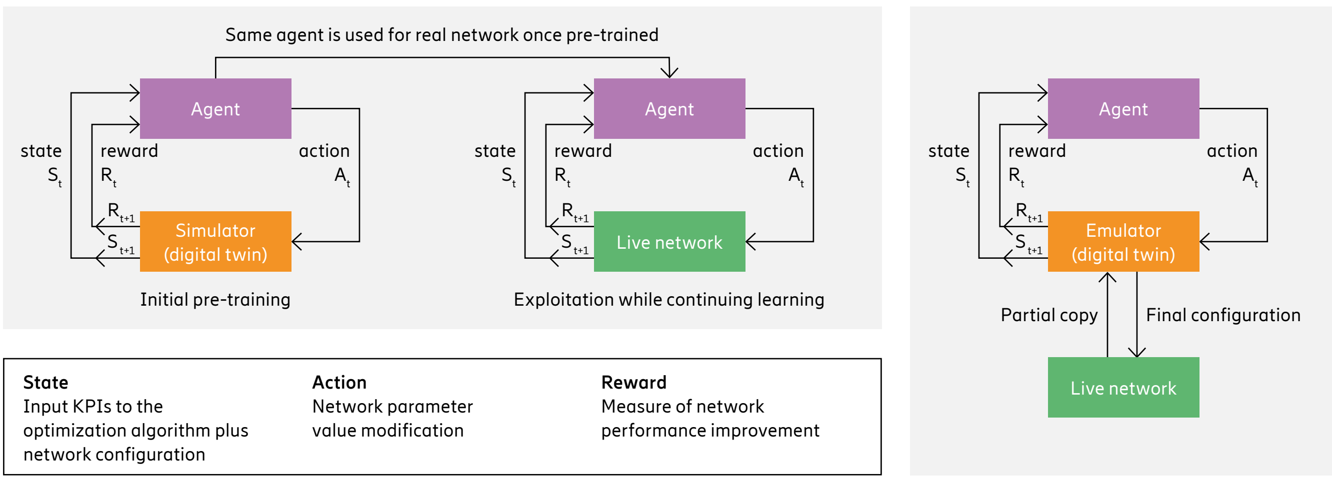
RL techniques mirror behavioral psychology. The agent accumulates knowledge about the dynamics of the environment – the mobile network – through different interactions that may result in positive or negative outcomes depending on how technically sound they are.

To train the system, a software agent interacts with the environment by repeatedly observing its state and then – based on the knowledge available to the agent at each stage – taking actions that are meant to maximize a long-term reward, that is, the improved situation based on defined criteria. In each iteration, the agent will learn from the outcome of the suggested actions and will become increasingly "wiser". At the beginning of the process, exploration of the environment will naturally be highly erratic, and then gradually become more focused and precise as the iterations proceed and knowledge about the environment's dynamics is improved.

At the end of the training phase, the agent should contain enough knowledge to facilitate a decision for each possible state of the environment. Later, when applying the agent to a specific network, the RL system will continue learning and a configurable degree of exploration can be carried out at the same time. This technique has been applied in many different fields, from video games to chess and self-driving cars.

In mobile network optimization, most existing solutions are based on rules defined by highly skilled domain experts who need to translate that knowledge into the proper automation frameworks. These rules are typically static and universal for all networks. The complexity of 5G makes it very challenging to manually devise rule modifications that benefit a specific network case. On the other hand, an RL agent can be pre-trained with general knowledge and then continue to learn in production, allowing an optimal policy for each specific scenario.

Figure 24: Live networks using simulators and emulators as digital twins



Digital twins enabling rewards from first implementation

Digital twins are a suitable solution to avoid the effects of erratic initial explorations on live mobile networks. Exploration is performed on an external entity that mimics the behavior of the live network. Once the agent has acquired all the necessary knowledge from the digital twin, the achieved policy can be safely applied to the live network. From that moment onwards, the agent will decide optimal actions on the live network, while continuing to learn from its feedback and also allowing a configurable degree of controlled exploration.

Typically, two types of digital twins can be considered for initial offline learning: emulators and simulators, as shown in Figure 24. An emulator contains a partial replica of the live network, providing accurate results but requiring big data techniques for efficient operations. A simulator is a software program that models the behavior of a network based on a set of hypothetical scenarios. In many cases, simulators are suitable to capture general trade-offs and trends.

Network-wide, coordinated approach to individual, cell-based optimization

Certain network parameters are configured on a per-cell level but might have a strong impact on the performance of surrounding cells, for example antenna electrical tilt and downlink transmission power. A change in any of these parameters also affects users served by the surrounding cells. Finding the optimal configuration for these types of parameters is a complex exercise.

This problem can be circumvented by means of a local per-cell reward definition that, when assessing the consequences of carrying out a change in one cell, also considers the impact of that change in its closest neighboring cells. This ensures implicit coordination and an operations strategy in which the agents will aim at improving not only each cell individually, but also the network as a whole.

These concepts have been successfully validated in two different live networks: remote electrical tilt (RET) optimization in MásMóvil and downlink transmission power optimization in Swisscom.

MásMóvil: improving customer experience during peak hours

MásMóvil wanted to improve congestion and downlink throughput during busy hours in Malaga, Spain. In this area they have one of the highest per-cell RET support rates. Antennas fitted with RET permit tilting adjustments via remote software commands instead of site visits, ideally suited for innovation towards the vision of zero-touch network optimization.

The RET optimization approach consisted of two phases:

- An initial pre-training phase during which the agent acquired all relevant knowledge from a digital twin, which was a network simulator.
- An online optimization phase, which was an iterative process, in which the pre-trained agent was fed with network performance measurements and applied incremental changes to the cells in the live network, while it continued learning from the resulting rewards.

The trial area consisted of several carriers at different frequency bands, with independent RET devices, making it possible to adjust the antenna tilt in one cell while keeping the tilts of all other co-located cells unaltered. In total, 127 out of 267 4G cells were selected for RET optimization in one carrier of the 1,800MHz band. The remaining cells were also monitored for benchmarking and to build the rewards of their surrounding optimizable neighbors.

During five weeks of automated decisions, the algorithm carried out eight parameter-changing iterations in total. Figure 25 illustrates how the improvements for two of the KPIs, contributing to the reward, were realized during the five weeks in the real network, with the lines representing network parameter changes. The overall outcome achieved a congestion rate close to zero and the downlink user throughput was increased by 12 percent during the busy hours, while keeping similar traffic volume. All this was achieved without any expert human intervention in the decisions or manual filtering before applying the changes.

> **12%**
>
> MásMóvil increased downlink user throughput by 12 percent by using RL to optimize RET.

Figure 25: Evolution of main reward components (percentage)

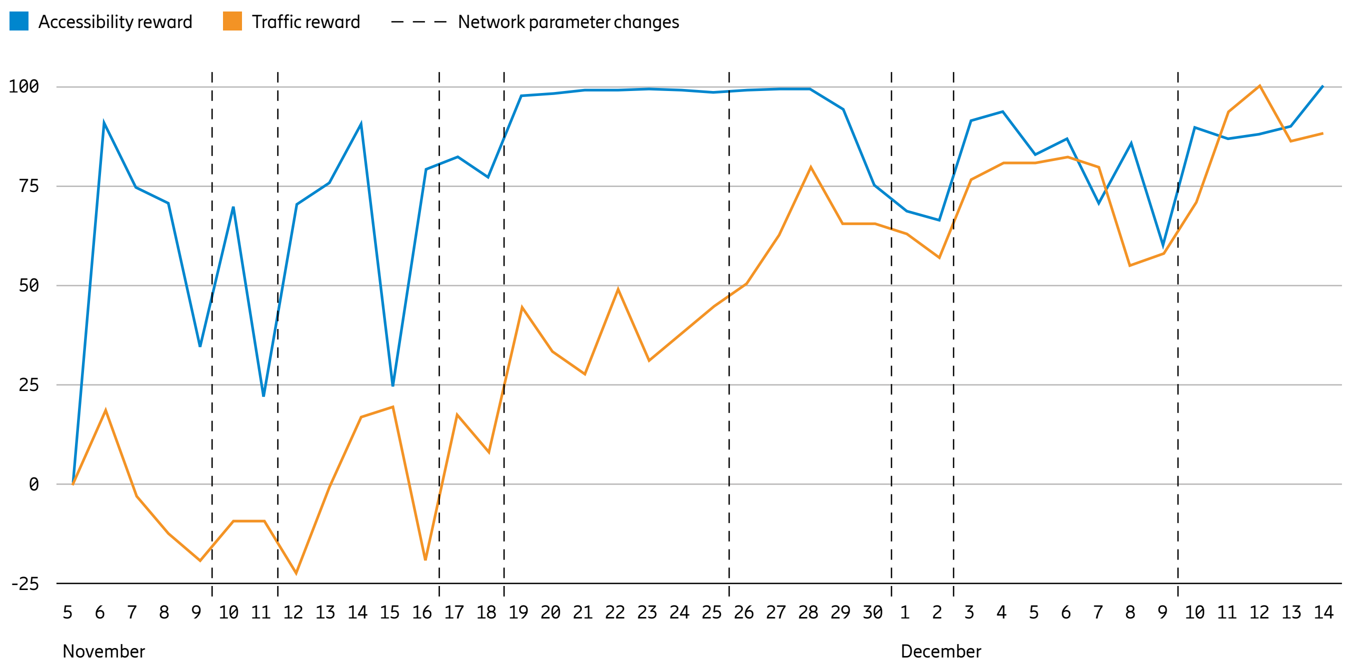


Figure 26: Power and RET changes in the Ticino area of Switzerland

Final power changes

Final RET changes

Swisscom: meeting strict regulations without compromising customer experience

Switzerland has stringent regulations for effective radiated power (ERP) from mobile networks. For Swisscom, one challenge was to lower power emissions within the existing low-band layer to create headroom to allow deployment of a new low-band layer which will be used by both 4G and 5G New Radio (NR). To begin with, the new low-band layer was unable to match the coverage of the existing one due to a lack of available power. A method based on RL using a network emulator as a digital twin was used to reduce ERP in the 4G network as much as possible while keeping the coverage and quality levels, followed by RET optimization using the simulator-based approach.

A trial to optimize both downlink transmission power and RET was executed in the Ticino area of Switzerland. The studied cluster consisted of 163 4G cells in the 800MHz band, from which 100 were selected for downlink transmission power optimization, followed by RET optimization.

The emulation of the network's behavior after a power change is so accurate that no iterative interaction with the live network is required. Instead, the final optimized values were fully obtained by solely interacting with the digital twin, and then these values were directly implemented in the network. After this phase, RET optimization was applied to the network. The final changes are illustrated in Figure 26.

The transmission power was reduced by 10 percent while simultaneously achieving a 12 percent increase in downlink throughput. An additional round of both power and RET optimization steps were executed to explore the potential limits of the solution, resulting in a final cumulative transmission power reduction of 20 percent while still achieving a 5.5 percent throughput gain. This reduction in ERP implies a 3.4 percent decrease in base station power consumption.

20%

Swisscom achieved, on average, a cell downlink transmission power decrease of 20 percent using RL.

RL in the cognitive network

Zero-touch network management and operations is a vision in which networks are deployed and operated with minimum human intervention, using trustworthy AI technologies. The cognitive network will be based on control design, using both machine reasoning and machine learning techniques that outperform previous methodologies.

RL enables the network to continuously learn from its environmental observations, interactions and previous experiences. The cognitive processes understand the current network situation, plan for a wanted outcome, decide on what to do and act accordingly. Desired outcomes serve as input to learn from its actions. The cognitive network will be able to optimize its existing knowledge, build on experience and reason to solve new problems.

Planning in-building coverage for 5G: from rules of thumb to statistics and AI

Improving the ability of network planners to estimate indoor traffic demand will contribute to more efficient 5G network deployments. Accurate indoor traffic ratio estimates are especially useful to operators rolling out mmWave coverage.

Traditionally, it has been assumed that 70–80 percent of mobile data traffic is generated indoors. Now, methods are being developed to accurately estimate the proportion of traffic in outdoor base stations that is due to indoor activity. The results of applying statistical approaches to three different environments in a metro area is recorded in Figure 27.

In urban deployments, the majority of mobile traffic is usually indoors, which is difficult to serve from outdoor base stations due to radio signal attenuation through walls and windows. With 5G systems, this can be even more of a challenge due to the use of ultra-high frequency bands.

The attenuation of radio signal power intensity, as a signal travels through the space between sender and receiver, is referred to as path loss and is the combined result of a number of factors including free-space loss, penetration losses, reflection, refraction and various other forms of fading.

5G systems can operate on a wide range of carrier frequencies, from below 1GHz in the low-band, up to 39GHz in the mmWave spectrum. Lower frequencies have good coverage characteristics, while high-band frequencies are useful for capacity, as the bandwidth available to be allocated is greater. However, signal attenuation increases with frequency.

The effect of frequency on path loss can be exemplified by measuring signal strength between two antennas 500m apart in line-of-sight. At the extremes, compared with a signal on 800MHz, a 39GHz signal has approximately 34dB (around 99.96 percent) more free-space path loss.

Another challenge of the higher frequency bands is the attenuation of signals penetrating buildings. In terms of signal propagation, buildings can be broadly classified into two types: modern thermally-efficient buildings with metallized glass windows, foil-backed panels for the walls, insulated cavity walls and thick reinforced concrete; and traditional buildings without any such material.

The median building loss for a thermally-efficient building is 50 times more than a building made with traditional materials at 800MHz and about 240 times more at 39GHz.[1]

To compensate for the loss associated with mmWave frequencies, service providers can use a range of solutions, including advanced antenna systems, beam-forming and indoor systems. Considering the high building penetration losses, high indoor traffic demand may make in-building solutions more economic. On the other hand, to properly serve the outdoor traffic, macro site densification may be needed. Having a realistic estimate of the indoor traffic ratio provides a solid ground for network investment decisions.

Figure 27: Percentage of traffic in outdoor base stations that is due to indoor activity

	Dense urban 191 cells	Urban 112 cells	Residential 13 cells
Macro	37%	65%	42%
Small cells	40%	46%	
Aggregated	38%	64%	42%

[1] itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.2109-0-201706-I!!PDF-E.pdf

New methodologies
Two distinct but interrelated approaches to the indoor traffic challenge are currently being explored by data scientists: one statistical and the other AI-based.

Both can be applied to network data that is already available, for example from a 4G network, and used to estimate the indoor traffic ratio at cell level or in a cluster of cells. The data comes from network nodes, as well as crowdsourced data from user equipment (UE), such as smartphones.

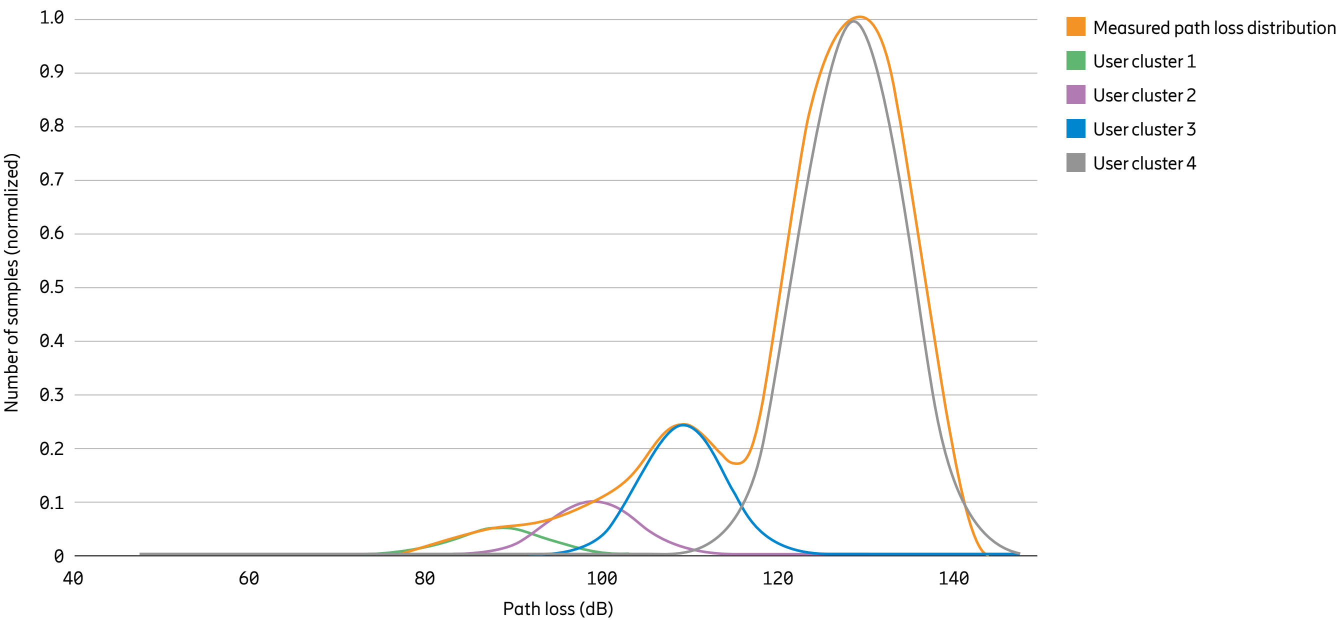
Uplink data from performance management (PM) counters can be used. A key PM counter is the uplink path loss distribution (including free space, building penetration and other losses). Crowdsourced data is collected by third parties with the users' permission through apps that log a range of data types. These include radio signal strength as reference signal received power (RSRP), location information and battery charging status.

The statistical approach
For uplink path loss distribution, a sample is collected at each transmission time interval (TTI), resulting in sufficient samples to allow the use of Gaussian Mixture Modeling (GMM). There is higher path loss for a smartphone located inside a building connected to an outdoor radio base station than for one outdoors due to the building penetration loss. The model works by taking all the data samples in a defined geographic area or a cell and then creating a path loss distribution for the data set. The model subsequently separates the data into user clusters by determining the best fit into a number of Gaussian distributions, each with its own statistical profile. Finally, by analyzing the data from each distribution, it can be determined which user clusters are indoors and outdoors, as can be seen in Figure 28. The statistical approach has the advantages of simplicity and transparency.

The AI approach: unsupervised learning
Compared to the statistical approach, machine learning techniques allow the use of data without directly specifying their contribution to the result. Using a technique called unsupervised learning, more data sources may be added with low effort, and more subtle information in the data can be exploited without direct human interaction.

To label a mobile phone as indoor or outdoor, unsupervised learning is used on data including RSRP, battery charging status and throughput. The machine learning model splits the feature space (that is, a set of measurements which describe the data) into a number of clusters and predicts if a cluster belongs to indoor or outdoor activity. All samples of the mobile phones falling inside an indoor cluster will be labeled as indoor.

Figure 28: Gaussian Mixture Model analysis of path loss distribution of a cell



37%

In a dense urban high-rise area, 37 percent of macro traffic was served to indoor users during busy hours, indicating that in-building cell deployment could be increased to meet indoor traffic demand.

Analysis and results

The methods were applied on the path loss distribution from performance management counters during business hours on 21 weekdays in the metropolitan area for the 4G cells. Data from a mobile service provider was analyzed after segregating the path loss distribution for macro and small cell base stations. The statistical analysis included three different environments: urban, dense urban (high-rise) and residential.

In the urban district, the average indoor traffic for outdoor cells was about 64 percent, and the 4G small cell base stations were serving 54 percent or more of the outdoor traffic. These results suggest that the service provider could consider deploying in-building solutions where possible and then augmenting the number of outdoor small cells.

For the dense urban high-rise area, around 37 percent of the macro traffic is served to indoor users, indicating in-building cell deployment should be increased to meet this demand, which is mostly in modern thermally-efficient buildings.

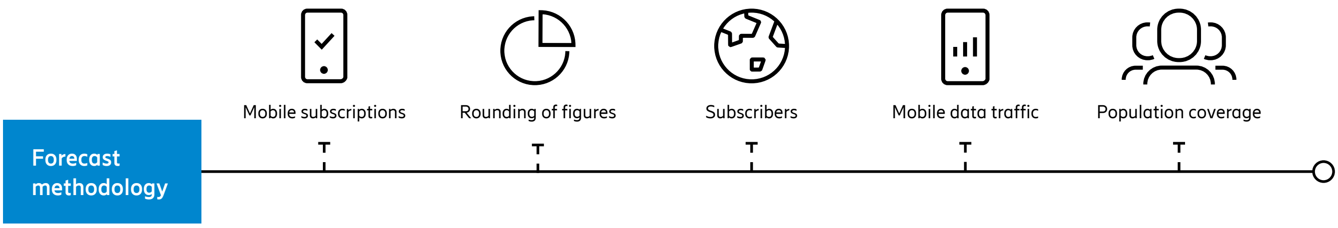
Using the previously assumed 70–80 percent ratio in the dense urban environment, the service provider may overestimate the need for additional in-building coverage. Moreover, this would also indicate fewer small cells and macro base stations than actually needed as the operator would be targeting only 20–30 percent of the outdoor traffic rather than the estimated 62 percent (inverse of the aggregate 38 percent identified in Figure 27 as indoor traffic served by outdoor base stations) according to the statistical approach, risking poor initial quality of service for the outdoor users served by macro and small cells.

The unsupervised learning approach was applied to a larger area that included all three metro districts mentioned in the previous approach. It has the capability of handling more data efficiently and can handle multiple inputs instead of relying on one measure like the statistical approach. More granular results can be obtained, since the labeling is done at the device/sample level rather than an aggregate measure. This allows not only the computation of an indoor traffic ratio but also of any indoor–outdoor ratio using the same model. The percentage of devices that are indoor, and the traffic percentage ratio that is generated from indoor devices, is then calculated; 61 percent of devices were detected to be indoor in the data set with 59 percent of traffic on outdoor base stations serving those devices. These results align with and complement the results from the statistical methodology.

Rolling out 5G networks

Designing Radio Access Networks (RAN) has grown in complexity with every generation of mobile communications. Now, as 5G is being rolled out, finding an optimum design for the service provider – balancing quality of service with efficiency – is made more challenging by the use of high-band frequencies, which combine high capacity with increased absorption losses through obstructions. The ability to increase prediction accuracy to find an optimal distribution between outdoor and indoor radio solutions faster helps deal with the growing complexity. Ultimately these approaches will be automated, allowing for continuous monitoring of 5G RAN efficiency.

Methodology



Forecast methodology
Ericsson makes forecasts on a regular basis to support internal decisions and planning, as well as market communications. The forecast time horizon in the Mobility Report is six years and is moved forward one year in the November report each year. The subscription and traffic forecast baseline in this report 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 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 a mobile network enabled customer premises equipment (CPE). This includes both indoor (desktop and window) 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 in two or three 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 traffic. More detailed measurements are made in a selected number of commercial networks with the purpose of understanding how mobile data traffic evolves. No subscriber data is included in these measurements.

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.

Ericsson Mobility Visualizer
Explore actual and forecast data from the Mobility Report in our new 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
www.ericsson.com/en/mobility-report/mobility-visualizer

Glossary

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

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)

5G TF: A pre-3GPP NR technical forum open specification

AI: Artificial intelligence

App: A software application that can be downloaded and run on a smartphone or tablet

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

EDGE: Enhanced Data Rates for Global Evolution

EN-DC: EUTRA-NR Dual connectivity

FDD: Frequency division duplex

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

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)

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

NR: New Radio as defined by 3GPP Release 15

NR-DC: NR-NR Dual connectivity

PB: Petabyte, 1015 bytes

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

Smartphone: Mobile phone with OS capable of downloading and running "apps", e.g. iPhones, Android OS phones, Windows phones and also Symbian and Blackberry OS

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

Global and regional key figures

Global key figures

Mobile subscriptions	2019	2020	Forecast 2026	CAGR* 2020–2026	Unit
Worldwide mobile subscriptions	7,930	7,950	8,770	2%	million
• Smartphone subscriptions	5,650	6,060	7,690	4%	million
• Mobile PC, tablet and mobile router subscriptions	270	290	450	8%	million
• Mobile broadband subscriptions	6,120	6,430	8,010	4%	million
• Mobile subscriptions, GSM/EDGE-only	1,670	1,390	630	-12%	million
• Mobile subscriptions, WCDMA/HSPA	1,870	1,660	720	-13%	million
• Mobile subscriptions, LTE	4,290	4,630	3,900	-3%	million
• Mobile subscriptions, 5G		220	3,520	59%	million
• FWA connections	51	62	180	20%	million
Mobile data traffic					
• Data traffic per smartphone	6.6	9.0	35	25%	GB/month
• Data traffic per mobile PC	15	17	29	9%	GB/month
• Data traffic per tablet	6.9	8.1	18	15%	GB/month
Total data traffic**					
Mobile data traffic	34	49	237	30%	EB/month
• Smartphones	32	47	232	31%	EB/month
• Mobile PCs and routers	0.8	0.9	1.3	6%	EB/month
• Tablets	0.9	1.1	3.9	23%	EB/month
Fixed wireless access	6.1	9.1	64	39%	EB/month
Total mobile network traffic	40	58	301	32%	EB/month
Total fixed data traffic	140	170	490	19%	EB/month
Fixed broadband connections	**1,170**	**1,220**	**1,520**	**4%**	**million**

Regional key figures

Mobile subscriptions	2019	2020	Forecast 2025	CAGR* 2019–2025	Unit
North America	380	390	430	2%	million
Latin America	660	650	710	1%	million
Western Europe	510	510	520	0%	million
Central and Eastern Europe	570	560	560	0%	million
North East Asia	2,050	2,060	2,210	1%	million
China[1]	1,600	1,600	1,680	1%	million
South East Asia and Oceania	1,140	1,130	1,220	1%	million
India, Nepal and Bhutan	1,130	1,130	1,260	2%	million
Middle East and North Africa	710	710	810	2%	million
Gulf Cooperation Council (GCC)[2]	79	76	85	2%	million
Sub-Saharan Africa	770	820	1,040	4%	million

Smartphone subscriptions	2019	2020	Forecast 2025	CAGR* 2019–2025	Unit
North America	310	320	350	2%	million
Latin America	490	500	580	3%	million
Western Europe	420	420	430	0%	million
Central and Eastern Europe	400	410	450	2%	million
North East Asia	1,760	1,850	2,080	2%	million
China[1]	1,390	1,450	1,600	2%	million
South East Asia and Oceania	790	840	1,100	5%	million
India, Nepal and Bhutan	660	810	1,240	7%	million
Middle East and North Africa	420	470	680	7%	million
GCC[2]	62	62	74	3%	million
Sub-Saharan Africa	390	440	760	9%	million

Regional key figures

LTE subscriptions	2019	2020	Forecast 2026	CAGR* 2020–2026	Unit
North America	350	350	70	-24%	million
Latin America	330	390	340	-2%	million
Western Europe	360	400	140	-16%	million
Central and Eastern Europe	230	280	370	5%	million
North East Asia	1,800	1,720	740	-13%	million
China[1]	1,230	1,410	560	-14%	million
South East Asia and Oceania	390	470	700	7%	million
India, Nepal and Bhutan	560	680	830	3%	million
Middle East and North Africa	180	220	420	11%	million
GCC[2]	53	61	19	-18%	million
Sub-Saharan Africa	88	130	300	15%	million

5G subscriptions	2019	2020	Forecast 2026	CAGR* 2020–2026	Unit
North America	1	14	360	-	million
Latin America	0	1	240	-	million
Western Europe	1	8	360	-	million
Central and Eastern Europe	0	0	180	-	million
North East Asia	10	190	1,430	-	million
China[1]	5	173	1,170	-	million
South East Asia and Oceania	0	2	400	-	million
India, Nepal and Bhutan	0	0	330	-	million
Middle East and North Africa	1	1	150	-	million
GCC[2]	0	1	62	-	million
Sub-Saharan Africa	0	0	70	-	million

Data traffic per smartphone	2019	2020	Forecast 2026	CAGR* 2020–2026	Unit
North America	8.4	11.1	48	27%	GB/month
Latin America	3.9	5.9	30	31%	GB/month
Western Europe	7.3	11	47	28%	GB/month
Central and Eastern Europe	5.1	7.2	29	26%	GB/month
North East Asia	7.8	10.9	39	24%	GB/month
China[1]	7.8	11	38	23%	GB/month
South East Asia and Oceania	4.3	6.2	39	36%	GB/month
India, Nepal and Bhutan	13	14.6	40	18%	GB/month
Middle East and North Africa	4.4	6.5	32	30%	GB/month
GCC[2]	14	18	42	15%	GB/month
Sub-Saharan Africa	1.6	2.2	9	26%	GB/month

Mobile data traffic	2019	2020	Forecast 2026	CAGR* 2020–2026	Unit
North America	2.8	3.7	17	29%	EB/month
Latin America	1.6	2.5	15	34%	EB/month
Western Europe	3	4.4	18	26%	EB/month
Central and Eastern Europe	1.6	2.3	10	28%	EB/month
North East Asia	12.4	18	74	26%	EB/month
China[1]	9.9	15	56	25%	EB/month
South East Asia and Oceania	3.1	4.7	39	42%	EB/month
India, Nepal and Bhutan	6.9	9.5	41	27%	EB/month
Middle East and North Africa	1.6	2.6	18	38%	EB/month
GCC[2]	0.7	0.9	2.5	18%	EB/month
Sub-Saharan Africa	0.54	0.87	5.9	38%	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.

Ericsson enables communications service providers to capture the full value of connectivity. The company's portfolio spans Networks, Digital Services, Managed Services, and Emerging Business and is designed to help our customers go digital, increase efficiency and find new revenue streams. Ericsson's investments in innovation have delivered the benefits of telephony and mobile broadband to billions of people around the world. The Ericsson stock is listed on Nasdaq Stockholm and on Nasdaq New York.

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