ERICSSON

ERICSSON MOBILITY REPORT

ON THE PULSE OF THE NETWORKED SOCIETY

NOVEMBER 2016

KEY FIGURES

Mobile subscription essentials	2015	2016	2022 forecast	CAGR 2016–2022	Unit
Worldwide mobile subscriptions	7,300	7,500	8,900	2%	million
> Smartphone subscriptions	3,300	3,900	6,800	10%	million
> Mobile PC, tablet and mobile router* subscriptions	240	250	320	4%	million
> Mobile broadband subscriptions	3,500	4,300	8,000	10%	million
> Mobile subscriptions, GSM/EDGE-only	3,600	3,100	900	-20%	million
> Mobile subscriptions, WCDMA/HSPA	2,100	2,300	2,800	5%	million
> Mobile subscriptions, LTE	1,100	1,700	4,600	20%	million
> Mobile subscriptions, 5G			550		million

Traffic essentials**	2015	2016	2022 forecast	CAGR 2016–2022	Unit
> Data traffic per smartphone	1.4	1.9	11	35%	GB/month
> Data traffic per mobile PC	5.7	7.7	23	20%	GB/month
> Data traffic per tablet	2.5	3.5	11	20%	GB/month
Total mobile data traffic	5.3	8.5	69	45%	EB/month
Total fixed data traffic	60	70	170	20%	EB/month

Mobile traffic growth forecast	Multiplier 2016–2022	CAGR 2016–2022
All mobile data	8	40%
> Smartphones	10	45%
> Mobile PC	2	15%
> Tablets	5	30%

Data traffic per smartphone	2016	2022	Unit
> Western Europe	2.7	22	GB/month
> Central and Eastern Europe	1.9	15	GB/month
> Middle East and Africa	1.3	7.6	GB/month
> Asia Pacific	1.7	9.5	GB/month
> North America	5.1	25	GB/month
> Latin America	1.6	9.6	GB/month

* Fixed Wireless Access (FWA) devices not included

** Active devices

Traffic Exploration Tool:
Create your own graphs, tablets and data using the Ericsson Traffic Exploration Tool. The information available here can be filtered by region, subscription, technology, traffic and device type.

To find out more, visit www.ericsson.com/mobility-report
There you will also find new regional reports

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ERICSSON MOBILITY REPORT

550 million 5G subscriptions in 2022

Commercial 5G networks based on ITU standards are expected to be available in 2020, and early deployments of pre-standard networks are anticipated in several markets. By the end of 2022, we forecast 550 million 5G subscriptions and a population coverage for the technology of 10 percent, starting in metropolitan and urban areas.

In addition to enhancing mobile broadband services, 5G will enable a wide range of use cases for the Internet of Things (IoT). We continue to forecast IoT connections, this time describing the split between wide-area and short-range connections.

We have included five feature articles in this edition of the Ericsson Mobility Report.

In the first article, we present findings from our study on time-to-content for popular websites. A key finding is that a limited uplink in many cases leads to slow time-to-content.

The second article explores how the use of live video streaming is now spreading across markets and user segments. One important reason for this is the inclusion of live streaming capabilities in social apps. This is creating new expectations around network performance.

As a special theme, we have an IoT focus section in this report. Here we feature three articles with different perspectives on IoT and its transformational potential. The first two articles are co-written with operators that have built IoT solutions around their core assets, creating additional business value. The third article explores the cellular networks' capabilities to support a realistic massive IoT use case scenario.

I hope you find this report relevant and engaging. All of our content is available at www.ericsson.com/mobility-report

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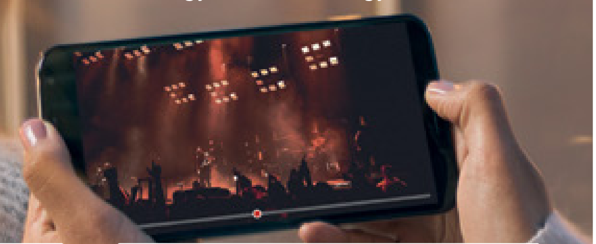


PAGE 9

25% of all mobile subscriptions in North America are forecast to be for 5G in 2022

PAGE 10

VoLTE is becoming mainstream – now launched in more than 80 networks in around 50 countries

MOBILE SUBSCRIPTIONS Q3 2016

84 million new mobile subscriptions were added in Q3, reaching a total of 7.5 billion

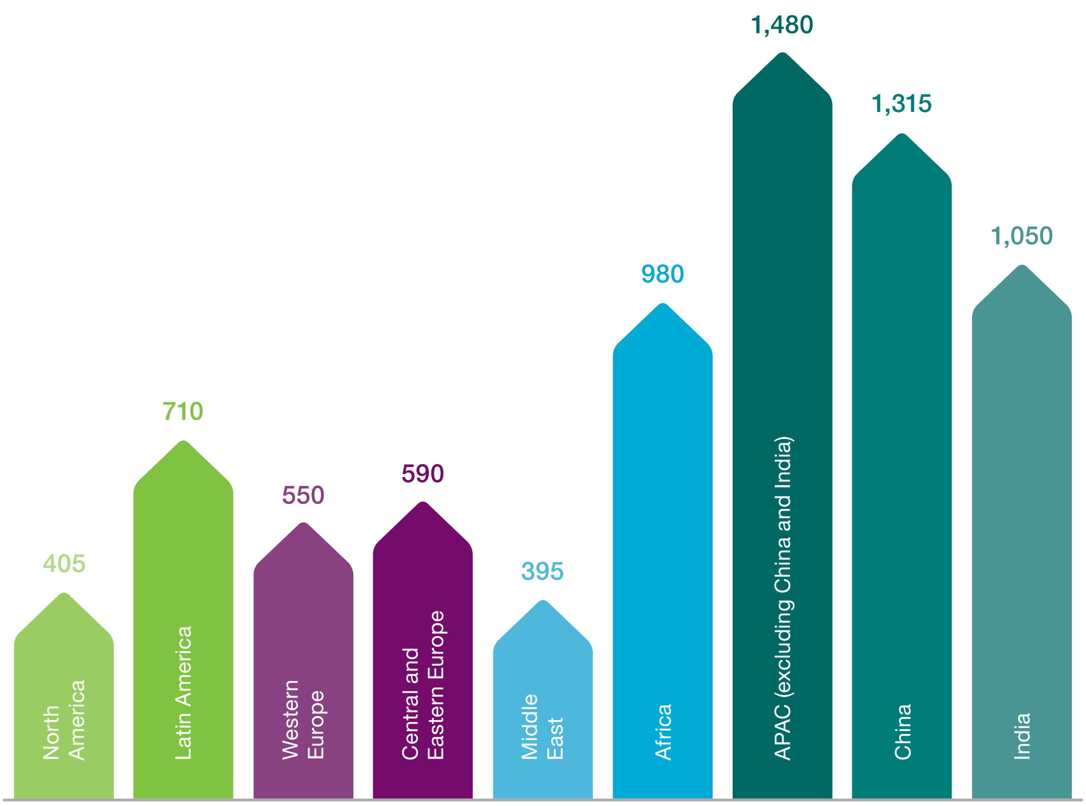
Mobile subscriptions are growing at around 3 percent year-on-year globally and reached 7.5 billion in Q3. India grew the most in terms of net additions during the quarter (+15 million), followed by China (+14 million), Indonesia (+6 million), Myanmar (+4 million) and the Philippines (+4 million).

Mobile broadband subscriptions[1] are growing by around 25 percent year-on-year, increasing by approximately 190 million in Q3 2016 alone. The total number of mobile broadband subscriptions is now around 4.1 billion.

LTE subscriptions continue to grow strongly, with 160 million new subscriptions added during the quarter to reach a total of around 1.5 billion. WCDMA/HSPA added around 60 million subscriptions during the quarter. The majority of 3G/4G subscriptions have access to GSM/EDGE as a fallback. GSM/EDGE-only subscriptions declined by 100 million during Q3 2016.

Subscriptions associated with smartphones continue to increase and have surpassed those for basic phones. 55 percent of all subscriptions are now for smartphones and, in Q3, smartphones accounted for close to 80 percent of all mobile phones sold.

Subscriptions for smartphones now account for 55% of all mobile subscriptions

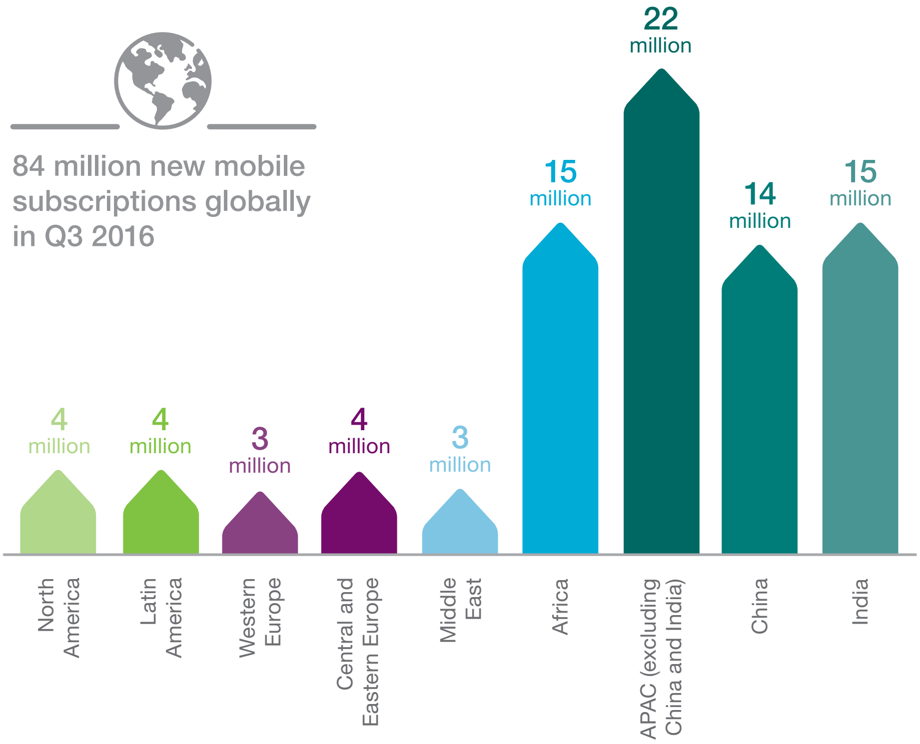


Mobile subscriptions (millions)

[1] Mobile broadband is defined as HSPA, LTE, CDMA2000 EV-DO, TD-SCDMA and Mobile WiMAX

New mobile subscriptions Q3 2016

84 million new mobile subscriptions globally in Q3 2016



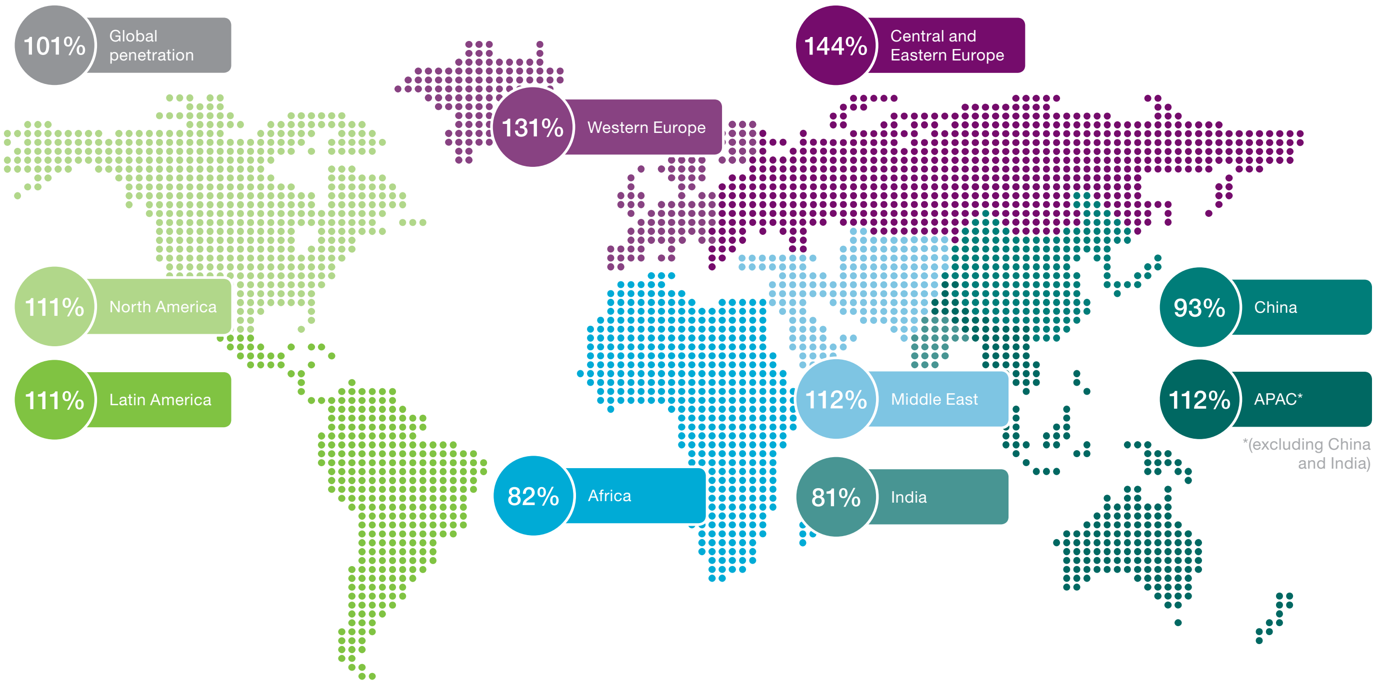
5.1 BILLION subscribers

Top 5 countries by net additions Q3 2016

1	India	+15 million
2	China	+14 million
3	Indonesia	+6 million
4	Myanmar	+4 million
5	Philippines	+4 million

A penetration rate of over 100% means that there are more subscriptions than people

The number of mobile subscriptions exceeds the population in many countries, which is largely due to inactive subscriptions, multiple device ownership or optimization of subscriptions for different types of calls. As a result, the number of subscribers is lower than the number of subscriptions. Today there are around 5.1 billion subscribers globally compared to 7.5 billion subscriptions.



Subscription penetration (percent of population)

MOBILE SUBSCRIPTIONS OUTLOOK

5G networks based on ITU standards are expected to be available in 2020, with the number of subscriptions reaching around 550 million by the end of 2022

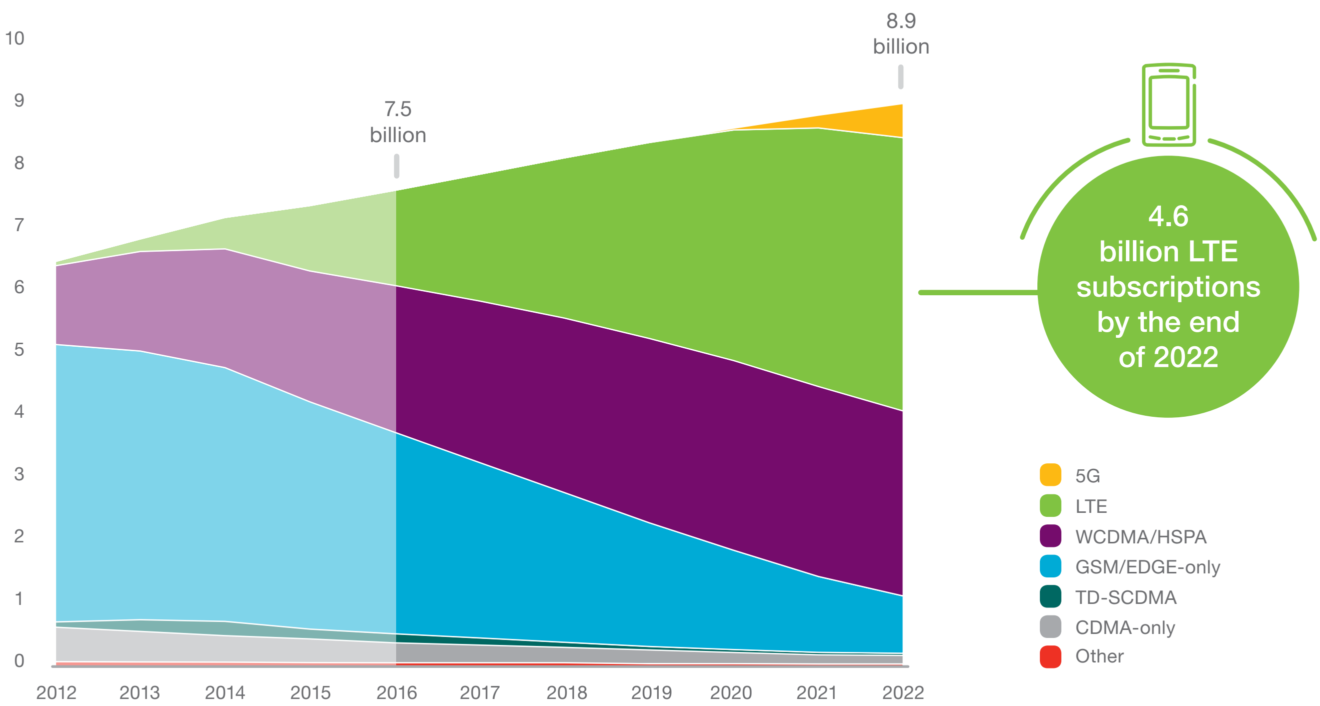
The interest in launching pre-standard 5G networks has increased over the year and deployments before 2020 are anticipated in several markets. Early 5G deployments are driven by the need for enhanced mobile broadband services, and as a complement for fixed internet services – referred to as Fixed Wireless Access (FWA).

In addition, 5G will enable a wide range of use cases for the IoT.

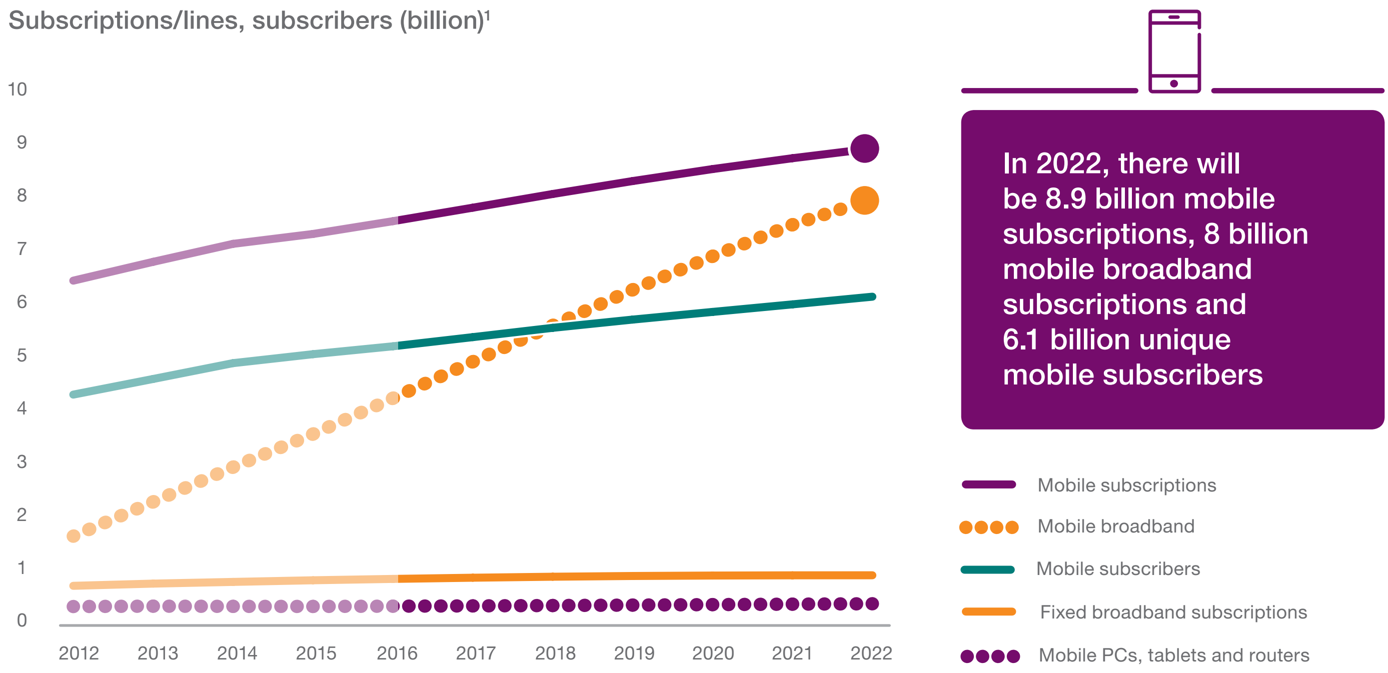
GSM/EDGE-only subscriptions is still the largest category of mobile subscriptions. However, LTE is anticipated to become the dominant mobile access technology in 2019, and reach 4.6 billion subscriptions by the end of 2022. In 2022, the number of LTE subscriptions will be more than five times higher than GSM/EDGE-only subscriptions, while the number of WCDMA/HSPA subscriptions will be three times higher. In developing markets, GSM/EDGE will remain a viable option, and the majority of 3G/4G subscriptions in all regions will still have access to GSM/EDGE as a fallback. GSM/EDGE will also continue to play an important role in IoT applications.

There will be 550 million 5G subscriptions by the end of 2022

Mobile subscriptions by technology (billion)



Subscriptions/lines, subscribers (billion)[1]



Mobile broadband will account for 90 percent of all subscriptions by 2022

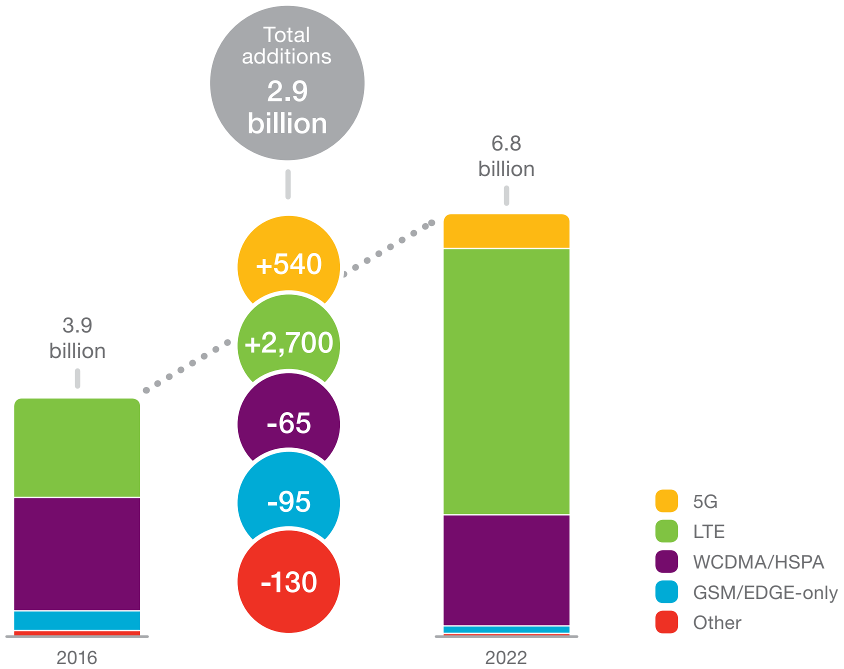
By the end of 2022, we anticipate that there will be 8.9 billion mobile subscriptions. Mobile broadband subscriptions will reach 8 billion, thereby accounting for 90 percent of all mobile subscriptions. The number of unique mobile subscribers is estimated to reach 6.1 billion by the end of 2022.

Mobile broadband will complement fixed broadband in some segments, and will be the dominant mode of access in others.[2] Many PCs and tablets are currently used without a mobile subscription, one reason being the price difference between Wi-Fi only models and those with mobile capabilities. Despite this, the number of PCs and tablets with mobile capabilities and a subscription will increase 30 percent by 2022.

Almost 90 percent of smartphone subscriptions on 3G and 4G networks today

By the end of 2016, there will be 3.9 billion smartphone subscriptions. The majority of these subscriptions – almost 90 percent – will be registered on WCDMA/HSPA and LTE networks. This is despite the fact that GSM/EDGE-only subscriptions is still the largest subscription category. By 2022, the number of smartphone subscriptions is forecast to reach 6.8 billion, with more than 95 percent of the subscriptions registered on WCDMA/HSPA, LTE and 5G networks.

Mobile smartphone subscription by technology



[1] Fixed Wireless Access (FWA) subscription not included
[2] The number of fixed broadband users is at least three times the number of fixed broadband connections, due to multiple usage in households, enterprises and public access spots. This is the opposite of the mobile phone situation, where subscription numbers exceed user numbers

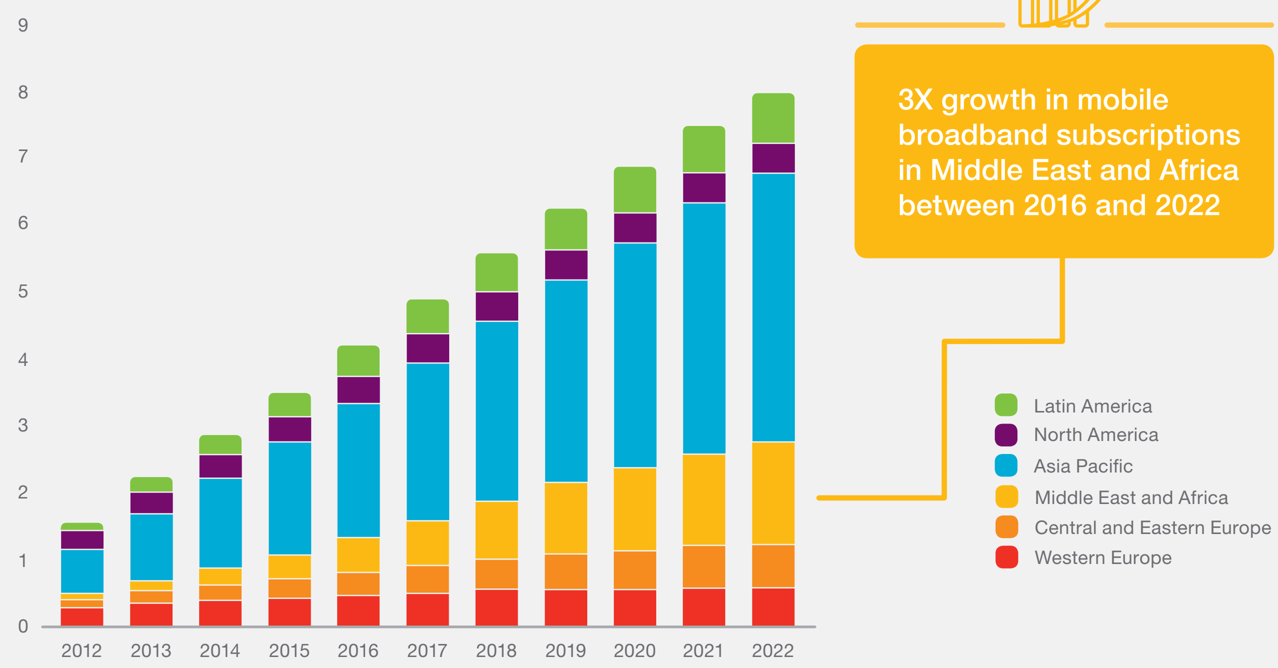
REGIONAL SUBSCRIPTIONS OUTLOOK

Mobile broadband is the key driver for subscriptions growth across all regions

The number of mobile subscriptions continues to grow across the regions, fueled by the strong uptake of mobile broadband subscriptions.[1] As can be seen on the following page, in 5 out of 6 regions, mobile broadband subscriptions now make up more than 50 percent of all subscriptions. Many consumers in developing markets first experience the internet on a smartphone, mainly due to limited access to fixed broadband.

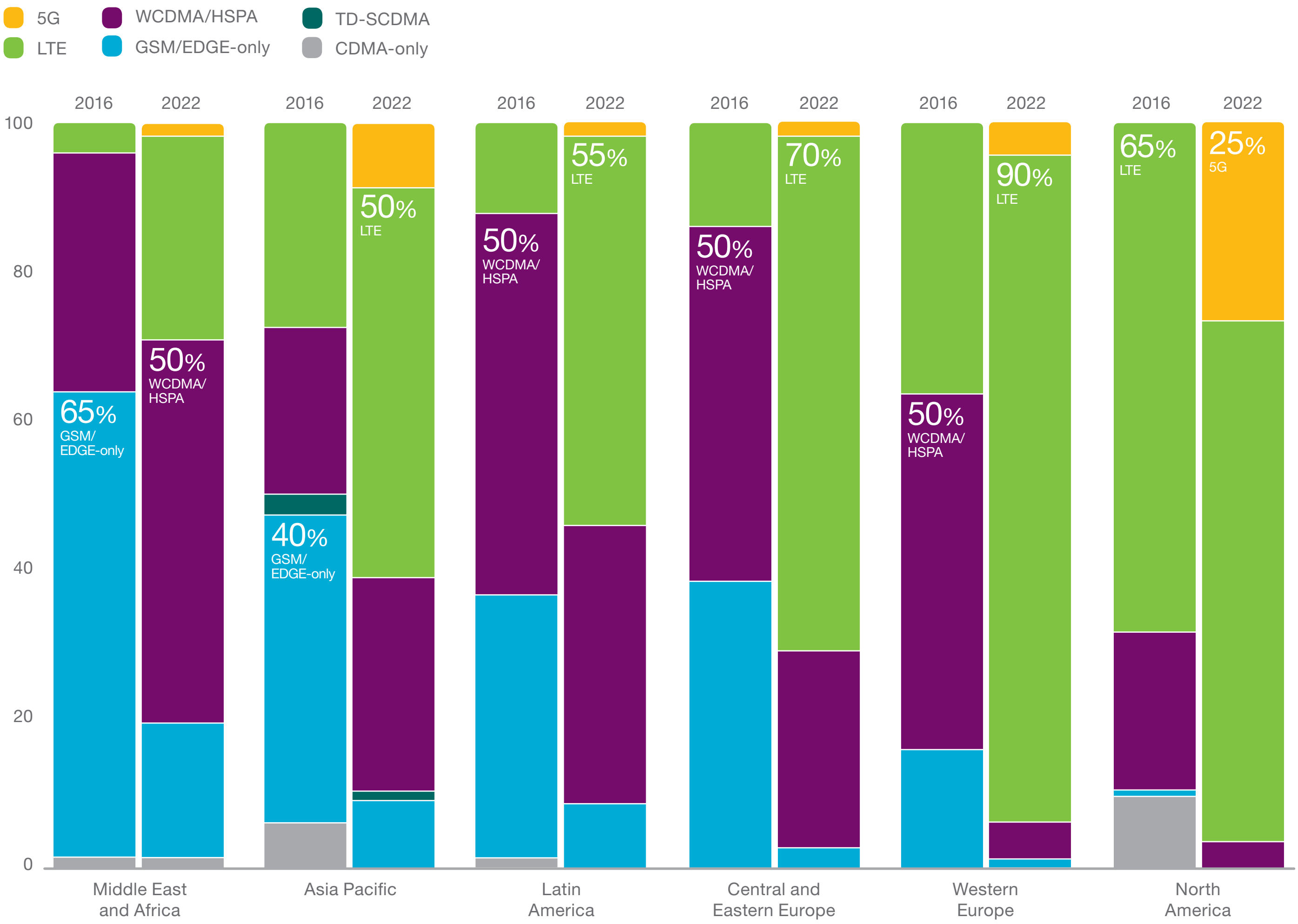
Greater device affordability is encouraging new subscribers in developing regions, while growth in mature markets is largely due to individuals adding more devices. In Middle East and Africa, where the penetration of mobile broadband is currently lower than in other regions, the growth in mobile broadband subscriptions is expected to be particularly strong moving forwards. A driving factor is the growing economy in several countries, supported by a young and growing population and more affordable smartphones.

Mobile broadband subscriptions by region (billion)



[1] Mobile broadband is defined as HSPA, LTE, CDMA2000 EV-DO, TD-SCDMA and Mobile WiMAX

Mobile subscriptions by region and technology (percent)



Mobile subscriptions in Middle East and Africa are mainly GSM/EDGE-only, while in Western Europe and North America the majority are WCDMA/HSPA and LTE

Over the forecast period, Middle East and Africa will dramatically shift from a region with a majority of GSM/EDGE-only subscriptions, to a region where 80 percent of the subscriptions will be WCDMA/HSPA and LTE. However, GSM/EDGE-only subscriptions will still account for a significant share of subscriptions by 2022. In Latin America, WCDMA/HSPA and LTE already account for around 60 percent of all mobile subscriptions – a number that is expected to increase to 90 percent in 2022.

Asia Pacific is a diverse region. Despite ongoing deployment of LTE in China, which will result in more than 1.2 billion LTE subscriptions in the country by the end of 2022, LTE subscriptions will represent just 50 percent of all subscriptions in the region by the end of the same period. This will be around one quarter of the global total. 5G subscriptions will account for around 10 percent of all subscriptions in the region in 2022, with deployments starting in South Korea, Japan and China. All three of these countries will host Olympic games in the coming six years, and have stated intentions to launch 5G services in conjunction with the games.

25% of subscriptions in North America and 10% in Asia Pacific will be for 5G in 2022

In Central and Eastern Europe, the share of LTE subscriptions is anticipated to grow strongly from around 10 percent in 2016 to 70 percent of all mobile subscriptions in 2022.

In Western Europe, the share of mobile broadband subscriptions is high due to well-developed WCDMA/HSPA networks and early LTE rollout. The regional share of 5G subscriptions will be 5 percent in 2022. Overall, North America is the region with the highest share of LTE subscriptions due to rapid migration from CDMA and WCDMA/HSPA-based networks. In 2022, the region will have the highest share of 5G subscriptions at 25 percent.

VOICE OVER LTE OUTLOOK

During the first 3 quarters of 2016, the number of VoLTE subscriptions has grown strongly and is estimated to surpass 200 million by the end of the year

With around 100 million new subscriptions[1] in 12 months, VoLTE is becoming mainstream, and the technology has now been launched commercially in more than 80 networks in around 50 countries. Uptake is projected to accelerate and reach 3.3 billion by the end of 2022, making up more than 60 percent of all LTE subscriptions globally.

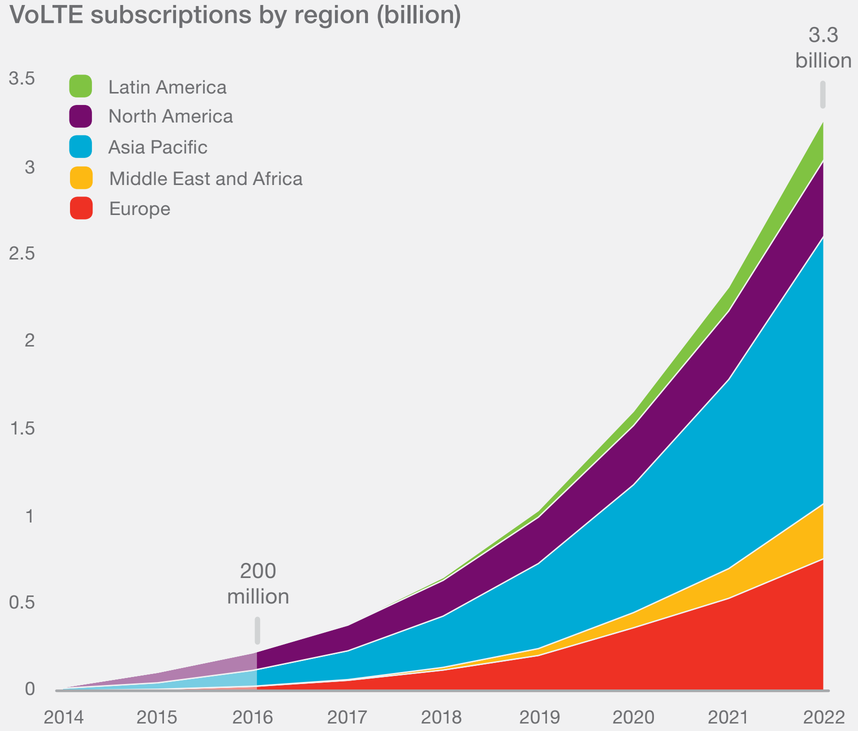
In countries like the US, Canada, Japan and South Korea, uptake is expected to be even faster, with around 90 percent of all LTE subscriptions using VoLTE by the end of the same period. Live network measurements show that there are already networks where around 75 percent of voice calls on LTE smartphones are provisioned using VoLTE, and some large operators have shown a doubling of VoLTE usage in just 6 months. Roaming and interconnect with VoLTE have started in the Asia Pacific and North American markets.

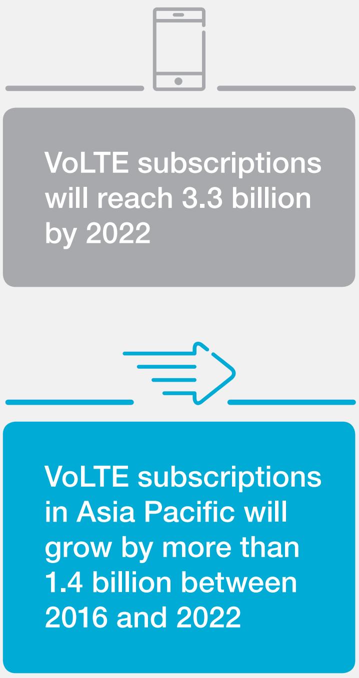
VoLTE-enabled smartphones on the rise

The penetration of VoLTE-capable smartphones is rapidly increasing. In October 2016, there were more than 600 VoLTE-enabled smartphone models, supporting different regions and frequencies.[2] The GSMA initiative for Open Market Devices (OMD) will further support this development by ensuring that devices with the OMD profile will be pre-configured with the standard VoLTE calling profiles, decreasing the need for operator-specific device testing prior to market launch.[3]

The VoLTE platform enables services such as HD voice, enhanced HD voice, video communication, IP messaging, content sharing within calls, multi-device, Wi-Fi calling and new service innovations. The VoLTE service will also be leveraged when evolving to 5G.

VoLTE subscriptions by region (billion)



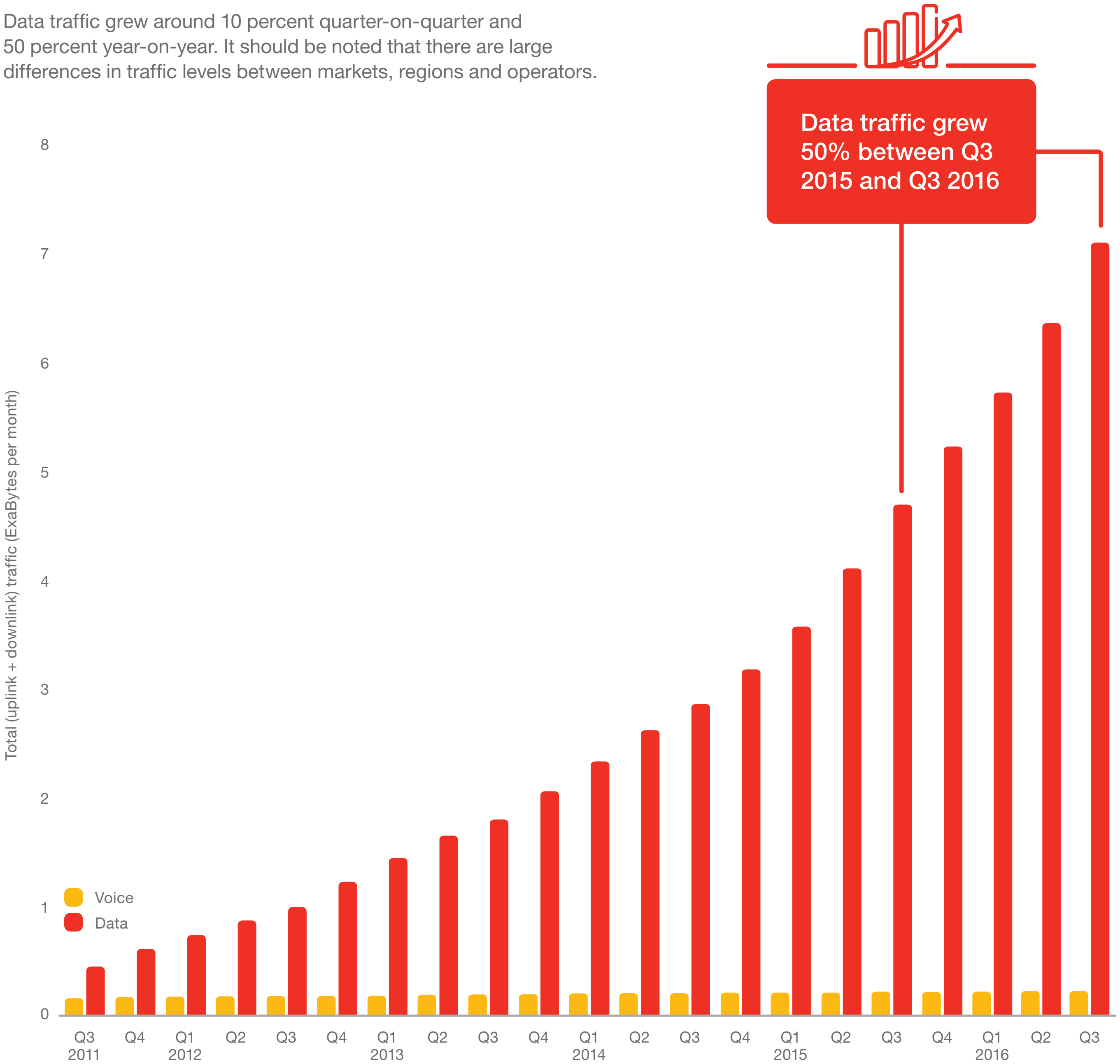


[1] Making at least one VoLTE call per month
[2] GSA (October 2016)
[3] GSMA (July 2016)

MOBILE TRAFFIC Q3 2016

Mobile data traffic continues to grow, and the graph below shows total global monthly data and voice traffic from Q3 2011 to Q3 2016.[1] It depicts a continued strong increase in data traffic and voice traffic in the mid-single digits per year. The growth in data traffic is being driven both by increased smartphone subscriptions and a continued increase in average data volume per subscription, fueled primarily by more viewing of video content.

Data traffic grew around 10 percent quarter-on-quarter and 50 percent year-on-year. It should be noted that there are large differences in traffic levels between markets, regions and operators.

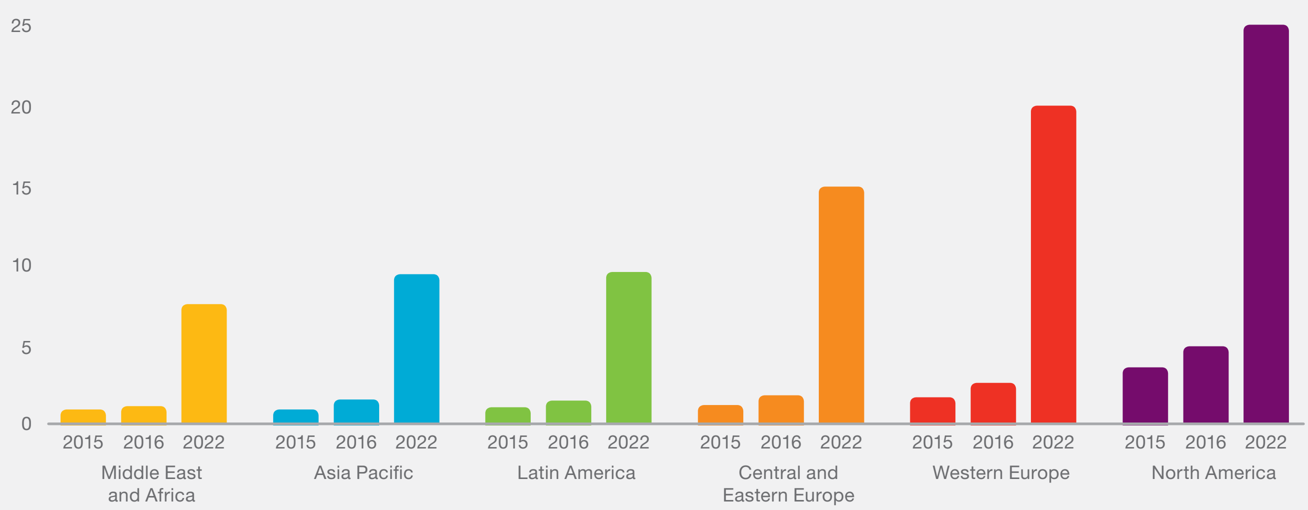


Source: Ericsson traffic measurements (Q3 2016)

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

MOBILE TRAFFIC OUTLOOK

Data traffic per smartphone (GB per month)



In 2022, monthly mobile data traffic per active smartphone in North America will reach 25 GB

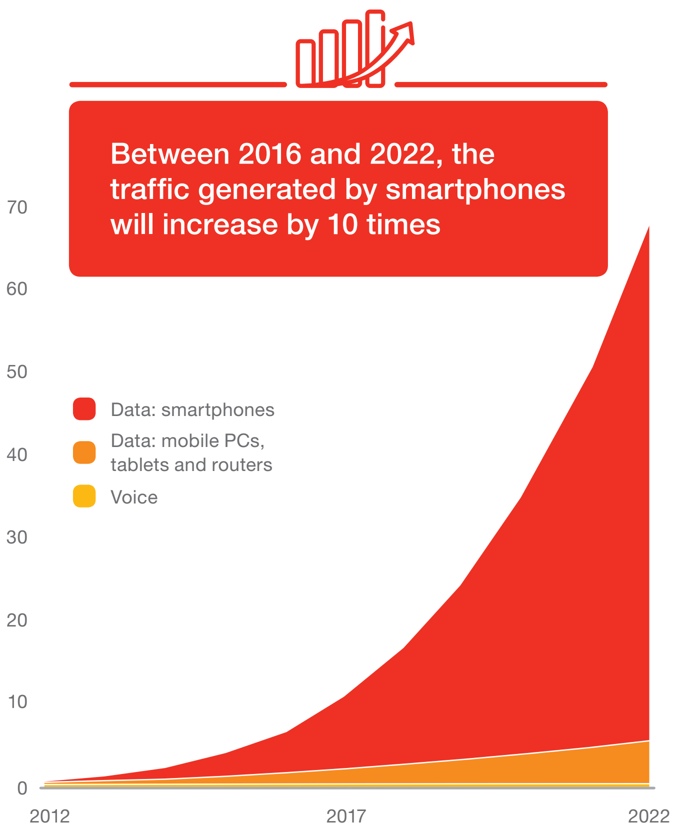
Monthly data traffic per smartphone continues to increase in all regions, even though there are large differences in data consumption patterns between networks, markets and subscriber segments. North America has the highest usage, with 5.1 GB per month per active smartphone expected by the end of this year. This is an increase of almost 40 percent since the end of 2015, and is almost twice as high as the region with the second highest usage, Western Europe, which is set to reach 2.7 GB per month per smartphone by the end of 2016.

In 2022, North America will still be the region with the highest monthly usage (25 GB), but other regions will be catching up. Factors that will drive usage include an increase in the number of LTE subscriptions, improved device capabilities and more attractive data plans, as well as an increase in data-intensive content.

Total mobile data traffic is expected to rise at a compound annual growth rate (CAGR) of around 45 percent

In the future, traffic generated by smartphones will dominate even more than it does today. Between 2016 and 2022, smartphone traffic is expected to increase by 10 times and total mobile traffic for all devices by 8 times. By the end of this period, more than 90 percent of mobile data traffic will come from smartphones.

Global mobile traffic (ExaBytes per month)



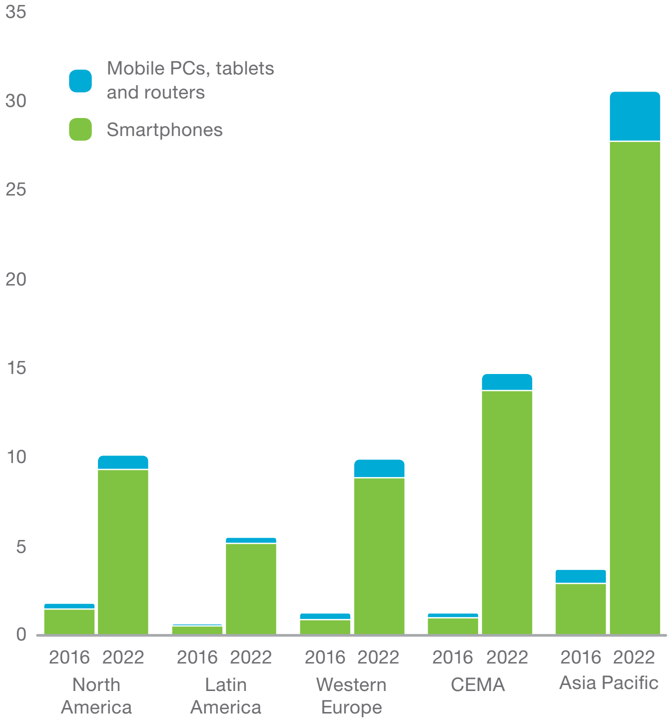
Mobile data traffic by region	2016 (EB/month)	Multiplier 2016–2022
Asia Pacific	3.6	8
CEMA	1.2	12
Western Europe	1.2	8
North America	1.8	6
Latin America	0.7	8

As the most populous region, Asia Pacific has the largest share of mobile data traffic. This is likely to continue into 2022, with a rapid growth in mobile broadband subscriptions expected in the region. China alone is set to add 440 million mobile broadband subscriptions between the end of 2016 and 2022

The level of mobile broadband maturity still varies greatly between countries in Asia Pacific. For instance, South Korea and Japan deployed LTE early with fast uptake, and markets like Singapore and Hong Kong are highly advanced. In less developed countries, GSM is still the dominant technology, and insufficient network quality and the cost of data subscriptions remain barriers to higher mobile data consumption.

The region Central & Eastern Europe and Middle East & Africa (CEMA) will experience a twelvefold increase in mobile data traffic up to 2022, driven by a strong growth in smartphone subscriptions and demand for data-intensive applications like video.

Global mobile data traffic (ExaBytes per month)



North America and Western Europe currently have a larger share of total traffic volume than their subscription numbers imply. This is due to high penetration of high-end user devices and well built-out WCDMA and LTE networks, complemented with affordable packages of large data volumes. This leads to higher data usage per subscription.

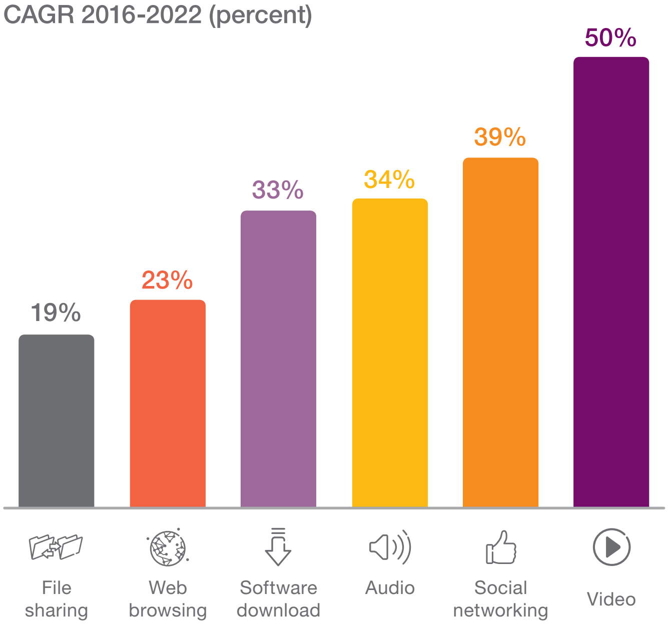
MOBILE TRAFFIC BY APPLICATION CATEGORY

Mobile video traffic is increasingly dominant

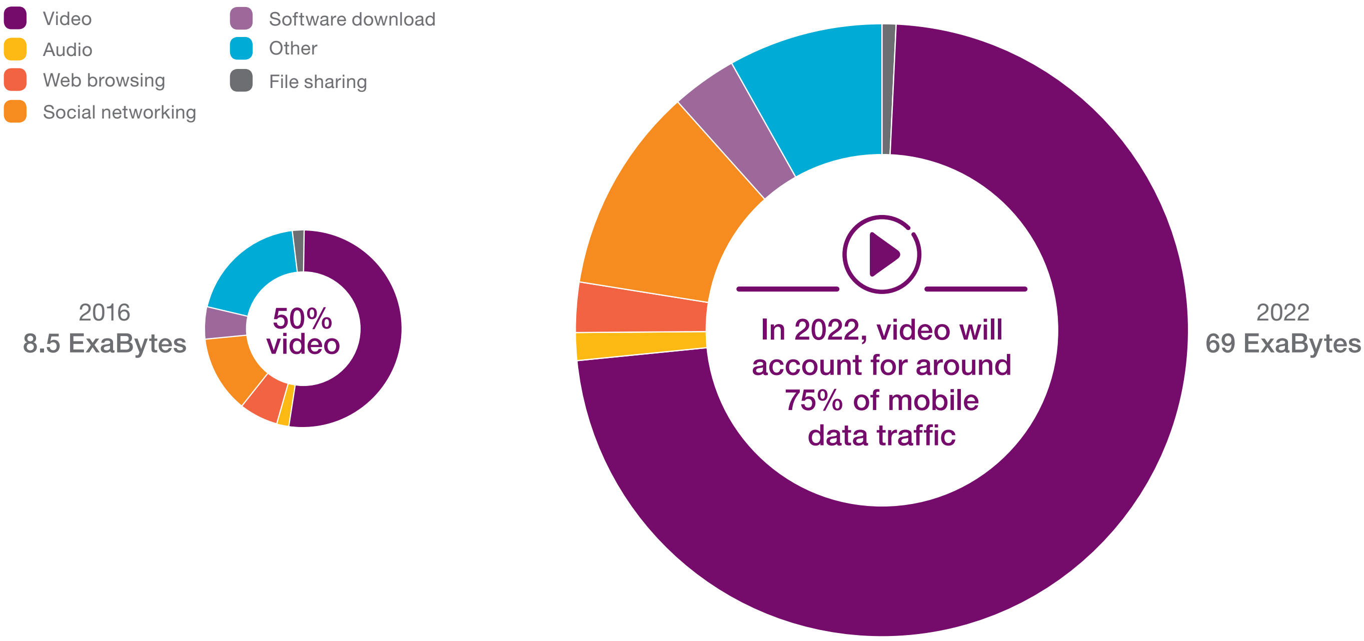
Mobile video traffic is forecast to grow by around 50 percent annually through 2022 to account for nearly 3 quarters of all mobile data traffic.[1] Social networking is expected to grow by 39 percent annually over the coming 6 years. However, its relative share of traffic will decline from 15 percent in 2016 to around 10 percent in 2022, as a result of the stronger growth in the video category. Other application categories have annual growth rates ranging from 19 to 34 percent, so are shrinking as a proportion of overall traffic. Additionally, the use of embedded video in social media and web pages continues to grow, fueled by larger device screens, higher resolution and new platforms supporting live streaming. Embedded video in social media and web pages is counted as video traffic.

The emergence of new applications can shift the relative volumes of different types of traffic, although the proliferation of different sized smart devices will also affect the traffic mix; for example, tablets are associated with a higher share of video traffic than smartphones. Typically, tablets and smartphones are used equally for watching short video content, but tablets are used more for watching longer video content.[2]

Mobile traffic by application category
CAGR 2016-2022 (percent)

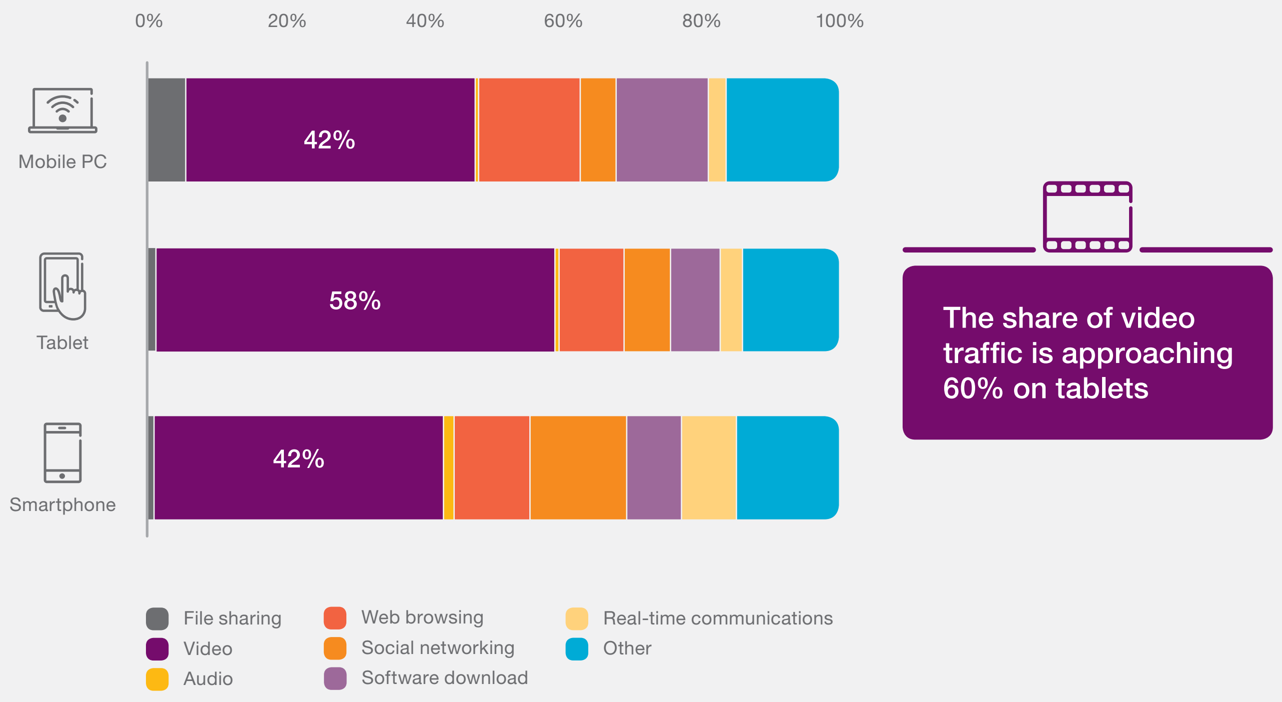


Mobile traffic by application category per month (ExaBytes)



[1] Video is likely to form a major part of file sharing traffic in addition to the identified application type 'video'
[2] Ericsson ConsumerLab, TV and Media (2016)

Mobile data traffic volumes by application category and device type



Source: Ericsson network traffic measurements 2016

Video traffic dominates across devices

Average values from measurements[3] in a selected number of commercial HSPA and LTE networks in the Americas, Asia and Europe show that, regardless of device type, video is the largest contributor to traffic volumes. However, there is a large variation between networks.

Compared to similar measurements done in the second half of 2015, the share of video traffic is still increasing on tablets, approaching 60 percent of total traffic. On smartphones, the share of video traffic is slightly lower than 12 months ago. YouTube still dominates video traffic in most mobile networks, although it's being challenged by local players in some countries. YouTube traffic accounts for between 40–70 percent of total video traffic for almost all measured networks, regardless of device type. Netflix is available in most markets now and, in some, its share of video traffic can reach 10–20 percent of total mobile video traffic. In other markets, Netflix's share of traffic is still very small.

The traffic share of traditional social networks, such as Facebook and Twitter, has decreased for all device types, as usage has shifted towards more communication-oriented services like Snapchat and WhatsApp. Traffic for these services is included in the real-time communications category in the figure above. Social networking is, however, still the second largest traffic volume contributor for smartphones.

The share of traffic for software updates has increased slightly since last measurements, presumably due to more frequent updates of apps.

File sharing is more prominent on mobile PCs than on other devices, but overall is decreasing, constituting around 5 percent of traffic. The very small proportion of file sharing associated with smartphones and tablets comes predominantly from tethering traffic.

[3] Measurements do not include Wi-Fi traffic. 'Other' includes application categories not possible to identify or that aren't one of the listed application types

STATE OF THE NETWORKS

Mobile networks continue to evolve with higher speeds, new functionality and increased population coverage in the evolution towards 5G

Achieving a major technology milestone: LTE downlink peak data speeds of 1 Gbps

With expanding LTE coverage and subscriber count, the demand for enhanced app coverage continues to accelerate the development of LTE data rates. LTE networks and devices supporting downlink data speeds of up to 1 Gbps are now commercially available and launches are expected in the coming months. This represents more than a sixfold increase in speed since LTE's introduction.

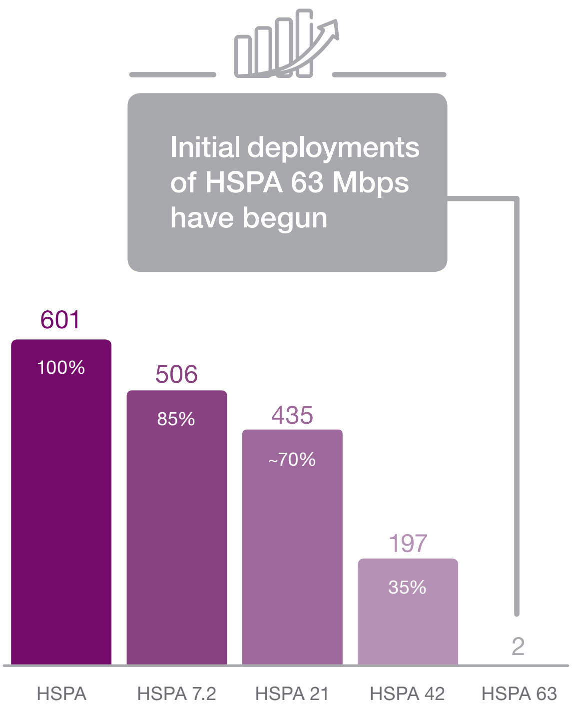
Peak data speeds of 1 Gbps will provide users with significantly faster time-to-content and will enhance the usefulness of personal hotspots, as well as making LTE a more attractive alternative to deliver fixed wireless services.

Greater spectral efficiency enables higher LTE data speeds, as LTE-Advanced (LTE-A) enhancements are becoming more widely deployed. These enhancements include:

- Carrier aggregation – combining spectrum across different bands, increasing spectrum bandwidth and data speeds available to mobile users. In addition, aggregating FDD spectrum with TDD spectrum is an effective way to optimize app coverage and capacity.
- Higher order modulation – increasing the number of bits per data stream. 256 Quadrature Amplitude Modulation (QAM), used in the downlink, can increase data speeds by 33 percent. 64 QAM, used in the uplink, can increase uplink speeds by 50 percent.
- 4x4 Multiple Input Multiple Output (MIMO) – doubling the number of unique data streams, enabling up to twice the capacity and throughput.

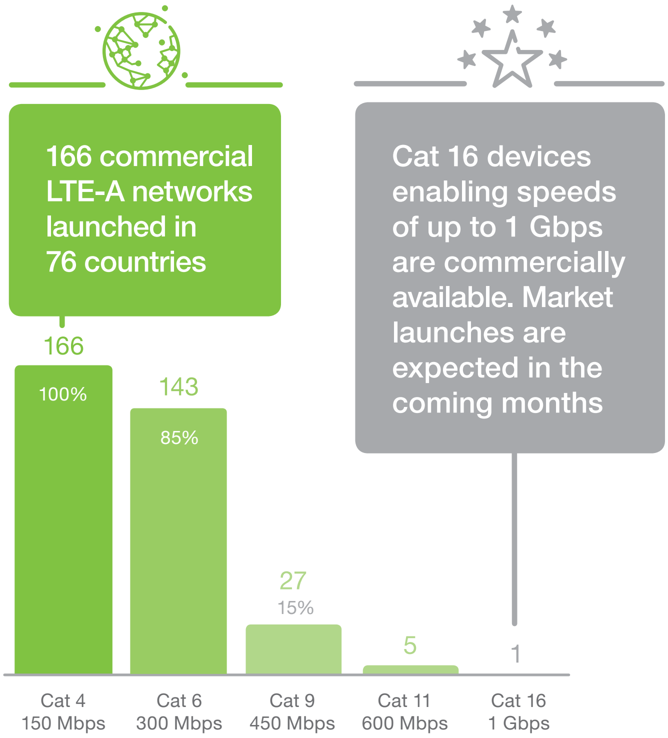
The number of commercial LTE-A carrier aggregation networks continues to increase. Operators are evolving their networks with Category (Cat) 4, 6, 9, 11 and 16 implementations.

Percentage and number of WCDMA networks upgraded to HSPA and to HSPA 7.2, 21, 42 and 63 Mbps



Source: Ericsson and GSA (November 2016)

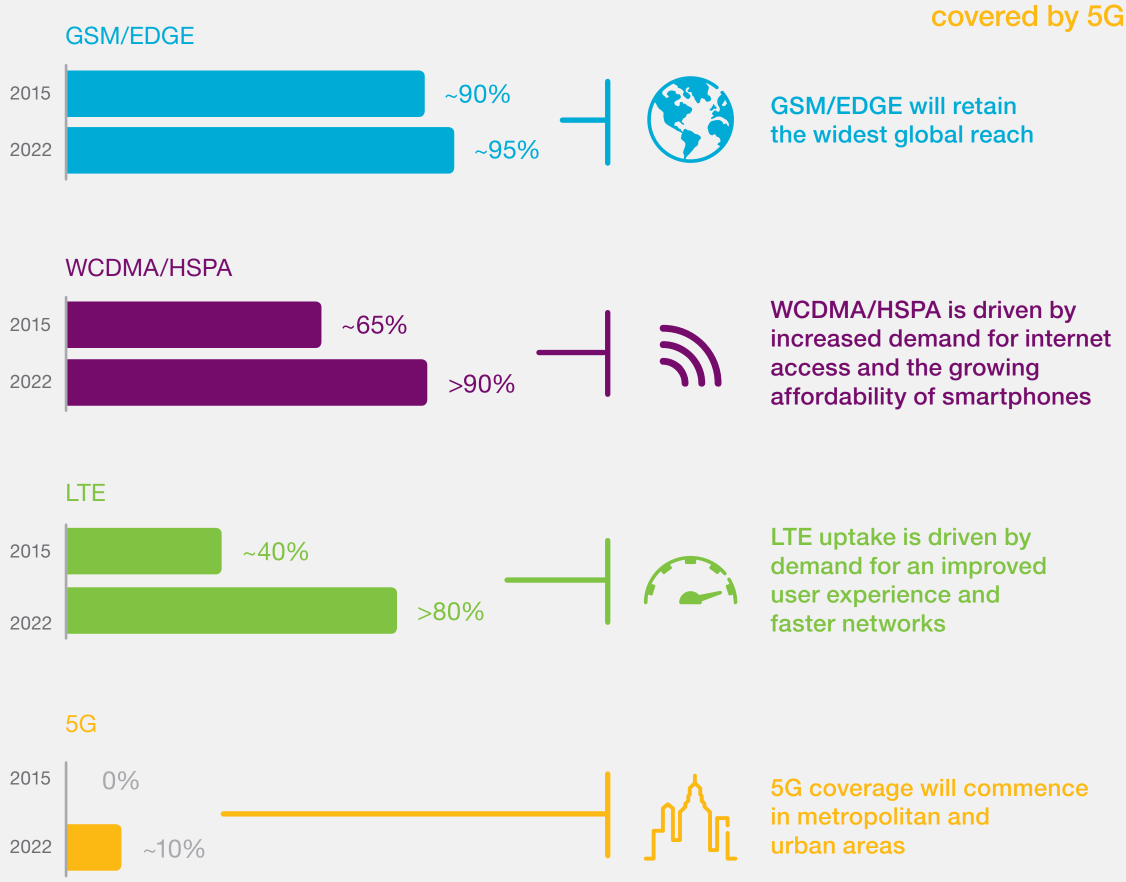
Percentage and number of LTE-Advanced networks supporting Cat 6, Cat 9, Cat 11 and Cat 16 devices



Source: Ericsson and GSA (November 2016)

World population coverage by technology[1]

By 2022, around 10% of the world´s population will be covered by 5G networks



As the deployment of LTE-A carrier aggregation, 4x4 MIMO and advanced modulation techniques becomes more widespread, an increase in the availability of devices capable of supporting these LTE capabilities is expected. As a result, users will see increases in their available data speeds.

Enabling IP-based communication services on the latest devices

VoLTE technology enables operators to offer high-quality, simultaneous communication and LTE data services on smartphones and other devices. Services include telecom-grade HD voice, video communication, multi-device capabilities and more. The latest GSMA initiative to drive global adoption of a universal profile for Rich Communication Services, which enables globally interoperable IP messaging and content sharing during calls, is now backed by more than 50 global operators and mobile OS manufacturers.[2]

Core networks based on Evolved Packet Core and IMS are being further developed to enable communication services on any device type as the device ecosystem evolves. The services can be run over LTE, Wi-Fi, fixed broadband and, in the future, 5G.

Taking HD voice to the next level in LTE and Wi-Fi networks

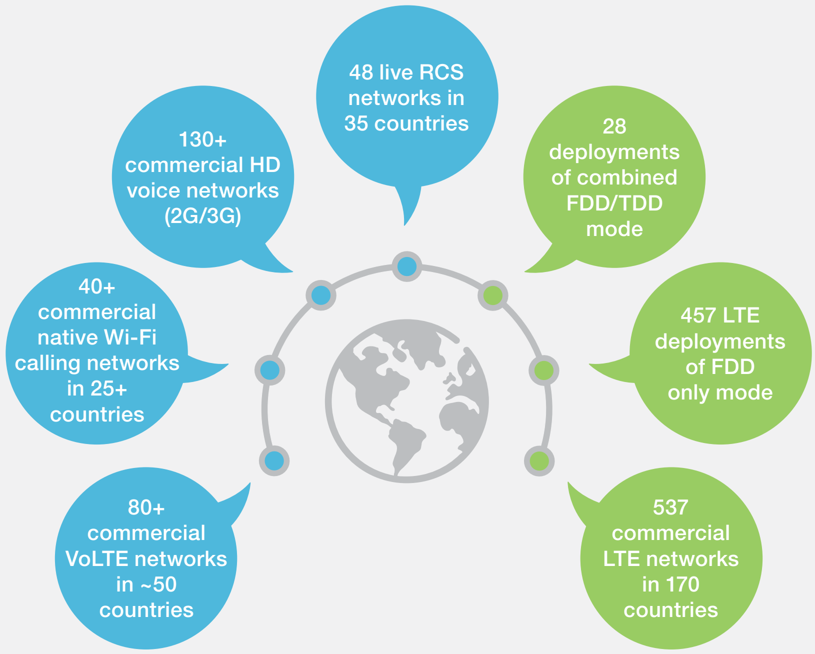
3GPP standardized Enhanced Voice Services (EVS) for VoLTE-enabled networks further improve quality compared to HD voice. Music quality within calls is enhanced; for example, call announcements or sharing music from a concert during a voice or video call. EVS provides a better quality service than HD voice in challenging LTE radio conditions, as well as better service robustness when using Wi-Fi calling. The first commercial rollouts of EVS have recently started in Asia Pacific, North America and Europe.

Wi-Fi calling is taking off with more commercial launches and new devices

With Wi-Fi calling, operators can extend their voice service indoors, allowing consumers to make calls in their homes over their own Wi-Fi access points, using any internet service provider. This benefits users with limited cellular coverage indoors, as well as roaming users.

Support for Wi-Fi calling is rapidly extending from high-end smartphone models to more affordable models. Some operators have also launched Wi-Fi calling on devices without a SIM card, such as tablets, smartwatches and personal computers. The service is supported on selected models.

[1] The figures refer to population coverage of each technology. The ability to utilize the technology is subject to factors such as access to devices and subscriptions
[2] GSMA (June 2016)



Source: Ericsson, GSMA and GSA (November 2016)

Evolving networks to 5G

5G is one of the most anticipated advances in the ICT industry. The introduction of 5G will accelerate transformation in many industry verticals, enabling new use cases in areas such as automation, IoT and big data.

With increases in radio performance and the flexibility enabled by network slicing and Network Functions Virtualization (NFV), networks can serve a much broader range of use cases. In 2015, deployments of NFV in core networks began. The first examples of services deployed with NFV were VoLTE, Wi-Fi calling and the expansion of mobile broadband to locations and industries needing high capacity or remote area connectivity. NFV enables faster and more flexible introduction of services, such as distributed mobile broadband, IoT, communication services and enterprise services. It is also a key building block on the path to future 5G deployments.

Capacity and throughput remain drivers, with user data consumption continuing to rise with increased use of video. Some specific use cases, like massive IoT and FWA, are likely to be implemented faster, as they can take advantage of the early evolution steps towards 5G.

Growth of 5G is linked to growth of the complete ecosystem. Network development and rollout needs to happen at pace with the development of devices, and this will be influenced by access to and licensing of suitable spectrum bands.

It is expected that most operators will introduce 5G from 2020, which is closely linked to the timeline for 5G standardization. Early deployments of pre-standard networks are anticipated in selected markets. As of today, there are around 30 operators that have publicly announced 5G introduction plans, with several trials already taking place. Rollout is expected to commence in metropolitan and urban areas, and is forecast to reach around 10 percent population coverage by 2022.

NFV is a first step to 5G core networks

NFV is currently being deployed in core networks, supporting EPC, IMS, SDM and other functions. Examples of services being deployed include:

MOBILE BROADBAND
Capacity expansions in hybrid networks

DISTRIBUTED MOBILE BROADBAND
Private networks and remote areas

INTERNET OF THINGS
NB-IoT, Cat-M1

ENTERPRISE
Operator data center or on premises

COMMUNICATION SERVICES
VoLTE, Wi-Fi calling, etc.

MVNO
Flexibility and simple operations

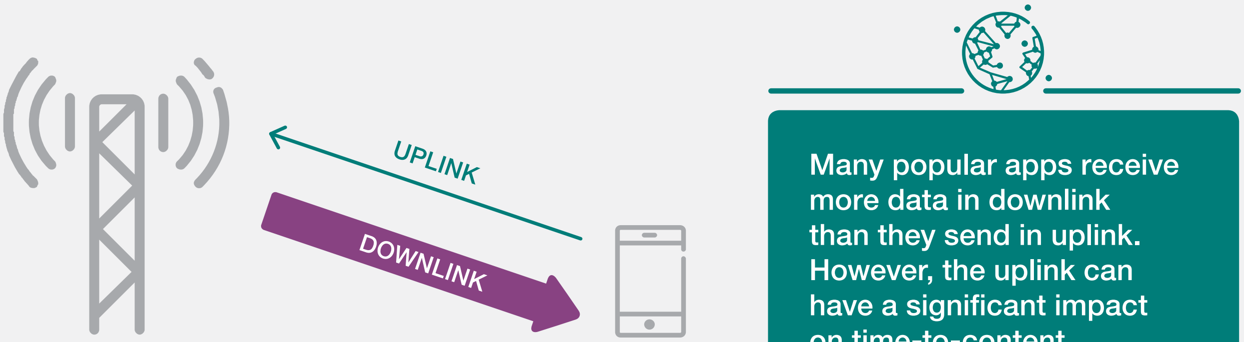
UPLINK AND SLOW TIME-TO-CONTENT

Time-to-content is important to mobile broadband subscribers. A limited uplink can be a critical factor in causing slow time-to-content on many popular websites. With an efficient way to identify cells with low uplink coverage, focused improvements can be made to enhance overall user experience

Providing good network performance is an important differentiator for mobile operators, and has a significant impact on both subscriber loyalty and Net Promoter Score (NPS). Nonetheless, many mobile broadband networks do not consistently provide the performance required for a responsive experience. Often it is the speed of the downlink (from the network to the device) that determines a good time-to-content, as many popular apps receive more data in downlink than they send in uplink. However, once uplink speed drops below a certain threshold, it becomes the bottleneck, limiting the speed at which content can be transferred in downlink.

App coverage can be measured in terms of time-to-content, defined as the time from when a user requests online content until it is rendered on a smart device's display. Benchmarking some of the most popular global and local websites – including e-commerce, e-banking, news and entertainment – it was found that many pages require an uplink speed of at least 300 kbps to meet a target time-to-content of 4 seconds or less. Ultimately, it is up to each mobile operator to define app coverage targets depending on subscriber expectations.

Downlink and uplink between a device and the network



Many popular apps receive more data in downlink than they send in uplink. However, the uplink can have a significant impact on time-to-content

Impact of uplink and downlink on time-to-content

Source: Ericsson Smartphone Lab measurements

Determining minimum uplink and downlink speeds

Time-to-content for popular websites is – in many instances – determined by the performance of the mobile network. This is because providers of popular content tend to ensure that the design and size of the content is optimized for smart devices connecting via mobile broadband, and that the content is served from a nearby cache server. A sample of popular web pages was benchmarked by repeatedly loading them on high-end smartphones while logging time-to-content. The smartphones were connected to the internet via an LTE lab network, where the uplink and downlink speeds of each device's connection were controlled.

Time-to-content for popular websites is – in many instances – determined by the performance of the mobile network

Two sets of measurements were performed. For the first set, the downlink speed was unrestricted while the uplink was set to a range of speeds by blocking LTE radio resources.

In the second set, the uplink speed was unrestricted, while the downlink was controlled in the same way.

A minimum uplink speed of about 300 kbps is required for a good time-to-content

The measurements showed that, with an unrestricted downlink (20 Mbps provided by the LTE lab network), an uplink of at least 300 kbps was required to consistently meet a target time-to-content of 4 seconds or less. On the other hand, with an unrestricted uplink (5 Mbps provided by the LTE lab network), there was a wide variation in how much downlink speed was required to render the content within the same 4 second target. In most cases, 1 Mbps was clearly insufficient, while time-to-content was reduced by 1 second or more as measurements were made at 3, 5 and even 20 Mbps in the downlink, depending on the website.

Target time-to-content not being met in live LTE networks

LTE network performance statistics from metropolitan areas around the world were analyzed. It was found that the probability of a smart device not getting an uplink speed of at least 300 kbps can be as high as 20 percent during peak hours. Given that good time-to-content requires a minimum uplink speed and a minimum downlink speed, the probability of not meeting a target time-to-content of four seconds is even higher.

In some metropolitan areas, there is up to a 20% chance of not getting a sufficient uplink speed during peak hours

Analyzing the network performance statistics also revealed the root causes for limited app coverage. When the uplink was the limiting factor, it was typically coverage-limited, and when the downlink was the bottleneck, it was typically capacity-limited.

A lack of capacity essentially means that the amount of information that can be transmitted per unit of time is limited, and a companion article[1] addresses downlink capacity bottlenecks.

A lack of uplink coverage indicates that a device is too far away to reach the serving radio base station with a sufficiently strong radio signal. The radio transmitter in a smart device can only transmit with a maximum power which is a fraction of the power available to the radio transmitter in a radio base station. Uplink coverage is a challenge both in rural areas and densely populated urban areas with high buildings. Mobile operators can address the lack of uplink coverage by densifying their network of radio base stations.

Network performance statistics can be used to monitor and manage app coverage. This is leading to more efficient ways of identifying bottlenecks and their root causes, enabling operators to target improvements where they matter the most to their subscribers. It is important that network performance statistics are continuously monitored for each radio network cell, as averaging across many cells or for long periods of time may hide where and when a mobile operator's app coverage target is not being met.

Uplink speed has been identified as a cause of slow time-to-content when rendering popular web pages. As web pages continue to grow richer and new apps such as live streaming become more popular, the demands on uplink are ever increasing.

[1] Ericsson Mobility Report, Managing User Experience (June 2016), pp. 26-27

LIVE STREAMING JOINS SOCIAL MEDIA

Consumers are increasingly using live video streaming apps to interact with friends, family and followers. Although live streaming has existed for some time in South Korea, there has been a recent surge in popularity for live video apps in markets like the US

Streaming apps focusing on user generated content (UGC), including Periscope and Bambuser, are being used by millennial power users and video-centric smartphone users in the US (see the box on the right for descriptions of user groups). In addition, smartphone users who are largely browser-centric or social-centric do find live streaming interesting and intend to use it going forwards. This is likely to drive overall video data traffic growth — both cellular and Wi-Fi— as consumers move beyond on-demand video to live streaming viewing behavior.

The inclusion of live streaming capabilities in social apps, such as Facebook and Twitter, is likely to make it easier for consumers to watch both user-generated and professionally made live video content. Based on consumer interest, the proportion of smartphone users in the US using live streaming apps is likely to triple in the coming year, while in South Korea it is likely to double.

Subsequently, this growth is likely to set new demands on network performance in order to offer consumers an optimal live video experience over mobile broadband networks.

User groups based on applications and services consumed via smartphones

Smartphone users can be segmented into six different groups based on the types of apps and services they use on their phones and how often they use them. Power users consume twice as much data on average per month than other smartphone users.

POWER USERS
Daily users of at least nine services

VIDEO-CENTRIC USERS
Users streaming videos on a daily basis

SOCIAL MEDIA-CENTRIC USERS
Users who access social networks on a weekly basis or more and instant messaging on a daily basis

BROWSER-CENTRIC USERS
Users who browse the internet at least weekly

UTILITY USERS
Weekly users of utility applications such as email, voice calls and internet calls

LIGHT DATA USERS
Users who don't access nine or more services on a daily basis

Source: Ericsson ConsumerLab

Moving beyond on demand

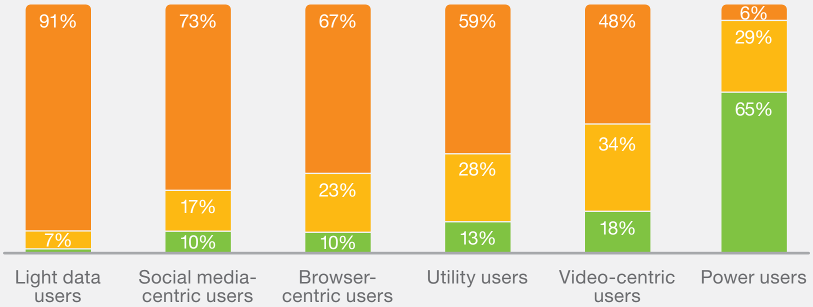
YouTube still dominates video traffic in most mobile networks, accounting for between 40–70 percent of total video traffic for almost all measured networks – regardless of terminal type. For smartphones, social networking is the second largest traffic volume contributor, with an average share of 15 percent in measured networks. Video traffic is likely to further increase as new apps with embedded live streaming emerge.

South Korea is arguably a leader in live streaming. For example, AfreecaTV is a popular app in the country, which allows anyone to freely broadcast live video.

While live streaming has been a success in South Korea, the global market is fragmented due to different content preferences and emerging trends. According to Ericsson ConsumerLab analysis of App Annie data, South Koreans watched more than 13 hours of live video broadcast over AfreecaTV in August 2016 – averaging 115 app sessions a month. In comparison, US smartphone users spent an average of around 1.5 hours using Periscope via Android smartphones over the same period. The differences in live video viewing behavior are also visible by age groups. In the US, 1 in 5 millennial smartphone users (age 20–34) has watched live UGC using apps, while only 1 in 10 teens (age 15–19) has done so. This is not to say that teens aren't interested in live streaming; in the US they spend, on average, around one hour a week watching live eSports content on apps like Twitch.[1]

[1] Ericsson ConsumerLab, TV and Media Study (2016)

Usage of live streaming apps by user groups in the US (percent)



Source: Ericsson ConsumerLab, Experience Shapes Mobile Consumer Loyalty study (2016)
Base: Smartphone mobile broadband users

In the US, power users are the predominant users of live streaming apps

- Don't do this and not interested in starting to use soon
- Don't do this but interested in starting to use soon
- Already do this

Conversely, in South Korea, UGC live video streaming is well established with both teens and older generations of smartphones users. This is evidenced by the fact that 33 percent of teens and 28 percent of those aged over 45 have used UGC live video streaming apps.

Live streaming is set to go mainstream

In the US, 7 percent of all smartphone users are power users, while browser-centric and social media-centric users constitute 22 and 25 percent respectively. Today, 65 percent of all power users in the US have used live streaming apps such as Periscope, while only 10 percent of social media-centric and browser-centric users claim they use such apps. This can be compared with South Korea, where live streaming has existed for some time and the usage of live streaming apps has moved beyond power users, with 26 percent of social media-centric and an equal share of browser-centric users engaged in live streaming.

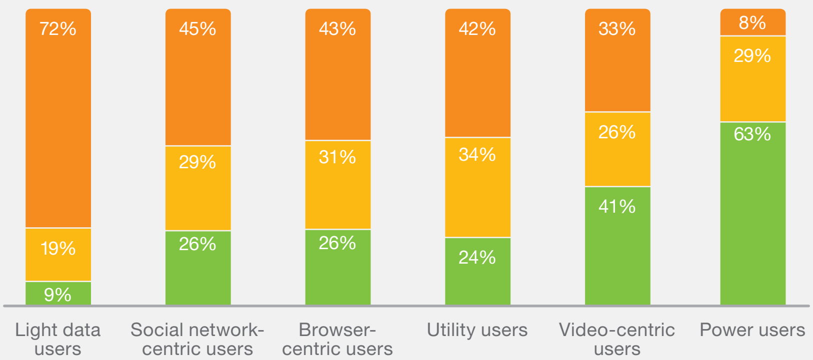
One of the reasons for the slow uptake of live streaming in markets beyond South Korea is that the number of people and brands creating live videos is still a small fraction of those who are watching.

Facebook Live is now available to the social network's 1.6 billion plus users and, as a result, a lot more consumers are likely to start streaming their activities live. One third of Facebook users on smartphones across 14 markets claim that they have watched a live video of a celebrity, politician or other influencer over the Facebook app before Facebook Live was launched to all users globally in April 2016.

Based on inclusion of live video streaming capabilities in social apps, the proportion of social media-centric and browser-centric users using live streaming apps is likely to double. Overall, the proportion of smartphone users accessing live video apps is likely to triple in the US, driving growth in wireless data traffic that is both cellular and Wi-Fi.

Around one in five smartphone users in the US expresses an interest in live video broadcast,[2] but there are twice as many smartphone users in high growth markets like India, Indonesia, Brazil and Oman who are interested in such apps. This indicates that, over the next 12 months, there will be a bigger appetite for live video streaming beyond the US.

Usage of live streaming apps by user groups in South Korea (percent)



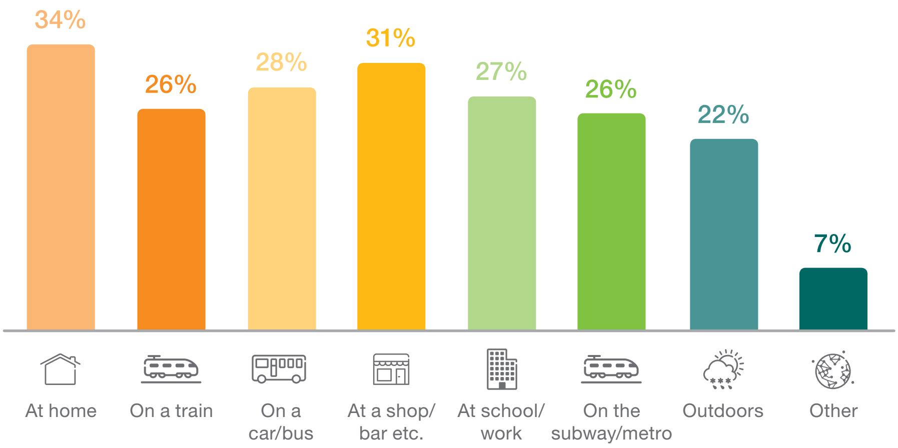
Source: Ericsson ConsumerLab, Experience Shapes Mobile Consumer Loyalty study (2016)
Base: Smartphone mobile broadband users

In South Korea usage of live streaming apps is more widespread

- Don't do this and not interested in starting to use soon
- Don't do this but interested in starting to use soon
- Already do this

[2] Ericsson ConsumerLab, Experience Shapes Mobile Consumer Loyalty study (2016)

Users who experience streaming issues while using video apps on a mobile broadband network in different locations (percent)



Source: Ericsson ConsumerLab, Experience Shapes Mobile Customer Loyalty (2016)
Base: Smartphone mobile broadband users accessing video apps across 14 markets

Users are experiencing streaming issues with videos on apps in a range of locations

Creating a high-definition video experience

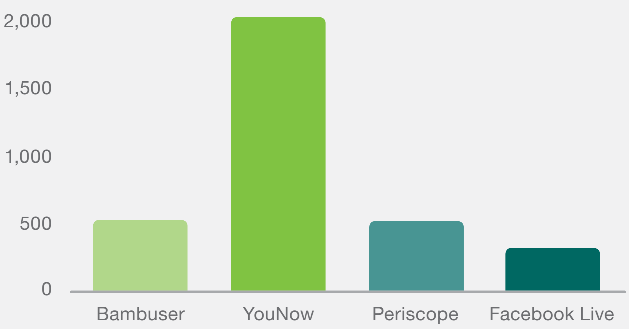
Consumers expect consistent high-quality network performance to stream videos. Research across 14 markets revealed that video streaming issues are common, including delays in loading and re-buffering.[3] Roughly one in every 5 smartphone users surveyed across the 14 markets globally faces video streaming issues on a daily basis.

Live video streaming has changed the way people interact with one another and experience live events, such as football games and concerts. A survey of 800 smartphone users attending the 2016 summer games in Rio de Janeiro found that one third engaged in broadcasting live video at least once, before, during, or right after an event.[4] Live streaming apps are also transforming citizen journalism by making it accessible to anyone with a smartphone, ushering in the potential future of real-time journalism.

Developments in live video streaming have raised consumer expectations of network performance when out and about. The figure above suggests that 22 percent of smartphone users across the 14 markets face video streaming issues while outdoors – irrespective of whether these are on-demand video streaming apps or live streaming apps like Periscope, Bambuser or AfreecaTV. It also shows that 34 percent face the same issues using these apps over mobile broadband while at home. Given the highly mobile video viewing behavior spread throughout the day, this indicates that improving the video streaming experience is crucial, and should result in wider adoption of live streaming apps and an increased demand for cellular data connectivity.

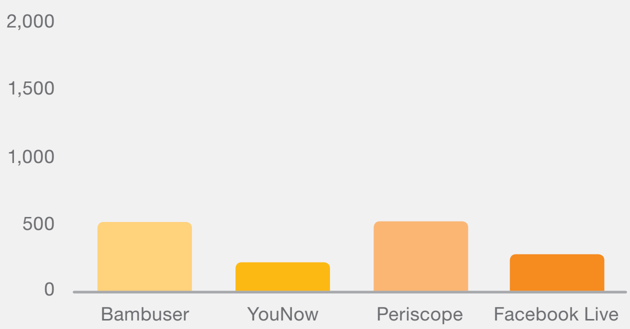
The figures below indicate the minimum data throughput necessary – both uplink and downlink – for an acceptable live streaming experience using various popular apps. YouNow Live stands out because it needs 2 Mbps in the uplink, which is perhaps related to its affiliation with professional content broadcasters, such as The Huffington Post, MTV and the Shorty Awards. While live streaming is currently a very small proportion of total traffic, as it grows it will set more stringent requirements on network performance.

Minimum bit-rate required to broadcast video in uplink (kbps)



Source: Ericsson Smartphone Lab

Minimum bit-rate required to watch video in downlink (kbps)



Source: Ericsson Smartphone Lab

[3] Ericsson ConsumerLab, Experience Shapes Mobile Customer Loyalty (2016)
[4] Ericsson ConsumerLab, Aiming Higher, summer games (2016)

INTERNET OF THINGS

ENABLER OF DIGITAL BUSINESS TRANSFORMATION

Developing a digital transformation strategy has become an increasingly important task for many companies, particularly as new consumer behavior demands new digitized offerings

There are several factors driving digital transformation among industries, from identifying new growth opportunities and improving cost efficiency to enhancing customer experience via new offerings. For mobile operators, a digital transformation will allow them to benefit from these opportunities and – through engaging in new business models and developing the required skills to compete in the market – gain a share of the incremental revenues.

IoT presents new opportunities for mobile operators to leverage their core assets and move up the value chain. Telia and Telenor Connexion are examples of operators that are already adding IoT value beyond connectivity by providing intelligent platforms, facilitating ecosystem collaboration, and even becoming a transformation partner to other industries.

In this IoT in Focus section, three articles provide different perspectives on the evolving IoT and its transformational potential.

DIGITAL TRANSFORMATION AND THE CONNECTED CAR

Connected cars have been available for a number of years, but mainly as new cars in the premium segment. Now, Swedish telecom operator Telia aims to connect cars up to 15 years old with a cloud-based solution. This exemplifies the opportunity for an operator to expand from data connectivity to offering smart data to an ecosystem of partners – creating innovative service offerings for car owners

Telia's ambition is to transform into a new generation telco, where applications and customer solutions have an important complementary role to traditional network services. Their connected car offering, Telia Sense, is central to this solution. According to Telia's research, simplifying ownership is a main concern for car owners, and connectivity can deliver on this requirement. However, the value of owning a connected car goes beyond connectivity, as it can be linked to an ecosystem of services relevant to car ownership.

Telia Sense

Telia Sense is an end-to-end, cloud-based solution that enables owners of both old and new cars to connect to the internet and access smart services. It consists of a telematics unit with a SIM-card that is plugged into the car's OBD-II port (on-board-diagnostics).

The unit communicates with a cloud-based platform over LTE and connects to an app in the car owner's smartphone. It also contains GPS, accelerometer, gyroscope, Wi-Fi hot spot and Bluetooth. Third party service providers can connect their services via an API and receive data from the car, if approved by its owner, enabling them to develop new service offerings.

The solution has been developed in cooperation with partners from the automotive and insurance industries, offering a combination of car-control functionalities, Wi-Fi connectivity and value added services like tailored car insurance.

Factors driving consumer interest in connected cars

A survey revealed that enhancing the car ownership experience is the main reason cited for owning a connected car, with cost reduction, increased control and safety, and greater convenience also cited as major factors. Car owners interact with their car in many different ways, which presents opportunities to offer a variety of services at different points in time.

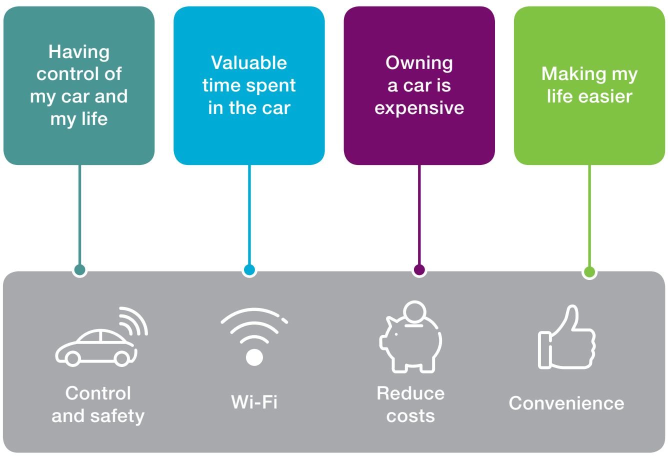
Consumers also want more value from their cars. Another survey of car owners indicated that interest can be divided into three areas: connectivity, car control and offerings from service partners.

Telia Company

This article was made in cooperation with Telia Company Global IoT Solutions: a global unit in the Telia Company group, responsible for business-critical IoT solutions and applications.

Telia Company provides network access and telecommunication services in the Nordic and Baltic countries, parts of Eurasia and in Spain.

Main factors driving consumer interest in connected cars



Source: Telia, in-depth-interviews with car owners (2015)

Digitalization of ecosystem partners

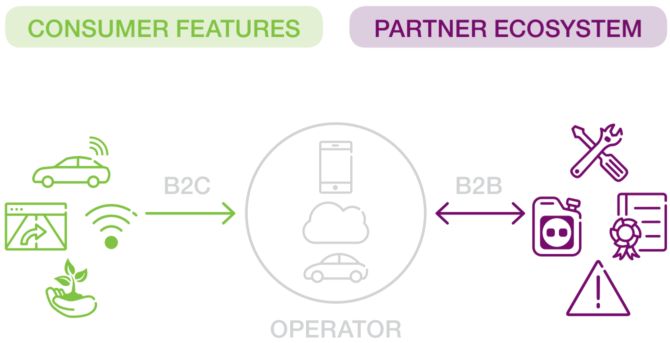
Ecosystem partners can reach drivers and passengers with new services and information, building on customer relationships and increasing their brand value. This is exemplified in the Telia Sense case with the objectives of initial partners, such as Bilprovningen, Bilia and Viking.

Consumers who were very interested/interested in feature

Feature	Percent	Category
Car Wi-Fi*	62%	Wi-Fi hotspot
Tampering alarm	76%	Car control
Find my car and position alarm	65%	Car control
Car info dashboard	57%	Car control
Drivers' journal	50%	Car control
Alerts and warnings	71%	Car control
Vehicle inspection	37%	Service partners
Car service	39%	Service partners

*Including 20 GB/month and data top-up possibilities
Source: Telia
Base: 502 respondents with driving licenses and access to a car, aged 18-65 in Sweden (2016)

Two-sided business model addressing both B2C and B2B revenue streams



B2C REVENUE STREAMS

- Hardware purchase
- Monthly connection fee

B2B REVENUE STREAMS

- Set-up fee
- Monthly fee per connected car or event

Source: Telia (2016)

Pay-how-you-drive offerings

Folksam[1] considers digital transformation to be an important focus area for the company going forward. A usage-based insurance offering is one example of how digitalization can enable new opportunities.

Folksam has created an offering called "Köra Säkert" (Safe Driving) to incentivize customers to drive more safely. This offering is based on a pay-how-you-drive concept, where the customer can influence their car insurance premium.

When signing up for the service, the customer receives a small LED indicator that can be mounted on the car's dashboard to inform the driver if they are speeding. A red, yellow or green light provides feedback to the driver on whether they are sticking to the speed limit or not. This indicator communicates with the telematics unit, and an app provides feedback that can encourage safer and more environmentally-friendly driving.

The long-term goal is to save lives and reduce the number of traffic accidents; the incentive could also result in a discount of up to 20 percent on drivers' insurance premiums.

Proactive servicing

Another possibility enabled by digitalization is proactive servicing. Auto inspection company, Bilprovningen, is aiming to enhance the customer relationship through providing proactive services, such as reminders of inspection times, as well as alerts relevant to car owners.

Automotive service company, Bilia, also aims to provide service offerings like car diagnostics and proactive car maintenance, as well as tailored customer offerings and promotions.

Road assistance company, Viking, sees opportunities for a deeper and proactive customer relationship with improved service offerings enabled by digitalization.

Value creation: an evolving two-sided business model

Many mobile operators have already built IoT solutions around their core assets, such as network connectivity and experience of aggregating, analyzing and acting on network and user data. In the Telia Sense case, connectivity is provided by an LTE network, which delivers app coverage for mobile broadband and supports IoT services. Another asset is the platform's capability to refine data and turn bulk data into smart data, which allows third party service providers to utilize the information.

The business model is twofold: B2C revenue streams are based on a one-time cost for the telematics unit, and a monthly fee for the connectivity and car control service, whereas the B2B revenue streams are from ecosystem partners; including a set-up fee for the service and a monthly fee per connected car or event. The size of the B2B revenue is based on the value of the refined data from the platform, which varies for different businesses. This value is leveraged by two interrelated factors: the local market knowledge of the B2B partners and the continuous refinement of the offerings enabled by analyzing the flow of data.

IoT presents new opportunities for mobile operators to leverage their core assets and move up the value chain, through providing intelligent platforms, facilitating ecosystem collaboration and becoming a transformation partner to other industries.

[1] Folksam is a customer-owned mutual insurance company in Sweden

ANALYZING IOT DEVICE PERFORMANCE

A small number of poorly configured connected devices can cause a signaling storm, degrading an IoT network's performance and, in the worst case, resulting in a network blackout. Telenor Connexion has combined real-time traffic monitoring with data analytics for IoT devices and networks to reduce the risk of signaling congestion and improve operational performance

Source: Telenor Connexion

telenor | connexion

This article was made in cooperation with Telenor Connexion.

With more than 15 years of experience in machine-type communications, the company has been a pioneer in the IoT space. Telenor Connexion is wholly owned by the Telenor Group, one of the world's major mobile operators.

Across the globe, a multitude of different IoT devices are being deployed and connected by mobile networks. Signaling storms triggered by aggressive connected devices negatively affect IoT network congestion and performance. To avoid this, control plane data from devices, as well as the networks they connect to, needs to be monitored, analyzed and managed in real-time. Improving reliability is also a pre-requisite to enable collection, processing and analytics of user plane data generated by connected devices.

Advanced Real-time troubleshooting Tool Set (ARTS)

ARTS is a cloud-based network connectivity analytics tool designed specifically for connected IoT devices. It can be accessed via a web interface by an enterprise customer support or operations team, providing real-time insights into the performance of IoT devices and networks based on big data analytics techniques and domain-centric data models. It also offers predictive analysis, identifying potential problems, based on patterns of network behavior to allow for faster and more efficient decision making.

As few as 500 aggressive devices can create a network signaling storm, which can cause congestion

A small number of devices can create significant network problems

The Telenor Connexion-managed base of connected devices (SIM based) has increased at a compound annual growth rate (CAGR) of more than 50 percent over the last 7 years. Presently, the total installed base is around 6 million connected devices, with the majority of traffic transmitted over GPRS and SMS.

In 2014, Telenor Connexion experienced occasions of network degradation caused by a limited number of connected devices. This prompted the company to investigate how their customers' devices were behaving in the mobile networks. It was found that as few as 500 aggressive devices can create a network signaling storm, which can cause congestion. In fact, some customer devices generated more than 100 network events per hour – 5 times the acceptable limit of around 20 network events per hour. Such aggressive signaling behavior can quickly develop into a situation where one congested network starts affecting other networks.

To address this issue, IoT operators need to work closely with roaming operators to shut down or redirect control plane messages for all IoT roaming devices. This impacts all IoT customers, as the whole roaming network range is blocked. Once a network is fully congested, it can take up to two hours to completely re-route roaming IoT devices, and then another two hours for network operations to normalize. For roaming operators, this can negatively affect consumer traffic and customer experience, resulting in negative brand impact.

A selection of monitored IoT traffic activity and network KPIs in a customer IoT network (October 16-18, 2016)

Source: Telenor Connexion (October 2016)

Using big data analytics to avoid network congestion

By collecting and analyzing every network event that an IoT device generates, it is possible to identify aggressive device behavior. Taking the appropriate action to avoid signaling storms then ensures network performance meets service level agreements.

One example of aggressive behavior is when a device attempts to attach to a network and doesn't succeed, and then immediately tries again a number of times in rapid succession. This generates a stream of signaling data that, collectively with similar devices also generating more signaling than usual, overloads the signaling network. Identifying this behavior, and then re-configuring the devices to double the time between each successive attempt to attach to the network, gives network operators time to recognize the situation and address the root cause, thus avoiding network congestion.

Additionally, traffic from connected devices can be migrated into different networks in order to avoid overloading a specific network. For example, some customers have devices in multiple networks in multiple countries; in these circumstances, the SIM in the connected devices can be configured to attach to a specific network in a country based on network performance analysis.

Monitoring IoT network KPIs

The figure shows a selection of network KPIs for the period October 16-18, 2016: the green histograms represent traffic activity, and the red histograms identify corresponding success rate KPIs for SMS and PDP (i.e. the ability of the IoT devices to establish a dedicated data bearer). The histogram on the top left demonstrates that, in this specific customer case, average network activity exhibited a range of three to six network transactions per hour per IoT device (base to peak). In the middle graph, the blue line indicates that the average data volume per IoT device had peak values slightly over 30 KB per hour, with a total of 24 GB per hour of data consumed by all IoT devices between 9 a.m. and 12 noon on October 17. During that same time period, SMS activity was averaging around 3 SMS per hour per IoT device, with total SMS traffic around 50,000 SMS per hour.

As such, the histograms provide an overview of IoT network activity and success rates, making it easy to spot any deviating changes over the 48-hour time span displayed.

Predictive analysis by applying big data analytics

An automatic reporting system monitors the traffic from all customers and generates a bandwidth forecast for the coming six months up to one year. The dimensioning forecast for both signaling traffic in the control plane and payload traffic in the user plane becomes increasingly accurate based on these reports, ensuring that customers avoid network congestion problems.

Applying data analytics to control plane data in networks of connected devices can bring a number of benefits to network operators and enterprises. The threat from IoT devices spamming networks with signaling traffic has been reduced, as a result of insights into which parts of the networks need to be improved. Based on those insights, fair network use policies that detail acceptable device signaling behavior can be implemented. During the past 2 years, the number of potentially aggressive customer devices in IoT networks managed by Telenor Connexion has reduced from 38 percent to 16 percent.[1] This is thanks to a combined knowledge of how the IoT devices perform in the network and implementation of connection efficiency guidelines. In addition, through predictive analytics capabilities, a very high degree of accuracy in bandwidth dimensioning forecast is achieved for both control plane and user plane traffic, enabling improved resource planning.

[1] The remaining 16 percent are distributed over several networks and not posing an immediate threat

MASSIVE IOT IN THE CITY

Cost-effective connectivity is a prime driver for IoT services uptake. Cellular networks are well-suited to enable this due to their ubiquitous deployments worldwide and the ease with which they can be upgraded to handle many potential IoT use cases. Additionally, cellular networks can handle traffic from a massive number of IoT devices in dense urban environments with minimal network capacity impact

IoT can be segmented into critical and massive applications. Critical IoT applications have stringent requirements on availability, delay and reliability; examples include traffic safety, automated vehicles, industrial applications and remote surgery in healthcare.

Massive IoT, on the other hand, is characterized by a very large number of connections, small data volumes, low-cost devices and stringent requirements on energy consumption; examples include smart buildings, smart metering, transport logistics, fleet management, industrial monitoring and agriculture.

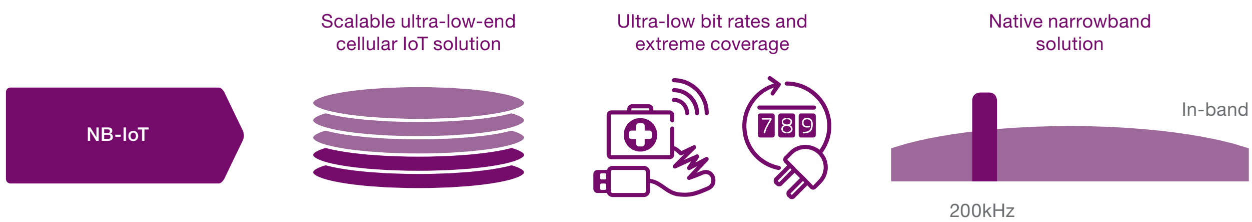
Complementary IoT technologies

These two segments represent a vast range of use cases with varying connectivity requirements. Cellular networks are suitable to support both segments, although no single technology is suited for all potential scenarios. To meet the use case requirements of different potential massive IoT applications, several cellular IoT technologies are being standardized, including Extended Coverage-GSM-IoT (EC-GSM IoT), Cat-M1 and Narrow Band-IoT (NB-IoT). These solutions can complement one another depending on technology availability, use case requirements and deployment scenarios. For instance, EC-GSM serves applications for all GSM markets, Cat-M1 supports a wide range of IoT applications, including content-rich ones, and NB-IoT is streamlined for ultra-low throughput applications and offers excellent coverage and deployment flexibility. Whether operators choose one or a combination of these solutions will depend on several factors, such as technology coverage, network technology strategies and targeted market segments.

Ultra-low-end massive IoT applications

To examine the capability of cellular networks to carry IoT traffic, knowledge about real IoT services scenarios and their network impact is important. Our scenario includes a traffic model consisting of a range of different IoT services, and includes assumptions on message size and traffic intensity per device, as well as the number of devices deployed in a dense urban environment. It focuses on ultra-low-end IoT applications with limited demands on throughput, such as metering and monitoring use cases, as these are expected to be the first massive IoT services deployed in many markets.

NB-IoT: tailored for ultra-low-end IoT applications



Traffic characteristics of deployed massive IoT connected devices in a city scenario

	WATER METERS	ELECTRICITY METERS	GAS METERS	VENDING MACHINES	BIKE FLEET MANAGEMENT	PAY-AS-YOU-DRIVE
Typical message size	100 bytes	100 bytes	100 bytes	150 bytes	150 bytes	150 bytes
Message interval	12 hours	24 hours	30 minutes	24 hours	30 minutes	10 minutes
Device density	10,000/km^2	10,000/km^2	10,000/km^2	150/km^2	200/km^2	2,250/km^2

Massive IoT traffic scenario

A dense urban environment with 10,000 households per km^2 – similar to the central area of London, Beijing or New York – was used as the base for a massive IoT services scenario. A selection of connected device types were assumed to be deployed in the area, including water, gas and electricity meters, vending machines, rental bike position monitors and accelerometers in cars[1] monitoring driver behavior. Traffic characteristics for each device are summarized in the diagram above.[2] The number of connected devices used in this scenario represents a mature, large scale massive IoT scenario. During an initial rollout phase device densities will be lower and the corresponding traffic load will not be as high.

The services represent a realistic range of massive IoT use cases that are expected to be deployed in an urban environment.[3]

Deployment environment and traffic models differ for these services: a remote-controlled meter may face an indoor coverage challenge, while a device mounted on a bike is usually found outside. The traffic intensity from meters may be once per day, whereas other devices may need to transmit every 10 minutes.

The data traffic for massive IoT devices is small; the typical data packet for a service is about 100-150 bytes, accounting for a payload of the device ID, time stamp and report data values.

Additionally, each packet has IP overhead and higher layer headers of around 65 bytes; the Media Access Control (MAC) layer overhead is 15 bytes, and standard control signaling within the mobile network is 59 bytes per event for uplink. In total, each event generates around 250-300 bytes to be transmitted by the IoT device.

The figure on the following page shows the resulting traffic demand. It clearly demonstrates that, despite the very high device density, the small traffic per device limits the traffic per area unit to a few kilobits per second (kbps) per km^2. As a comparison, mobile broadband traffic is approaching gigabit per second (Gbps) per km^2 in dense urban areas.

[1] Calculation based on an average of one car per household and every fourth in traffic
[2] In this scenario, the traffic is uplink dominated, as downlink traffic for application acknowledgement (ACK) and control plane signaling (RRC) between the device and the radio access network is comparably small
[3] Orange, Ericsson, "Traffic Model for legacy GPRS MTC" (February 15-19, 2016), document GP 160060, 3GPP GERAN meeting #69

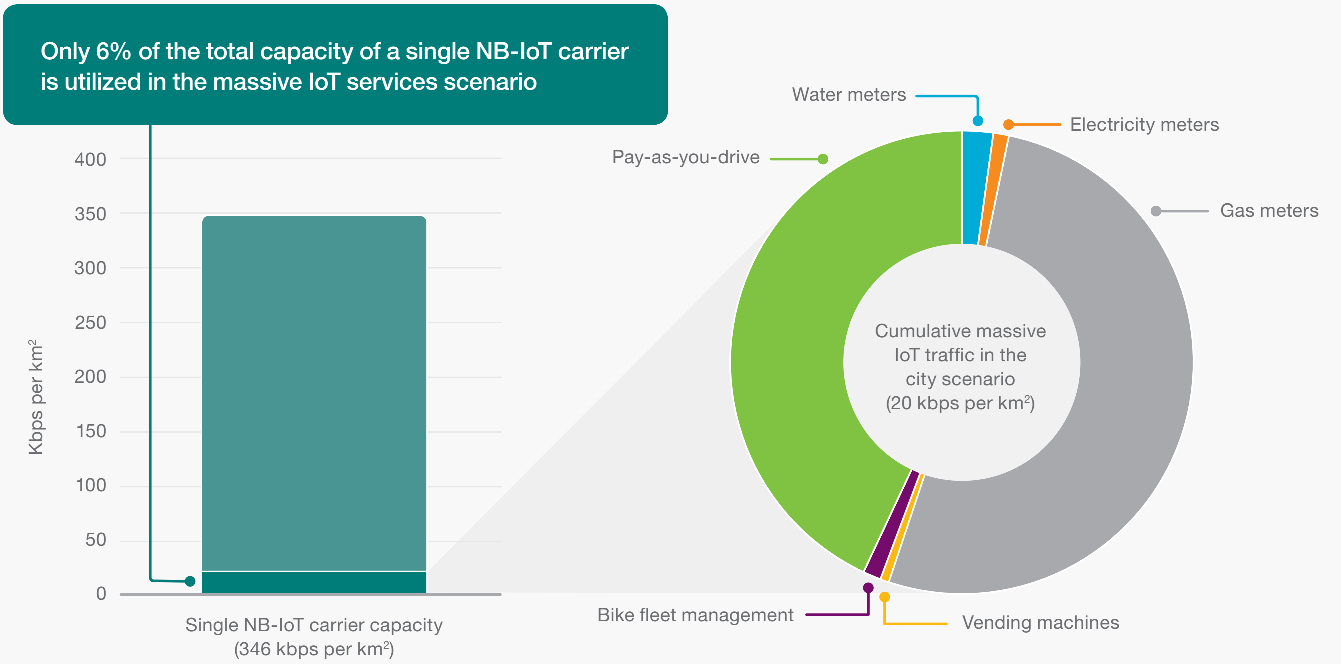
Deployment of a NB-IoT carrier for a massive IoT services scenario

NB-IoT is tailored for ultra-low-end IoT applications. The highest instantaneous data rate that a base station can communicate with a device is 227/250 kbps in downlink/uplink, while the sustained maximum throughput per device is 21/63 kbps. This is sufficient for supporting the services featured in the city scenario. Although its capacity is lower than that for mobile broadband, system level simulations show that one 180 kHz NB-IoT carrier can carry tens of kbps – depending on carrier configuration. Assuming that a single NB-IoT carrier is deployed on 3 sector sites, with a typical inter-site distance of 500 meters for an urban environment, an area capacity of hundreds of kbps per km^2 is achieved. This is much larger than the massive IoT services traffic demand in our dense urban city scenario.

The figure below illustrates the cumulative massive IoT traffic versus the capacity of a single NB-IoT carrier in our city scenario. The aggregate traffic from all the massive IoT services adds up to about 6 percent of the total available capacity, indicating that a 15-fold increase in massive IoT traffic volume over the considered scenario could be supported before another NB-IoT carrier is needed. As a side note, Cat-M1 supports even higher data rates and capacity than NB-IoT.

In addition to the capacity required for the traffic, coverage for reaching devices in challenging positions is necessary. For this reason, NB-IoT and Cat-M1 are designed to provide significantly better coverage than GSM and LTE. This improved coverage allows the radio signal to penetrate an additional couple of walls, or an Infrared Reflective (IRR) metalized glass window. Devices deployed deep indoors or in basements – typical locations for meters – can be reached.

Traffic versus capacity of a single NB-IoT carrier



Enabling business opportunities

Cellular networks can handle a large number of massive IoT devices with minimal network capacity impact. Our scenario shows that a single NB-IoT carrier – deployed in a guard band or in-band occupying around 2 percent of a 10 MHz LTE carrier – significantly exceeds the needs of the considered massive IoT services. These findings imply that an initial NB-IoT deployment will also be able to support other types of services, with potentially higher data demand and traffic intensity.

Generally, the effort for an operator to upgrade an existing network to support IoT traffic may be small, but the potential value it could generate is significant. Providing connectivity to tens of thousands of IoT devices from a single base station is an essential enabler for new business opportunities.

INTERNET OF THINGS OUTLOOK

Growth in the number of connected devices is driven by emerging applications and business models, and supported by standardization and falling device costs

Around 29 billion connected devices[1] are forecast by 2022, of which around 18 billion will be related to IoT.

In 2018, mobile phones are expected to be surpassed in numbers by IoT devices, which include connected cars, machines, meters, wearables and other consumer electronics. Between 2016 and 2022, IoT devices are expected to increase at a CAGR of 21 percent, driven by new use cases.

70% of wide-area IoT devices will use cellular technology in 2022

IoT device connections

In the figure below illustrating all connected devices, IoT is divided into short-range and wide-area segments.

The short-range segment consists of devices connected by unlicensed radio with a typical range of up to around 100 meters, such as Wi-Fi, Bluetooth and ZigBee. This category also includes devices connected over fixed line local area connections.

The wide-area category consists of devices using cellular connections (3GPP-based with some CDMA), as well as unlicensed low-power technologies, such as Sigfox, LoRa and Ingenu.

1.5 billion IoT devices with cellular connections by 2022

There will be around 400 million IoT devices with cellular connections at the end of 2016 and that number is projected to reach 1.5 billion in 2022, or around 70 percent of the wide-area category. This growth is due to increased industry focus and 3GPP standardization of cellular IoT technologies. Cellular IoT connections benefit from enhancements in provisioning, device management, service enablement and security.

Within the wide-area IoT segment, two distinct sub-segments with different requirements have emerged: massive and critical applications.

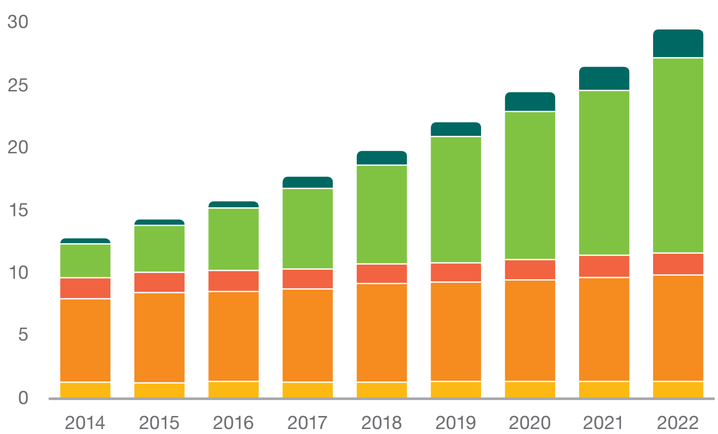
Massive IoT connections are characterized by high connection volumes and small data traffic volumes, low cost devices and low energy consumption. Many things will be connected through capillary networks.[2]

At the other end of the scale, critical IoT connections place very different demands on the network: ultra-reliability, availability, low latency and high data throughput.

There are, however, many use cases between these two extremes, which today rely on 2G, 3G or 4G connectivity.

Today, LTE's share of cellular IoT devices is around 5 percent. Declining modem costs, evolving LTE functionality and 5G capabilities are all expected to extend the range of applications for critical IoT deployments.

Connected devices (billions)



	2016	2022	CAGR
Wide-area IoT	0.4	2.1	30%
Short-range IoT	5.2	16	20%
PC/laptop/tablet	1.6	1.7	0%
Mobile phones	7.3	8.6	3%
Fixed phones	1.4	1.3	0%
	16 billion	29 billion	10%

[1] In our forecast a connected device is a physical object that has an IP stack, enabling two-way communication over a network interface. Traditional landline phones are included for legacy reasons
[2] Connected devices connecting to a wide-area network through a common gateway

METHODOLOGY

Forecast methodology

Ericsson performs forecasts on a regular basis to support internal decisions and planning, as well as market communication. The subscription and traffic forecast baseline in this report uses historical data from various sources, validated with Ericsson internal data, including extensive measurements in customer networks. Future development is estimated based on macroeconomic trends, user trends (researched by Ericsson ConsumerLab), market maturity, technology development expectations and documents such as industry analyst reports, on a national or regional level, together with internal assumptions and analysis. Historical data may be revised if the underlying data changes – for example, if operators report updated subscription figures.

Mobile subscriptions include all mobile technologies. Subscriptions are defined by the most advanced technology that the mobile phone and network are capable of. Figures are rounded and hence summing up rounded data may result in slight differences from the actual total.

Traffic refers to aggregated traffic in mobile access networks and does not include DVB-H, Wi-Fi or Mobile WiMAX traffic. VoIP is included in data traffic.

Traffic measurements

New devices and applications affect mobile networks. Having a deep and up-to-date knowledge of the traffic characteristics of different devices and applications is important when designing, testing and managing mobile networks. Ericsson regularly performs traffic measurements in over 100 live networks in all major regions of the world. Detailed measurements are made in a selected number of commercial WCDMA/HSPA and LTE networks with the purpose of discovering different traffic patterns. All subscriber data is made anonymous before it reaches Ericsson's analysts.

To find out more, scan the QR code, or visit www.ericsson.com/mobility-report

You may use charts generated from the Ericsson Traffic Exploration Tool in your own publication as long as Ericsson is stated as the source

There you will also be able to access regional appendices

GLOSSARY

2G: 2nd generation mobile networks (GSM, CDMA 1x)
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)
5G: 5th generation mobile networks (not yet standardized)
CAGR: Compound Annual Growth Rate
CDMA: Code Division Multiple Access
DL: Downlink
EB: ExaByte, 10^{18} bytes
EDGE: Enhanced Data Rates for Global Evolution
EPC: Evolved Packet Core
EVS: Enhanced Voice Services
FDD: Frequency Division Duplex
GB: GigaByte, 10^9 bytes
GHz: Gigahertz
Gpbs: Gigabits per second
GSA: Global Supplier Association
GSM: Global System for Mobile Communications
GSMA: GSM Association
HSPA: High Speed Packet Access
ICT: Information and Communications Technology
IMS: IP Multimedia Subsystem
ITU: International Telecommunication Union
IoT: Internet of Things
kbps: kilobits per second
LTE: Long-Term Evolution
MB: MegaByte, 10^6 bytes
MBB: Mobile Broadband (defined as CDMA2000 EV-DO, HSPA, LTE, Mobile WiMax and TD-SCDMA)
Mbps: Megabits per second
MIMO: Multiple Input Multiple Output
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: Narrowband IoT, new narrowband radio technology being standardized in 3GPP
NFV: Network Functions Virtualization
OS: Operating System
PB: PetaByte 10^{15} bytes
QAM: Quadrature Amplitude Modulation
RCS: Rich Communication Services
SDM: Subscriber Data Management
Smartphone: Mobile phones with open OS, e.g. iPhones, Android OS phones, Windows phones but 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
UL: Uplink
WCDMA: Wideband Code Division Multiple Access

Ericsson is the driving force behind the Networked Society – a world leader in communications technology and services. Our long-term relationships with every major telecom operator in the world allow people, business and society to fulfill their potential and create a more sustainable future.

Our services, software and infrastructure – especially in mobility, broadband and the cloud – are enabling the telecom industry and other sectors to do better business, increase efficiency, improve the user experience and capture new opportunities.

With approximately 115,000 professionals and customers in 180 countries, we combine global scale with technology and services leadership. We support networks that connect more than 2.5 billion subscribers. Forty percent of the world's mobile traffic is carried over Ericsson networks. And our investments in research and development ensure that our solutions – and our customers – stay in front.

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