Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2017–2022

February, 2019

The Cisco® Visual Networking Index (VNI) Global Mobile Data Traffic Forecast Update is part of the comprehensive Cisco VNI Forecast, an ongoing initiative to track and forecast the impact of visual networking applications on global networks. This report presents some of the major global mobile data traffic projections and growth trends.

Executive Summary

The Mobile Network in 2017

Global mobile data traffic grew 71 percent in 2017. Global mobile data traffic reached 11.5 exabytes per month at the end of 2017, up from 6.7 exabytes per month at the end of 2016. (One exabyte is equivalent to one billion gigabytes, and one thousand petabytes.)

Mobile data traffic has grown 17-fold over the past 5 years. Mobile networks carried 686 petabytes per month in 2012.

Fourth-generation (4G) traffic accounted for 72% of mobile traffic in 2017. Although 4G connections represented only 35 percent of mobile connections in 2017, they already accounted for 72 percent of mobile data traffic, while 3G connections represented 30 percent of mobile connections and 21 percent of the traffic. In 2017, a 4G connection generated nearly three times more traffic on average than a 3G connection.

Mobile offload exceeded cellular traffic by a significant margin in 2017. Fifty-four percent of total mobile data traffic was offloaded onto the fixed network through Wi-Fi or femtocell in 2017. In total, 13.4 exabytes of mobile data traffic were offloaded onto the fixed network each month.

Nearly Six hundred and fifty million mobile devices and connections were added in 2017. Global mobile devices and connections in 2017 grew to 8.6 billion, up from 7.9 billion in 2016.

Globally, smart devices represented 53 percent of the total mobile devices and connections in 2017; they accounted for 92 percent of the mobile data traffic. (For the purposes of this study, "smart devices" refers to mobile connections that have advanced multimedia/computing capabilities with a minimum of 3G connectivity.) **In 2017, on an average, a smart device generated 10 times more traffic than a nonsmart device.**

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Mobile network (cellular) connection speeds grew 1.3-fold in 2017. Globally, the average mobile network downstream speed in 2017 was 8.7 Megabits per second (Mbps), up from 6.8 Mbps in 2016.

Mobile video traffic accounted for 59 percent of total mobile data traffic in 2017. Mobile video traffic now accounts for more than half of all mobile data traffic.

The top 1 percent of mobile data subscribers generated 6 percent of mobile data traffic, down from 52 percent in 2010. The top 20 percent of mobile users generated 62 percent of mobile data traffic.

Average smartphone usage grew 49 percent in 2017. The average amount of traffic per smartphone in 2017 was 2.3 GB per month, up from 1.6 GB per month in 2016.

Smartphones (including phablets) represented only 51 percent of total mobile devices and connections in 2017, but represented 88 percent of total mobile traffic. In 2017, the typical smartphone generated 47 times more mobile data traffic (2.3 GB per month) than the typical basic-feature cell phone (which generated only 50 MB per month of mobile data traffic).

Globally, there were 526 million wearable devices (a sub-segment of the machine-to-machine [M2M] category) in 2017. Of these, 19 million wearables had embedded cellular connections.

Per-user iOS mobile devices (smartphones and tablets) data usage surpassed that of Android mobile devices data usage. By the end of August 2018, average iOS consumption exceeded average Android consumption in North America, where iOS usage was 9.1 GB per month and Android was 8.6 GB per month.

In 2017, 47 percent of mobile devices were potentially IPv6-capable. This estimate is based on network connection speed and OS capability.

In 2017, the number of mobile-connected tablets increased 14% to 176 million, and the number of mobile-connected PCs increased 1% to 135 million. In 2017, the average mobile data traffic per PC/Tablet was 3.3 GB per month, compared to 2.3 GB per month per smartphone.

Average nonsmartphone usage increased to 50 MB per month in 2017, compared to 34 MB per month in 2016. Basic handsets still made up 40 percent of handsets on the network.

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The Mobile Network Through 2022

Mobile data traffic will reach the following milestones within the next 5 years:

- Monthly global mobile data traffic will be 77 exabytes by 2022, and annual traffic will reach almost one zettabyte.
- Mobile will represent 20 percent of total IP traffic by 2022.
- The number of mobile-connected devices per capita will reach 1.5 by 2022.
- The average global smartphone connection speed will surpass 40 Mbps by 2022.
- Smartphones will surpass 90 percent of mobile data traffic by 2022.
- 4G connections will have the highest share (54 percent) of total mobile connections by 2022.
- 4G traffic will be more than seven-tenths (71 percent) of the total mobile traffic by 2022.
- 5G traffic will be more than ten percent (12 percent) of the total mobile traffic by 2022.
- Nearly three-fifths of traffic (59 percent) will be offloaded from cellular networks (on to Wi-Fi) by 2022.
- Nearly four-fifths (79 percent) of the world's mobile data traffic will be video by 2022.

Global mobile data traffic will increase seven-fold between 2017 and 2022. Mobile data traffic will grow at a Compound Annual Growth Rate (CAGR) of 46 percent from 2017 to 2022, reaching 77.5 exabytes per month by 2022.

By 2022 there will be 1.5 mobile devices per capita. There will be 12.3 billion mobile-connected devices by 2022, including M2M modules—exceeding the world's projected population at that time (8 billion) by one and a half times.

Mobile network connection speeds will increase more than three-fold by 2022. The average mobile network connection speed (8.7 Mbps in 2017) will reach 28.5 Megabits per second (Mbps) by 2022.

By 2022, 4G will be 54 percent of connections, but 71 percent of total traffic. By 2022, a 4G connection will generate nearly twice as much traffic on average as a 3G connection.

By 2022, 5G will be 3.4 percent of connections but 11.8 percent of total traffic. By 2022, a 5G connection will generate 2.6 times more traffic than the average 4G connection.

By 2022, nearly three-quarters of all devices connected to the mobile network will be "smart" devices. Globally, 72.8 percent of mobile devices will be smart devices by 2022, up from 52.8 percent in 2017. The vast majority of mobile data traffic (99 percent) will originate from these smart devices by 2022, up from 92 percent in 2017.

By 2022, 76 percent of all global mobile devices could potentially be capable of connecting to an IPv6 mobile network. There will be 9.4 billion IPv6-capable devices by 2022.

Nearly four-fifths of the world's mobile data traffic will be video by 2022. Mobile video will increase 9-fold between 2017 and 2022, accounting for 79 percent of total mobile data traffic by the end of the forecast period.

By 2022, mobile-connected tablets and PCs will generate 6.8 GB of traffic per month on average, a doubling over the 2017 average of 3.3 GB per month. Aggregate traffic associated with PCs and tablets will be three and a half times greater than it is today, with a CAGR of 28 percent.

The average smartphone will generate 11 GB of traffic per month by 2022, more than a four and a half-fold increase over the 2017 average of 2 GB per month. By 2022, aggregate smartphone traffic will be seven times greater than it is today, with a CAGR of 48 percent.

By 2017, 59 percent of all traffic from mobile-connected devices (111 exabytes) will be offloaded to the fixed network by means of Wi-Fi devices and femtocells each month. Of all IP traffic (fixed and mobile) in 2022, 51% will be Wi-Fi, 29% will be wired, and 20% will be mobile.

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The Middle East and Africa will have the strongest mobile data traffic growth of any region with a 56 percent CAGR. This region will be followed by Asia Pacific at 49 percent and Latin America at 43 percent.

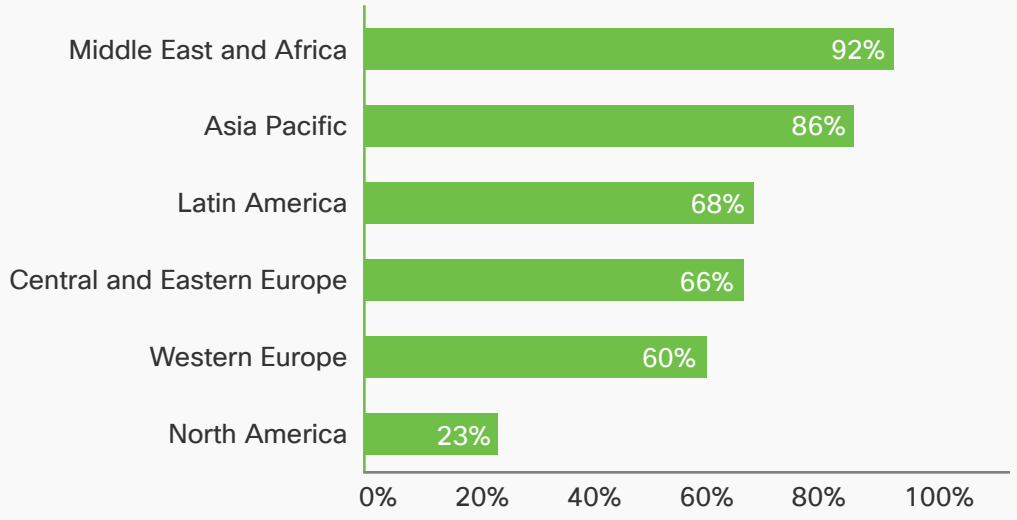
China's mobile traffic surpassed that of the United States by the end of 2017. China's mobile traffic reached nearly 2 exabytes per month by the end of 2017, and mobile traffic in the United States was 1.2 exabytes per month.

Appendix A summarizes the details and methodology of the VNI Mobile Forecast.

2017 Year in Review

Global mobile data traffic grew an estimated 71 percent Year over Year (YoY) in 2017. Growth rates varied widely by region, with Middle East and Africa having the highest growth rate (92 percent) followed by Asia Pacific (86 percent), Latin America (68 percent), and Central and Eastern Europe (66 percent). Western Europe grew at an estimated 60 percent, and North America trailed Western Europe at 23 percent growth in 2017 (refer to Figure 1). At the country level, China, France, and South Africa led global growth at 178, 149, and 98 percent, respectively. China along with Indonesia and India was among the top three countries that topped traffic growth in 2016, though in 2017 China's traffic growth accelerated.

Figure 1. Mobile Data Traffic Growth in 2017



Source: Cisco VNI Mobile, 2019

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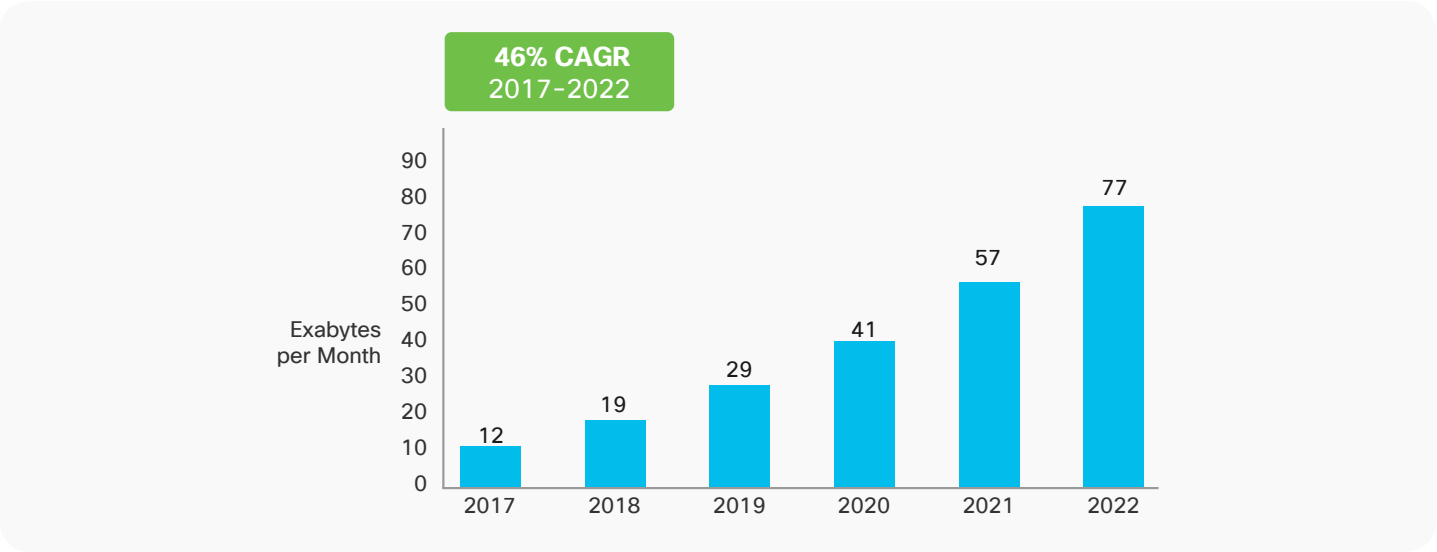
Global Mobile Data Traffic, 2017 to 2022

Overall mobile data traffic is expected to grow to 77 exabytes per month by 2022, a seven-fold increase over 2017. Mobile data traffic will grow at a CAGR of 46 percent from 2017 to 2022 (Figure 2).

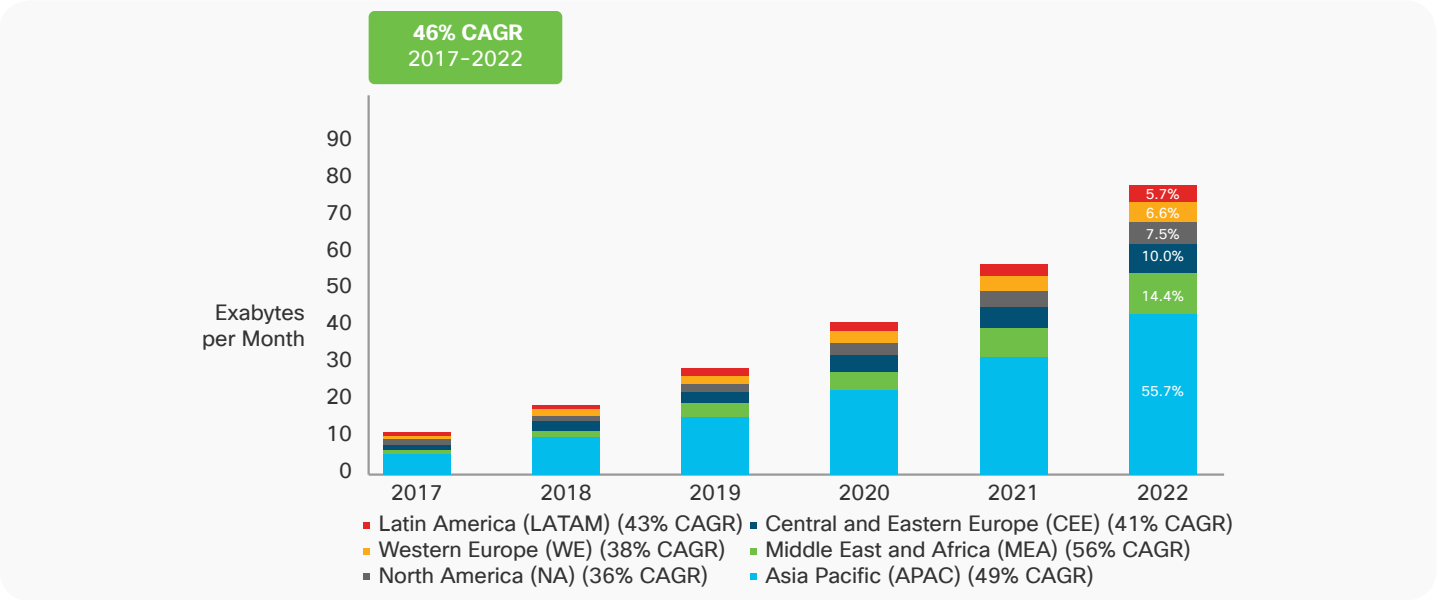
Figure 2. Cisco Forecasts 77 Exabytes per Month of Mobile Data Traffic by 2022



Source: Cisco VNI Mobile, 2019

Asia Pacific will account for 56 percent of global mobile traffic by 2022, the largest share of traffic by any region by a substantial margin, as shown in Figure 3. North America, once the region with largest traffic share, will have only the fourth-largest share by 2022, having been surpassed by Central and Eastern Europe and Middle East and Africa. Middle East and Africa will experience the highest CAGR of 56 percent, increasing 9-fold over the forecast period. Asia Pacific will have the second-highest CAGR of 49 percent, increasing 7-fold over the forecast period (Figure 3).

Figure 3. Global Mobile Data Traffic Forecast by Region



Source: Cisco VNI Mobile, 2019

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Top Global Mobile Networking Trends

The sections that follow identify 7 major trends contributing to the growth of mobile data traffic.

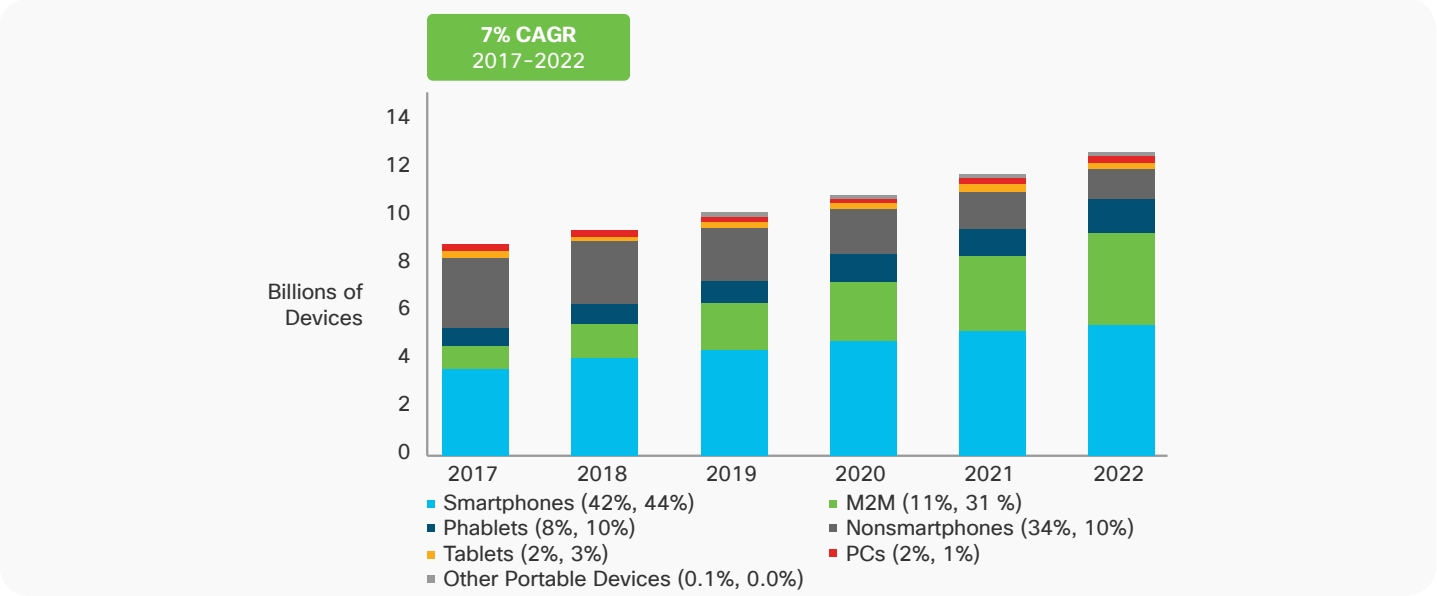
1. Evolving toward Smarter Mobile Devices
2. Defining Cell Network Advances–2G, 3G, 4G and 5G Projections
3. Measuring Mobile IoT Adoption–M2M and Emerging Wearables
4. Analyzing the Expanding Role and Coverage of Wi-Fi
5. Identifying New Mobile Applications and Requirements
6. Comparing Mobile Network Speed Improvements
7. Reviewing Tiered Pricing–Unlimited Data and Shared Plans

Trend 1: Evolving toward Smarter Mobile Devices

The ever changing mix and growth of wireless devices that are accessing mobile networks worldwide is one of the primary contributors to global mobile traffic growth. Each year several new devices in different form factors and increased capabilities and intelligence are introduced in the market. In the last couple of years, we have seen a rise of phablets and more recently we have seen many new M2M connections coming into the mix. More than 600 million (648 million) mobile devices and connections were added in 2017. In 2017, global mobile devices and connections grew to 8.6 billion, up from 7.9 billion in 2016. Globally, mobile devices and connections will grow to 12.3 billion by 2022 at a CAGR of 7.5 percent (Figure 4).

By 2022, there will be 8.4 billion handheld or personal mobile-ready devices and 3.9 billion M2M connections (e.g., GPS systems in cars, asset tracking systems in shipping and manufacturing sectors, or medical applications making patient records and health status more readily available, et al.). Regionally, North America and Western Europe are going to have the fastest growth in mobile devices and connections with 16 percent and 12 percent CAGR from 2017 to 2022, respectively.

Figure 4. Global Mobile Devices and Connections Growth



Note: Figures in parentheses refer to 2017, 2022 device share.
Source: Cisco VNI Mobile, 2019.

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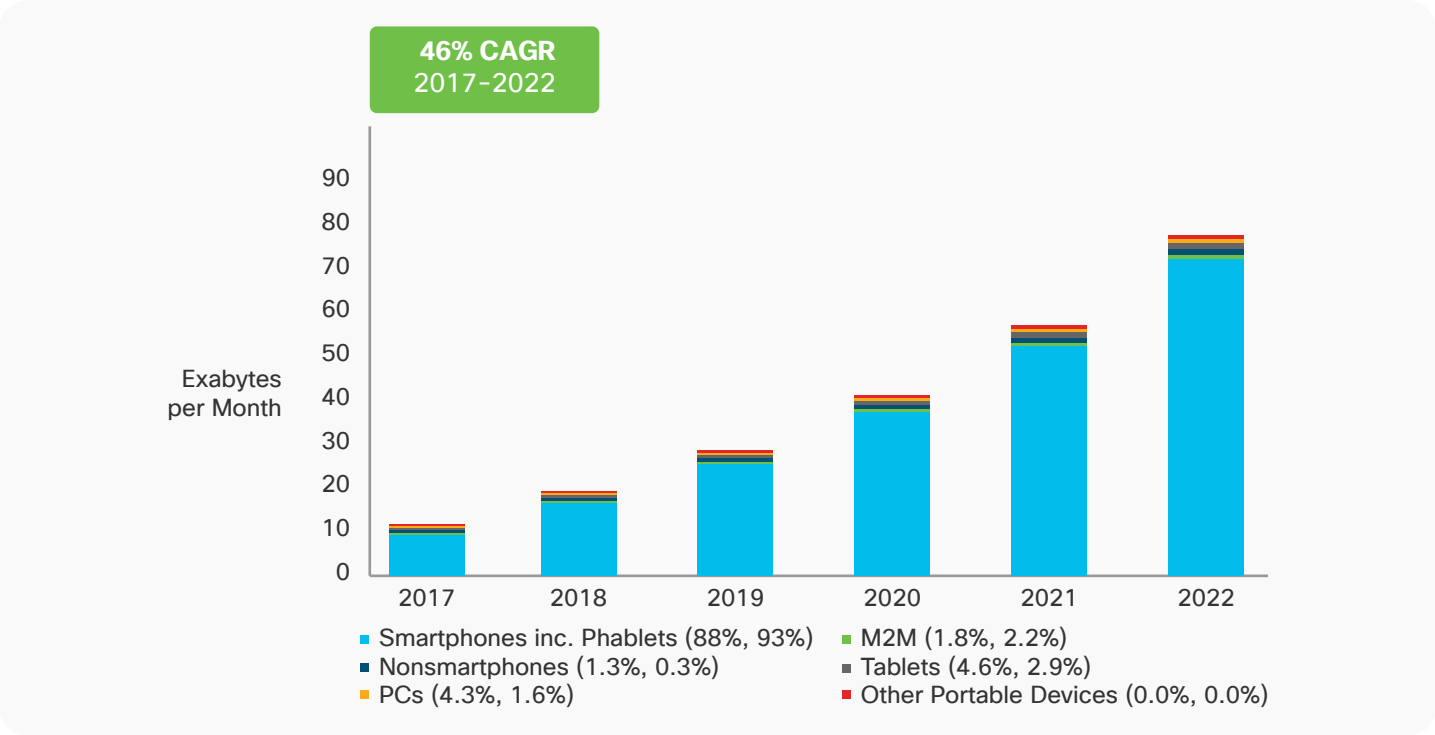
We see a rapid decline in the share of nonsmartphones from 34 percent in 2017 (3.0 billion) to 10 percent by 2022 (1.2 billion). Another significant trend is the growth of smartphones (including phablets) from 50 percent share of total devices and connections in 2017 to over 50 percent (54 percent) by 2022. The most noticeable growth is going to occur in M2M connections, followed by tablets. M2M mobile connections will reach nearly a third (31 percent) of total devices and connections by 2022. The M2M category is going to grow at 32 percent CAGR from 2017 to 2022, and tablets are going to grow at 14 percent CAGR during the same period. Along with the overall growth in the number of mobile devices and connections, there is clearly a visible shift in the device mix. This year, we see a further slowdown in the growth of tablets as well as laptops and a more rapid decline in nonsmartphones and other portables.

From a traffic perspective, smartphones and phablets will continue to dominate mobile traffic (93 percent) while the M2M category will continue to gain share by 2022 (refer to Figure 5).

Figure 5. Global Mobile Traffic Growth by Device Type



Note: Figures in parentheses refer to 2017, 2022 device share.
Source: Cisco VNI Mobile, 2019.

Throughout the forecast period, we see that the device mix is getting smarter with an increasing number of devices with higher computing resources, and network connection capabilities that create a growing demand for more capable and intelligent networks. We define smart devices and connections as those having advanced computing and multimedia capabilities with a minimum of 3G connectivity. The share of smart devices and connections as a percentage of the total will increase from 53 percent in 2017 to nearly three-fourths, at 73 percent, by 2022, growing two-fold during the forecast period (Figure 6).

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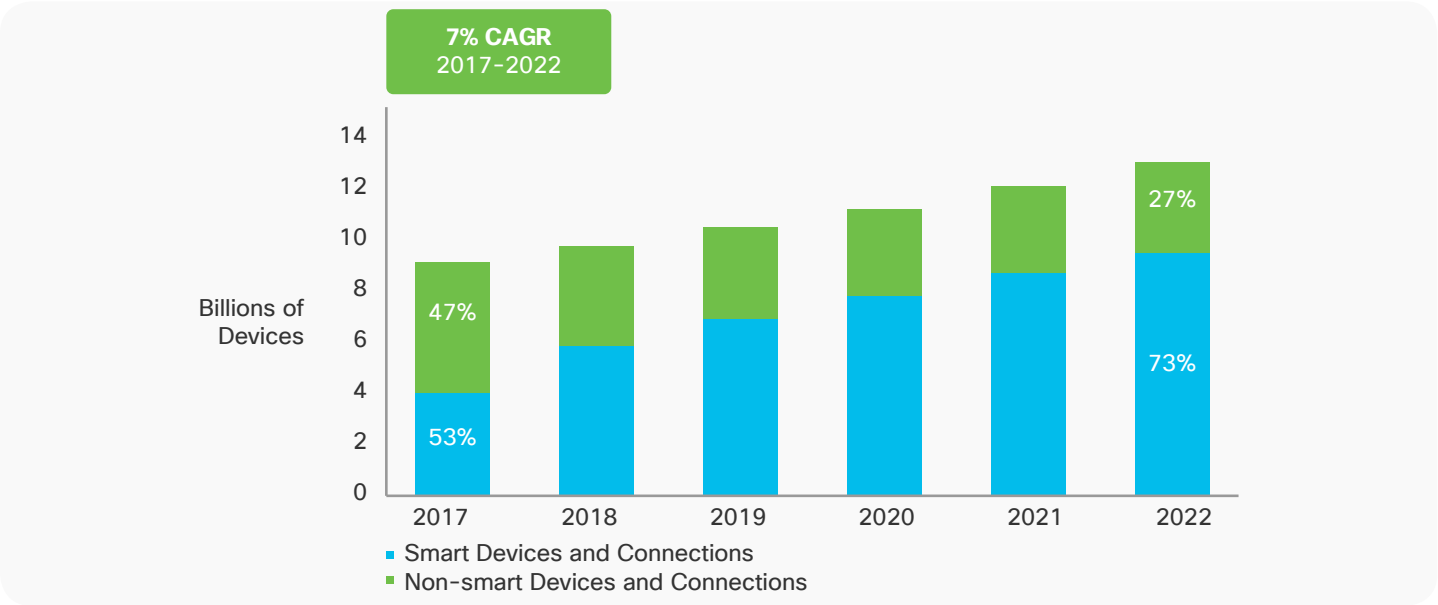
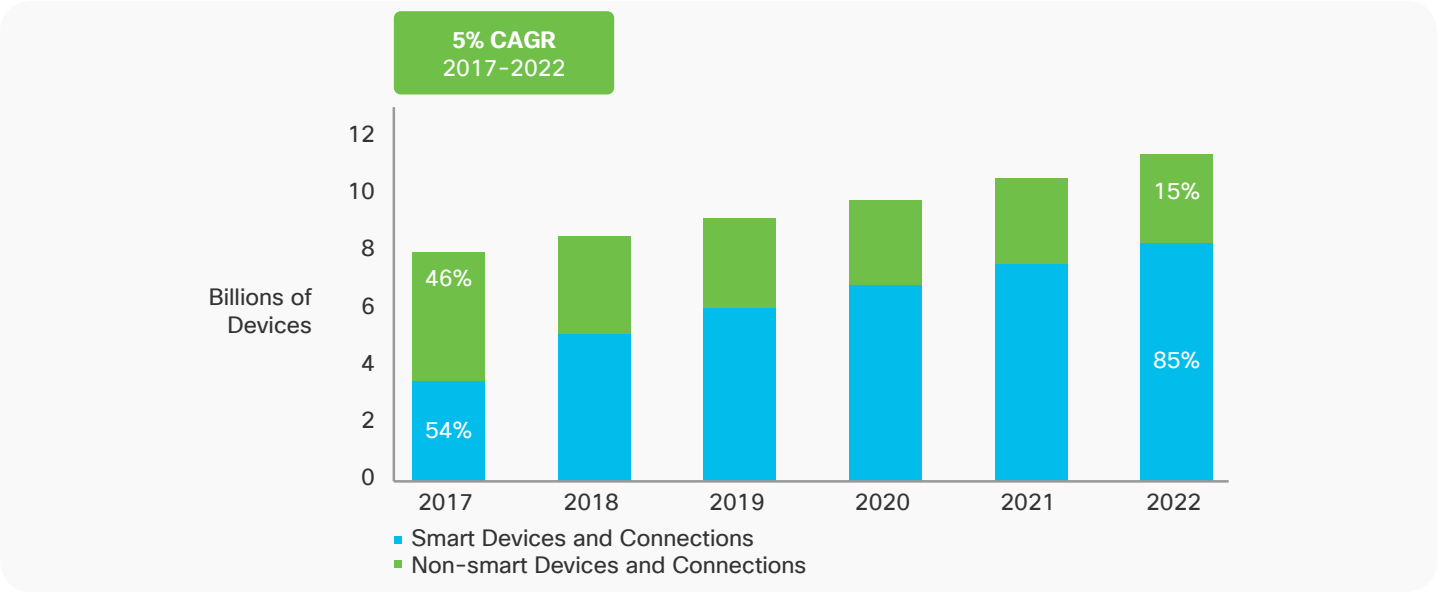
Figure 6. Global Growth of Smart Mobile Devices and Connections



Note: Percentages refer to device and connections share.
Source: Cisco VNI Mobile, 2019

Low-Power Wide-Area (LPWA) connections are included in our analysis. This wireless network connectivity is meant specifically for M2M modules that require low bandwidth and wide geographic coverage. Because these modules have very low bandwidth requirements and tolerate high latencies, we do not include them in the smart devices and connections category. For some regions, such as North America where the growth of LPWA is expected to be high, their inclusion in the mix would skew the percentage for smart devices and connections, so for regional comparison we have taken them out of the mix. Figure 7 provides a comparable global smart-to-nonsmart devices and connections split, excluding LPWA.

Figure 7. Global Growth of Smart Mobile Devices and Connections (Excluding LPWA)



Note: Percentages refer to device and connections share.
Source: Cisco VNI Mobile, 2019

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When we exclude LPWA M2M connections from the mix, the global percentage share of smart devices and connections is higher, at 85 percent by 2022.

Although this device mix conversion is a global phenomenon, some regions are ahead. By the end of 2022, North America will have 99 percent of its installed base converted to smart devices and connections, followed by Western Europe and Central and Eastern Europe with 95 percent smart devices and connections (Table 1).

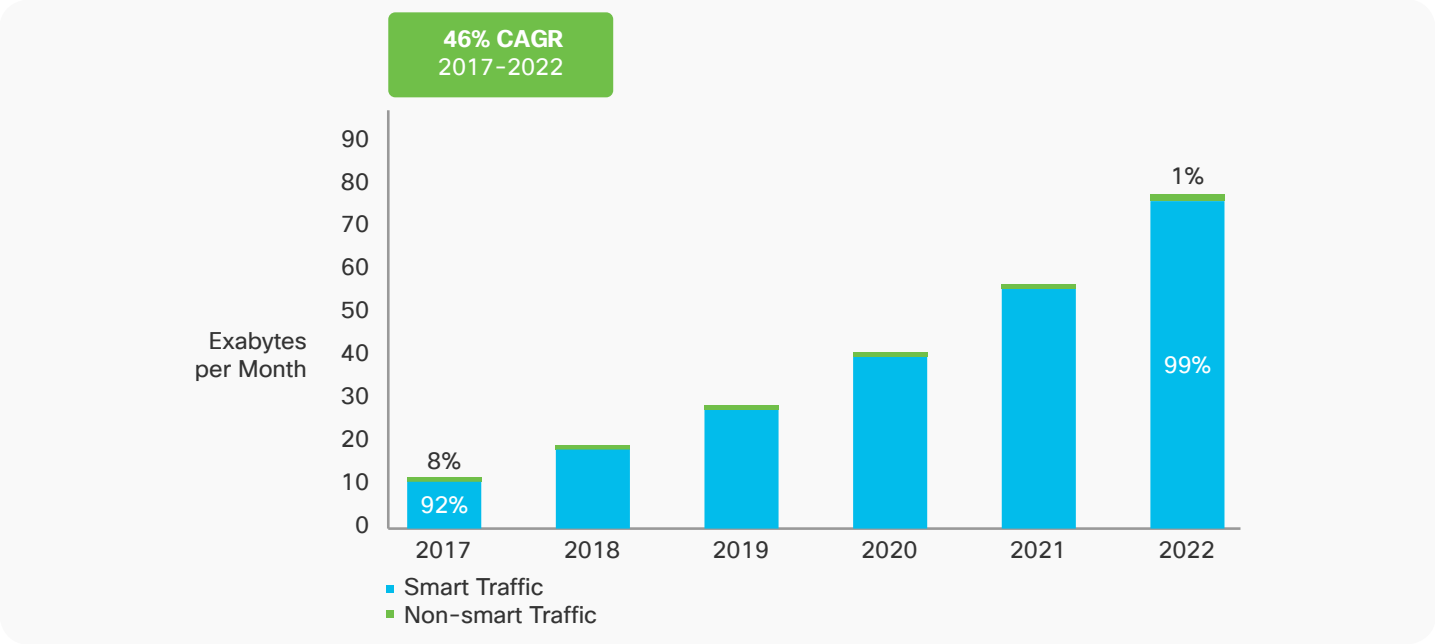
Table 1. Regional Share of Smart Devices and Connections (Percent of the Regional Total)

Region	2017	2022
North America	87%	99%
Western Europe	73%	95%
Central and Eastern Europe	63%	93%
Asia Pacific	54%	82%
Latin America	53%	86%
Middle East and Africa	27%	77%

Source: Cisco VNI Mobile, 2019

Figure 8 shows the impact of the growth of mobile smart devices and connections on global traffic. Globally, smart traffic is going to grow from 92 percent of the total global mobile traffic to 99 percent by 2022. This percentage is significantly higher than the ratio of smart devices and connections (73 percent by 2022), because on average a smart device generates much higher traffic than a nonsmart device. Globally, in 2017, a smart device generated 10 times more traffic than a nonsmart device, and by 2022 a smart device will generate 15 times more traffic.

Figure 8. Effect of Smart Mobile Devices and Connections Growth on Traffic



Note: Percentages refer to traffic share.
Source: Cisco VNI Mobile, 2019

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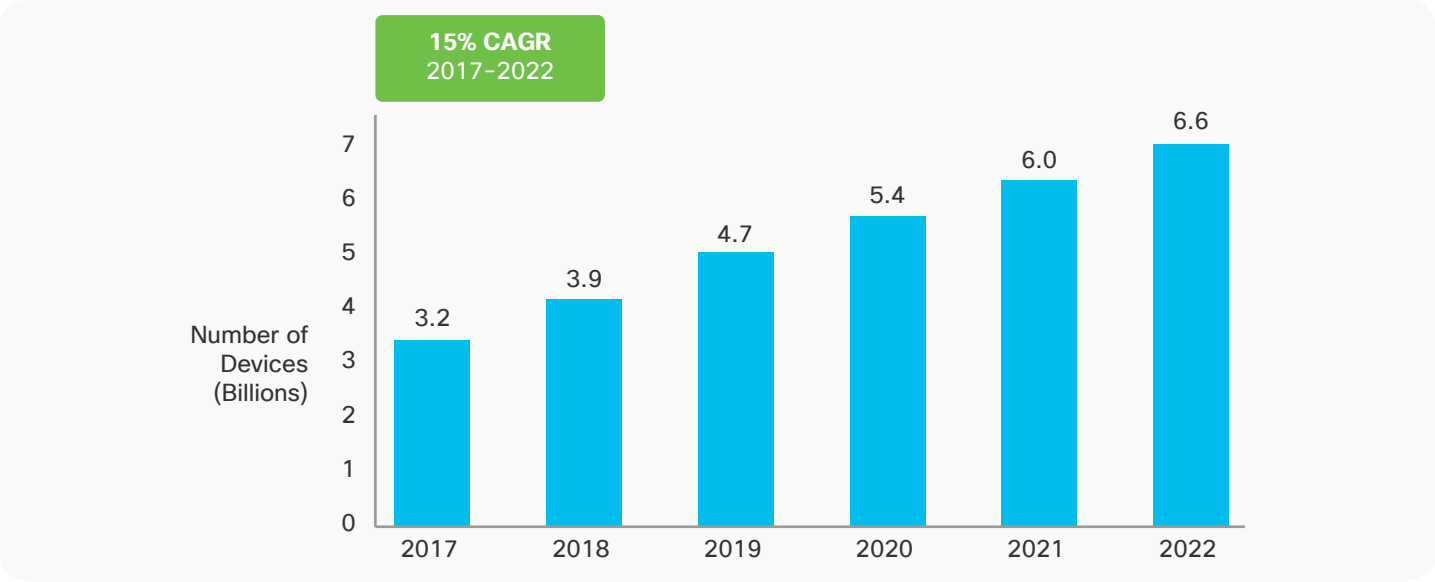
IPv6

With the exponential proliferation of multiple smart devices becoming a reality, the need for each device having its own specific, unique address that it uses to communicate with other devices and the Internet and to define its location is becoming a necessity. IPv4 addresses, the current protocol devices use to communicate on the Internet, have almost exhausted the world over with just a few remaining at the African Internet Registry (AFRINIC). In addition to solving the IPv4 address depletion problem by providing more than enough addresses, the transition to the newer, better IPv6 protocol offers additional advantages where every device will have a globally routable public IP address on the Internet. Hence there is not just a need, but far more a necessity, to move to IPv6 with its 340 undecillion addresses that will make smart devices and the IoT a reality.

The transition to IPv6, which helps connect and manage the proliferation of newer-generation devices that are contributing to mobile network usage and data traffic growth, is well underway. Continuing the Cisco VNI focus on IPv6, the Cisco VNI 2017–2022 Mobile Data Traffic Forecast provides an update on IPv6-capable mobile devices and connections and the potential for IPv6 mobile data traffic.

Focusing on the high-growth mobile-device segments of smartphones and tablets, the forecast projects that globally 94 percent of smartphones and tablets (6.6 billion) will be IPv6-capable by 2022 (up from 71 percent, or 3.2 billion smartphones and tablets in 2017; refer to Figure 9). This estimation is based on OS support of IPv6 (primarily Android and iOS) and the accelerated move to higher-speed mobile networks (3.5G or higher) capable of enabling IPv6. (This forecast is intended as a projection of the number of IPv6-capable mobile devices, not mobile devices with an IPv6 connection actively configured by the Internet Service Provider [ISP].)

Figure 9. Global IPv6-Capable Smartphones and Tablets



Source: Cisco VNI Mobile, 2019

For all mobile devices and connections, the forecasts project that, globally, 76 percent (9.4 billion) will be IPv6-capable by 2022, up from 47 percent (4 billion) in 2017 (refer to Figure 10). M2M emerges as a key segment of growth for IPv6-capable devices, reaching 2.3 billion by 2022, a growth at 31 percent CAGR during the forecast period. With its capability to vastly scale IP addresses and manage complex networks, IPv6 is critical in supporting the IoT of today and in the future.

Regionally, Asia Pacific will lead throughout the forecast period with the highest number of IPv6-capable devices and connections, reaching 4.7 billion by 2022. Middle East and Africa will have the highest growth rates during the forecast period, at 24 percent CAGR. (Refer to Table 8 in Appendix C for more regional detail.)

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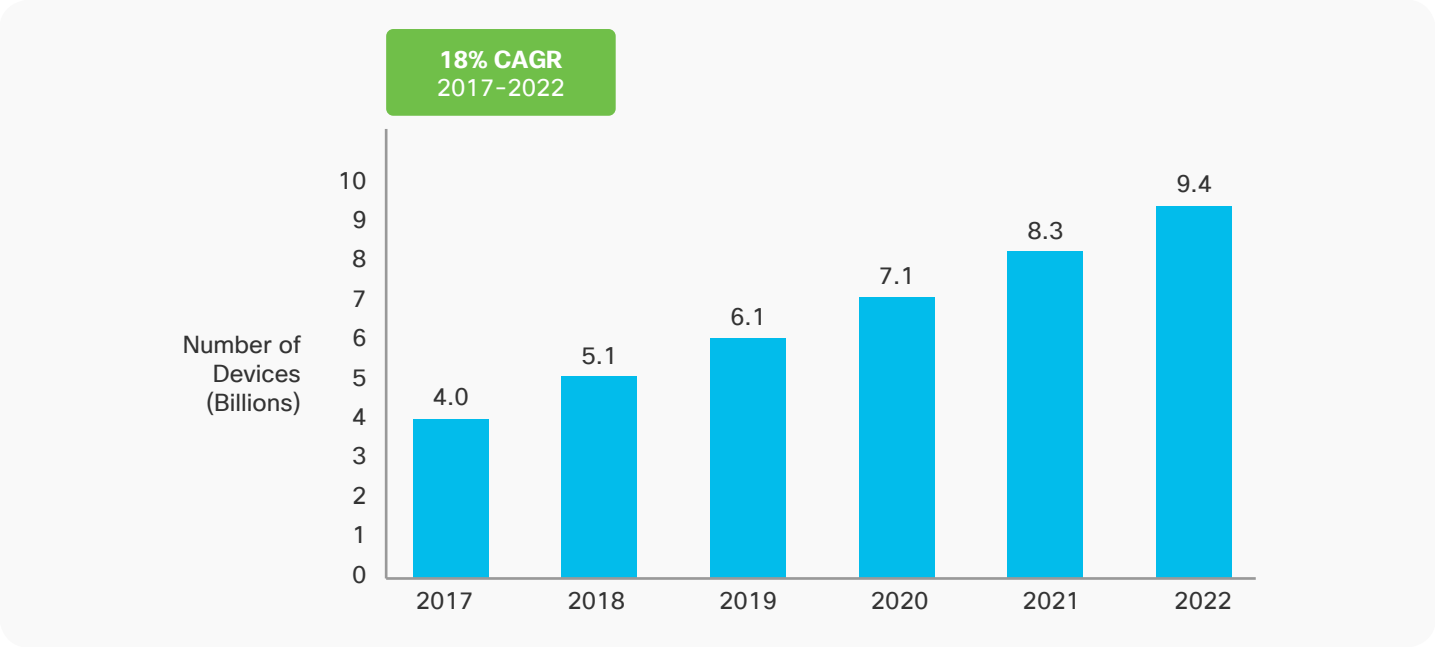
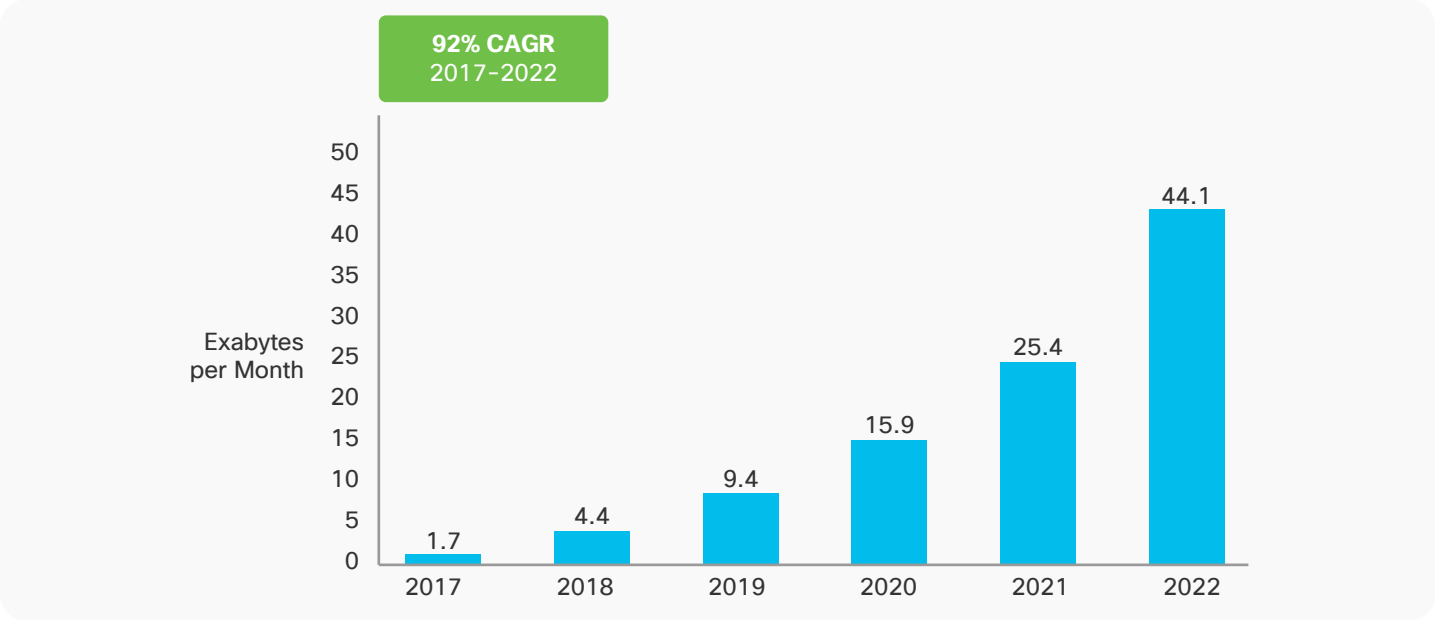
Figure 10. Global IPv6-Capable Mobile Devices



Source: Cisco VNI Mobile, 2019

Considering the significant potential for mobile-device IPv6 connectivity, the Cisco VNI Mobile Forecast provides estimation for IPv6 network traffic based on a graduated percentage of IPv6-capable devices becoming actively connected to an IPv6 network. Looking to 2022, if approximately 60 percent of IPv6-capable devices are connected to an IPv6 network, the forecast estimates that, globally, IPv6 traffic will amount to 44.1 exabytes per month or 57 percent of total mobile data traffic, a 26-fold growth from 2017 to 2022 (Figure 11).

Figure 11. Projected IPv6 Mobile Data Traffic Forecast 2017–2022



Source: Cisco VNI Mobile, 2019

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Security is the top concern in every enterprise's mind today and it is all the more important for IPv6 as compared to its predecessor (IPv4) given its vast addressable range.

IPSec is the most widely used protocol suite for security in any communication network and even in present day can be easily added to any IPv4 network. On the other hand, IPv6 includes native support for IPSec, which by itself may not be a big advantage, however when considered in combination with other capabilities, notably IPv6's self-discovery capabilities and peer-to-peer nature, IPv6's inherent support of IPSec plays an important role in creating networks that are both simple to set up and secure.

IPv6 with its vast addressable space makes any device supporting it more accessible at a global scale thus making the protocol more desirable for applications such as remote monitoring and support all the way from IT infrastructure to automobiles and appliances. Such capabilities also allow manufacturers to increase the life expectancy and functionalities of their products while decreasing the service costs.

IPv6 is also expected to give rise to entirely new applications that would either be difficult or impossible to deploy with IPv4. The multicast capabilities of IPv6, allowing one-to-many communications, may give rise to everything from new forms of games to social network applications.

Inherent support for IPSec within IPv6 makes it very easy to bring such new applications and benefits of IPv6 to life, something that may have been difficult or even impossible with IPv4.

However, given that IPv6 is still a network layer protocol it cannot prevent advanced security breaches on OSI layers that sit over the network layer.

For example:

- Application layer attacks: Attacks performed at the application layer (OSI Layer 7) such as buffer overflow, viruses and malicious codes, web application attacks, and so on.
- Brute -force password guessing attacks on authentication modules.
- Unauthorized devices introduced into the network.
- Denial of service attacks.
- Attacks using social networking techniques such as email spamming, phishing, etc.

For additional views on the latest IPv6 deployment trends, visit the Cisco site. The Cisco 6Lab analysis includes current statistics by country on IPv6 prefix deployment and IPv6 web-content availability, and estimations of IPv6 users. With the convergence of IPv6 device capability, content availability, and significant network deployment, the discussion of IPv6 has shifted focus from "what if" and "how soon will" to the "realization of the potential" that IPv6 has for service providers and end users alike.

Trend 2: Defining Cell Network Advances—2G, 3G, 4G and 5G Projections

Mobile devices and connections are not only getting smarter in their computing capabilities but are also evolving from lower-generation network connectivity (2G) to higher-generation network connectivity (3G, 3.5G, 4G or LTE and now also 5G). This is the second year, that we are projecting the growth of devices and connections with 5G connectivity based on some initial trial deployments (limited in scope) and larger-scale commercial efforts that are planned in the future for various locations around the world. Combining device capabilities with faster, higher bandwidth and more intelligent networks will facilitate broad experimentation and adoption of advanced multimedia applications that contribute to increased mobile and Wi-Fi traffic.

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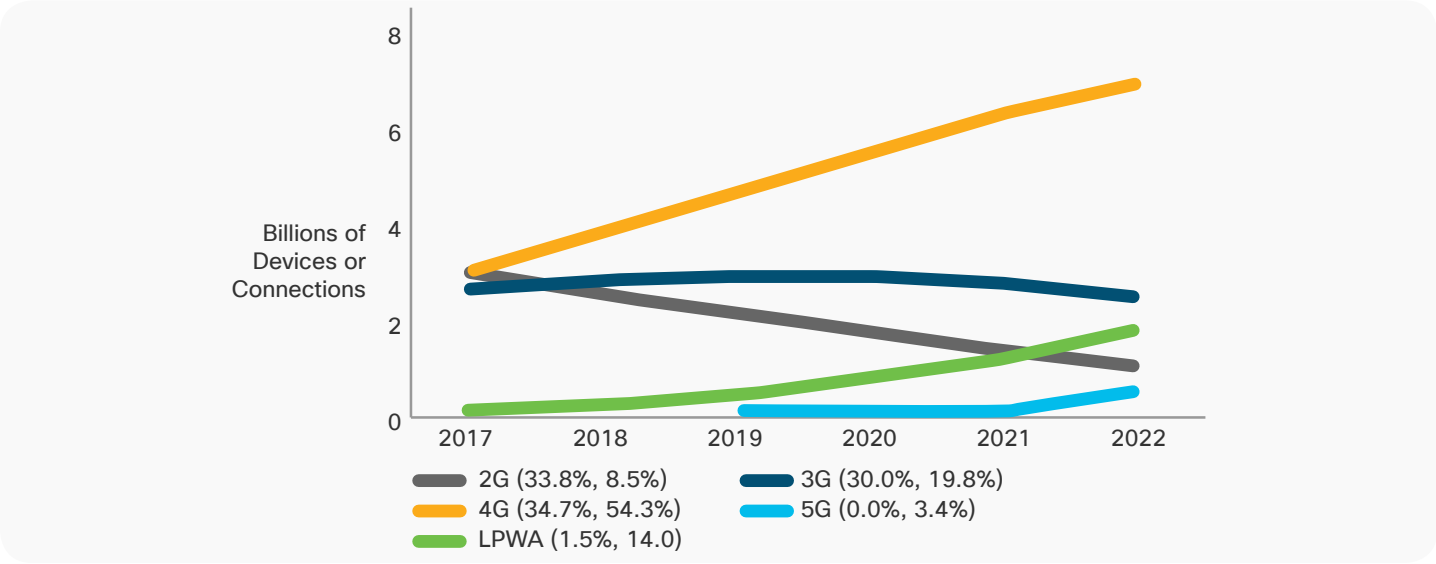
The explosion of mobile applications and the expanded reach of mobile connectivity to a growing number of end users has prompted the need for optimized bandwidth management and new network monetization models to sustain a maturing mobile industry. In a highly competitive mobile market, we have seen the growth of global 4G deployments as well as early-stage 5G implementations. Service providers globally are busy rolling out 4G networks to help them meet the growing end-user demand for more bandwidth, higher security, and faster connectivity on the move (Appendix B). Many providers have also started field trials for 5G and are gearing towards rolling out 5G deployments towards the middle of the forecast period to capture new market opportunities (and to establish competitive differentiation in some cases).

Although, 4G surpassed all other connection types and will be the predominant mobile network connectivity throughout the forecast period, by 2022, 5G impact will start to emerge. By 2022, 4G connections will be 54.3% of total mobile connections, compared to 34.7% in 2017 (Figure 12). The global mobile 4G connections will grow from 3 billion in 2017 to 6.7 billion by 2022 at a CAGR of 18 percent. 5G connections will appear on the scene in 2019 and will grow several thousand percent from under half a million in 2019 to over 400 million by 2022. Until last year, the 5G connectivity could be accurately described as nascent. But this year, 5G warrants its own category and analysis (for the first time in this study).

The relative share of 3G- and 3.5G-capable devices and connections surpassed 2G-capable devices and connections in 2018. There were 30% 3G connections in 2017 compared to about 34% 2G connections, but by the end of the forecast period, there will be 20% 3G connections and 2G will only have 8% of connections. By 2022, there will be 3.4% devices and connections with 5G capability.

Figure 12. Global Mobile Devices and Connections by Network Type



Note: Figures in parentheses refer to 2017, 2022 device and connection share by network type.
Source: Cisco VNI Mobile, 2019

We also include Low-Power Wide-Area (LPWA) connections in our analysis. This type of ultranarrowband wireless network connectivity is meant specifically for M2M modules that require low bandwidth and wide geographic coverage. It provides high coverage with low power consumption, module, and connectivity costs, thereby creating new M2M use cases for Mobile Network Operators (MNOs) that cellular networks alone could not have addressed. Examples include utility meters in residential basements, gas or water meters that do not have power connection, street lights, and pet or personal asset trackers. The share of LPWA connections (all M2M) will grow from about 2 percent in 2017 to 14 percent by 2022, from 130 million in 2017 to 1.8 billion by 2022.

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The network evolution toward more advanced networks is happening both across the end-user device segment and within the M2M connections category. This transition from 2G to 3G or 4G and now 5G deployment is a global trend. In fact, by 2022, about 60 percent of the mobile devices and connections in Western Europe (58%), Latin America (58%), Asia Pacific (61%) as well as Central and Eastern Europe (63%) will have 4G+ capability, surpassing 3G-capable devices and connections by several fold. North America will have 51 percent of 4G+ connections by 2022 (Appendix B). Middle East and Africa at 54% will have the highest share of its devices and connections on 3G by 2022. By 2022, North America with 37 percent and Western Europe with 27 percent share will be the two regions with highest LPWA adoption. By 2022, North America will be the region with highest share of connections on 5G at 9 percent. The top three 5G countries in terms of percent of devices and connections share on 5G will be Japan (12%), Sweden (11%) and United States (10%), by 2022.

5G is the next phase of mobile technology. 5G's primary improvements over 4G include high bandwidth (greater than 1 Gbps), broader coverage, and ultra-low latency. These features combined with enhanced power efficiency, cost optimization, high-precision positioning, massive IoT connection density and dynamic allocation of resources based on awareness of content, user, and location make 5G a flexible as well as transformative technology. 5G will be able to accommodate IoT applications such as sensors and meters at the low end of the of the IoT spectrum. But perhaps more importantly, it will also support autonomous cars and other tactile Internet driven applications such as augmented and virtual reality, factory automation (robotics), smart grid, et al. at the high end of the IoT spectrum. However, the true value of 5G will lie beyond the connectivity and besides advanced application and massive IoT enablement. Combined with enhanced network edge capabilities, data analytics, machine learning and artificial intelligence, 5G can truly unlock the business value for the customers and create new revenue opportunities for the providers. This technology is expected to solve frequency licensing and spectrum management issues. Currently, there are various standards bodies, regulatory agencies, and industry consortiums focused on concerted efforts to resolve issues such as network standardization, spectrum availability and auctioning and Return-on-Investment (ROI) strategies to justify the investment associated with new infrastructure transitions and deployments. Given these evolving technology and business dynamics, we anticipate that some large scale commercial 5G deployments may not be executed until after the current forecast period (after 2022). It is clear that a large number of mobile carriers perceive 5G as an imperative for future growth and long-term sustainability.

Traffic Impact of 4G and 5G

In 2017, 4G already carried 72 percent of the total mobile traffic and represented the largest share of mobile data traffic by network type. It will continue to grow faster than other networks, however the percentage share will go down slightly to 71 percent of all mobile data traffic by 2022 (Figure 13). By 2022, 5G will support 12 percent of mobile traffic. 5G connectivity with its very high bandwidth (100 Mbps) and ultra low latency (1 millisecond) is expected to drive very high traffic volumes.

Currently, a 4G connection generates about three times more traffic than a 3G connection. There are two reasons for the higher usage per device on 4G. The first is that many 4G connections today are for high-end devices, which have a higher average usage. The second is that higher speeds encourage the adoption and usage of high- bandwidth applications, such that a smartphone on a 4G network is likely to generate significantly more traffic than the same model smartphone on a 3G or 3.5G network. By 2022, a 4G connection will still generate nearly two times more traffic than a 3G connection.

By 2022, the average 5G connection will generate nearly 3 times more traffic than the average 4G connection.

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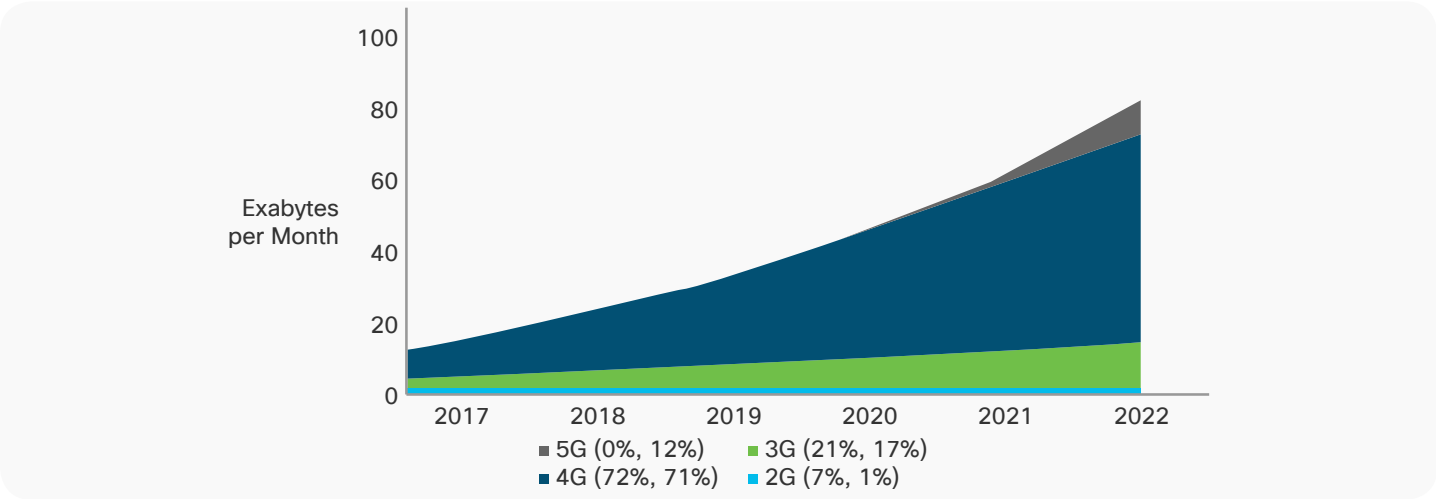
Figure 13. Global Mobile Traffic by Connection Type



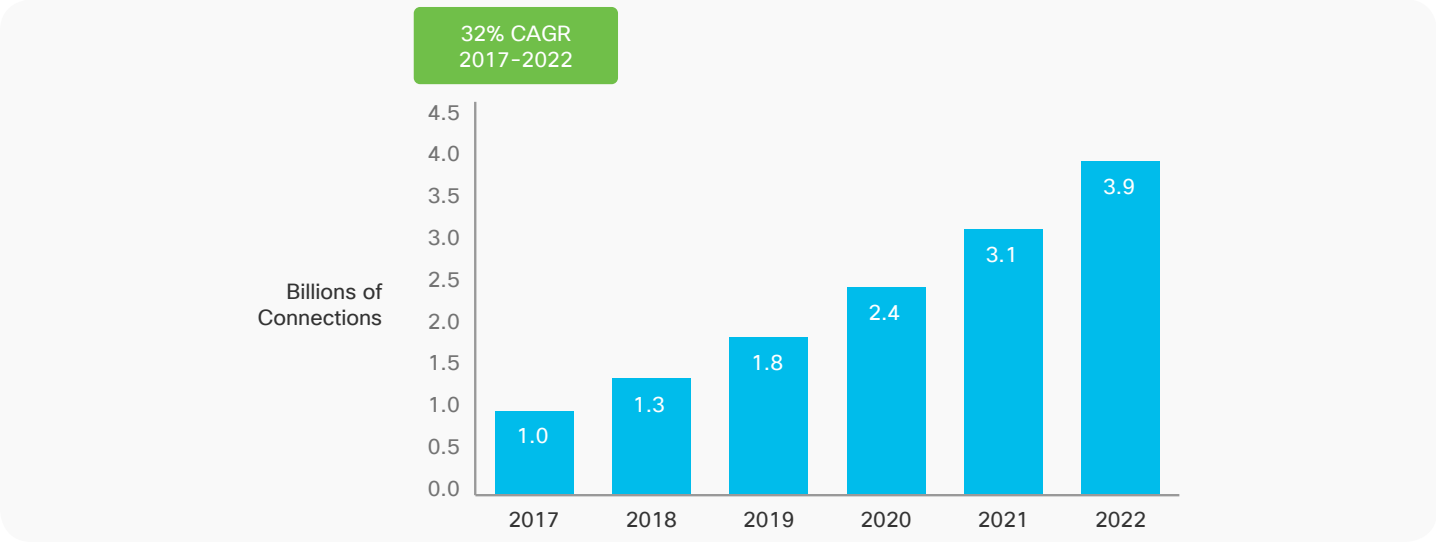
Note: Figures in parentheses refer to 2017, 2022 mobile traffic share by network type.
Source: Cisco VNI Mobile, 2019

Trend 3: Measuring Mobile IoT Adoption—M2M and Emerging Wearables

The phenomenal growth in smarter end-user devices and M2M connections is a clear indicator of the growth of IoT, which is bringing together people, processes, data, and things to make networked connections more relevant and valuable. This section focuses on the continued growth of M2M connections and the emerging trend of wearable devices. Both M2M and wearable devices are making computing and connectivity very pervasive in our day-to-day lives.

M2M connections—such as home and office security and automation, smart metering and utilities, maintenance, building automation, automotive, healthcare and consumer electronics, and more—are being used across a broad spectrum of industries, as well as in the consumer segment. As real-time information monitoring helps companies deploy new video-based security systems, while also helping hospitals and healthcare professionals remotely monitor the progress of their patients, bandwidth-intensive M2M connections are becoming more prevalent. Globally, M2M connections will grow from just under a billion in 2017 to 3.9 billion by 2022, a 32 percent CAGR—a four-fold growth. (Figure 14).

Figure 14. Global Machine-to-Machine Growth



Source: Cisco VNI Mobile, 2019

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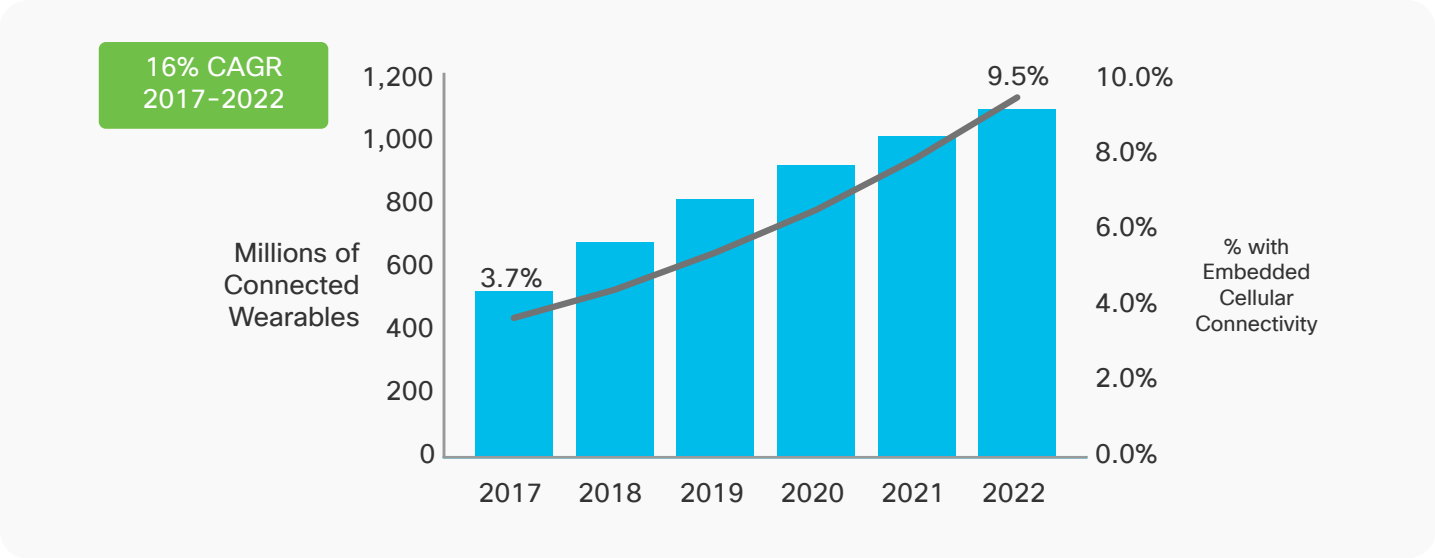
An important factor contributing to the growing adoption of IoT is the emergence of wearable devices, a category with high growth potential. Wearable devices, as the name suggests, are devices that can be worn on a person and have the capability to connect and communicate to the network either directly through embedded cellular connectivity or through another device (primarily a smartphone) using Wi-Fi, Bluetooth, or another technology.

These devices come in various shapes and forms, ranging from smart watches, smart glasses, Heads-Up Displays (HUDs), health and fitness trackers, health monitors, wearable scanners and navigation devices, smart clothing, etc. The growth in these devices has been fueled by enhancements in technology that have supported compression of computing and other electronics (making the devices light enough to be worn). These advances are being combined with fashion to match personal styles, especially in the consumer electronics segment, along with network improvements and the growth of applications, such as location-based services, Virtual Reality (VR) and Augmented Reality (AR). Although there have been vast technological improvements to make wearables possible as a significant device category, wide-scale availability of embedded cellular connectivity still has some barriers to overcome for some applications—such as technology limitations, regulatory constraints, and health concerns.

By 2022, we estimate that there will be 1.1 billion wearable devices globally, growing over two-fold from 526 million in 2017 at a CAGR of 16 percent (Figure 15). As mentioned earlier, there will be limited embedded cellular connectivity in wearables through the forecast period. Only 10 percent will have embedded cellular connectivity by 2022, up from 4 percent in 2017. Currently, wearables are included within our M2M forecast.

Figure 15. Global Connected Wearable Devices



Source: Cisco VNI Mobile, 2019

Regionally, North America will have the largest regional share of wearables, with 40 percent share in 2022 a little down from 41 percent share in 2017 (Appendix B). Other regions with significant share include Asia Pacific with 29 percent share in 2017, declining to 28 percent by 2022.

The wearables category will have a tangible impact on mobile traffic, because even without embedded cellular connectivity wearables can connect to mobile networks through smartphones. With high bandwidth applications such as virtual reality taking off the traffic impact might become even greater.

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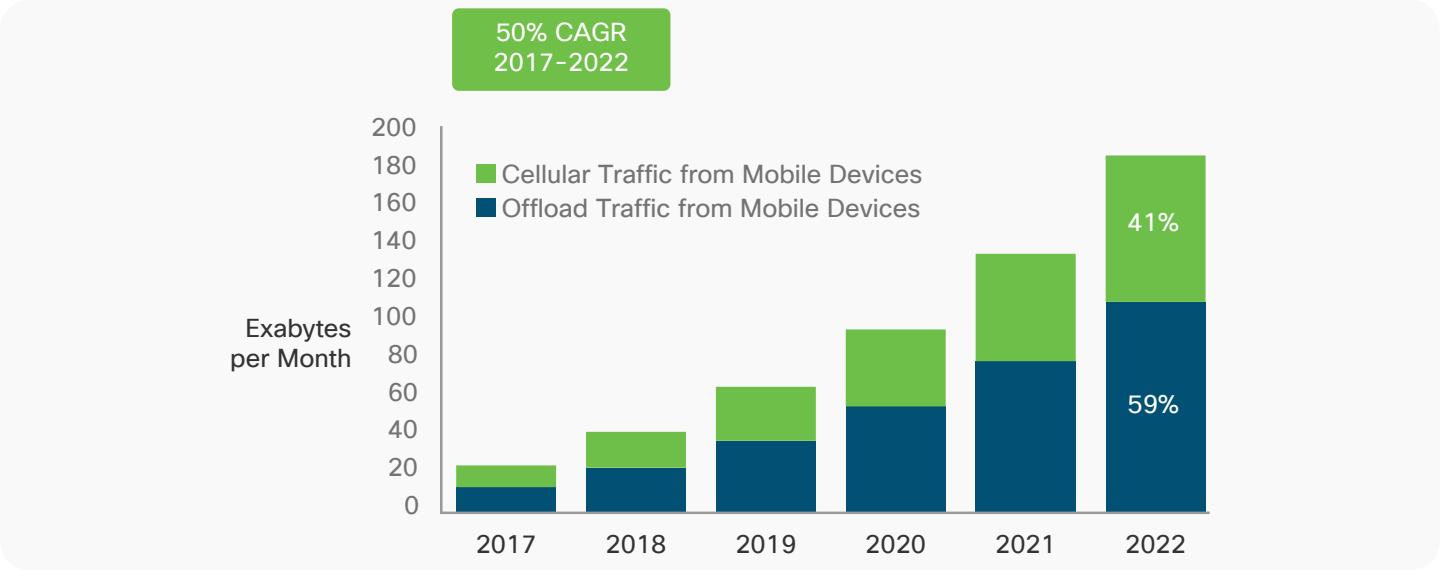
Trend 4: Analyzing the Expanding Role and Coverage of Wi-Fi

Offload

Much mobile data activity takes place within users' homes. For users with fixed broadband and Wi-Fi access points at home, or for users served by operator-owned femtocells and picocells, a sizable proportion of traffic generated by mobile and portable devices is offloaded from the mobile network onto the fixed network. For the purposes of this study, offload pertains to traffic from dual-mode devices (i.e., supports cellular and Wi-Fi connectivity, excluding laptops) over Wi-Fi and small-cell networks. Offloading occurs at the user or device level when one switches from a cellular connection to Wi-Fi or small-cell access. Our mobile offload projections include traffic from both public hotspots and residential Wi-Fi networks.

As a percentage of total mobile data traffic from all mobile-connected devices, mobile offload increases from 54 percent (13.4 exabytes/month) in 2017 to 59 percent (111.4 exabytes/month) by 2022 (Figure 16). Offload volume is determined by smartphone penetration, dual-mode share of handsets, percentage of home-based mobile Internet use, and percentage of dual-mode smartphone owners with Wi-Fi fixed Internet access at home.

Figure 16. Global Mobile Data Traffic Offload to Wi-Fi



Note: Offload pertains to traffic from dual-mode devices (excluding laptops) over Wi-Fi or small-cell networks.
Source: Cisco VNI Mobile, 2019

The amount of traffic offloaded from smartphones will be 59 percent by 2022, and the amount of traffic offloaded from tablets will be 72 percent.

Some have speculated that Wi-Fi offload will be less relevant after 4G networks are in place because of the faster speeds and more abundant bandwidth. However, 4G networks have attracted high-usage devices such as advanced smartphones and tablets, and now 4G plans are subject to data caps similar to 3G plans while, possibly, similar data caps will be in store for 5G.

For these reasons, we expect, Wi-Fi offload is going to be higher on 4G and 5G networks than on lower-speed networks, according to our projections. The amount of traffic offloaded from 4G was 57 percent at the end of 2017, and it will be 59 percent by 2022 (Figure 17). The amount of traffic offloaded from 3G will be 40 percent by 2022, and the amount of traffic offloaded from 2G will be 30 percent. As 5G is being introduced, while we expect plans to be generous with data caps and speeds will be higher than ever, the new application demands on 5G are also going to move upwards as well encouraging similar behaviors of offload as 4G. The offload percentage on 5G is estimated to be 71 percent by 2022. As the 5G network matures, we may see offload rates come down.

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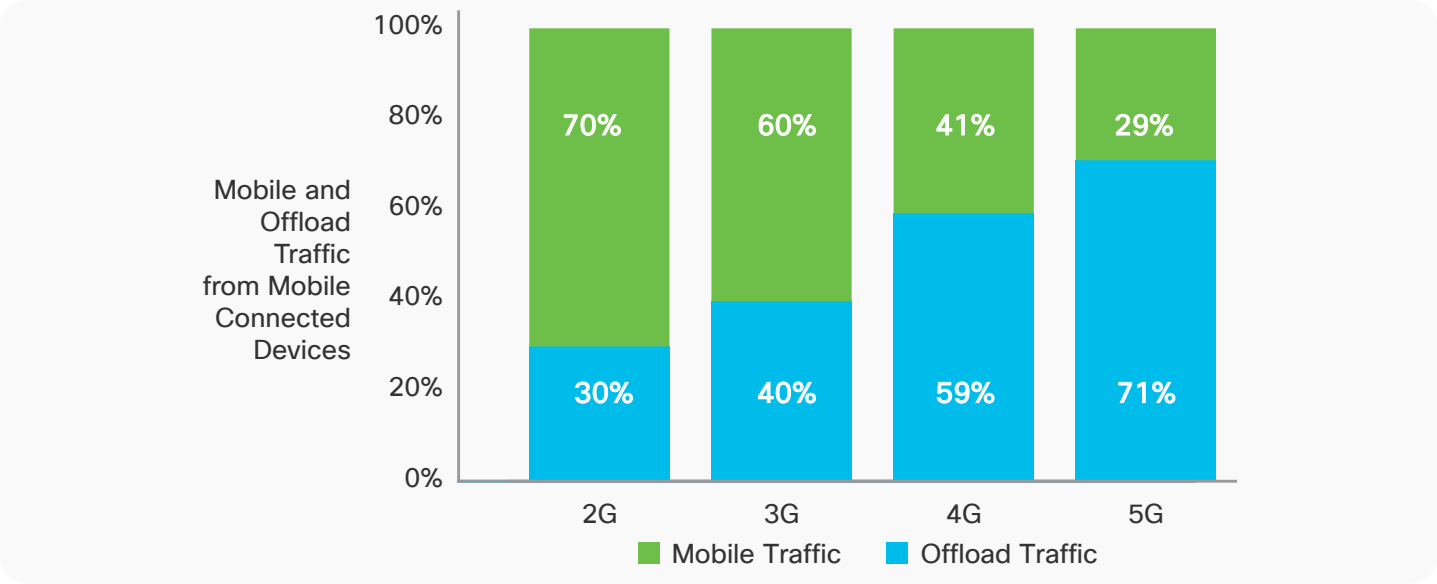
Figure 17. Mobile Data Traffic and Offload Traffic, 2022

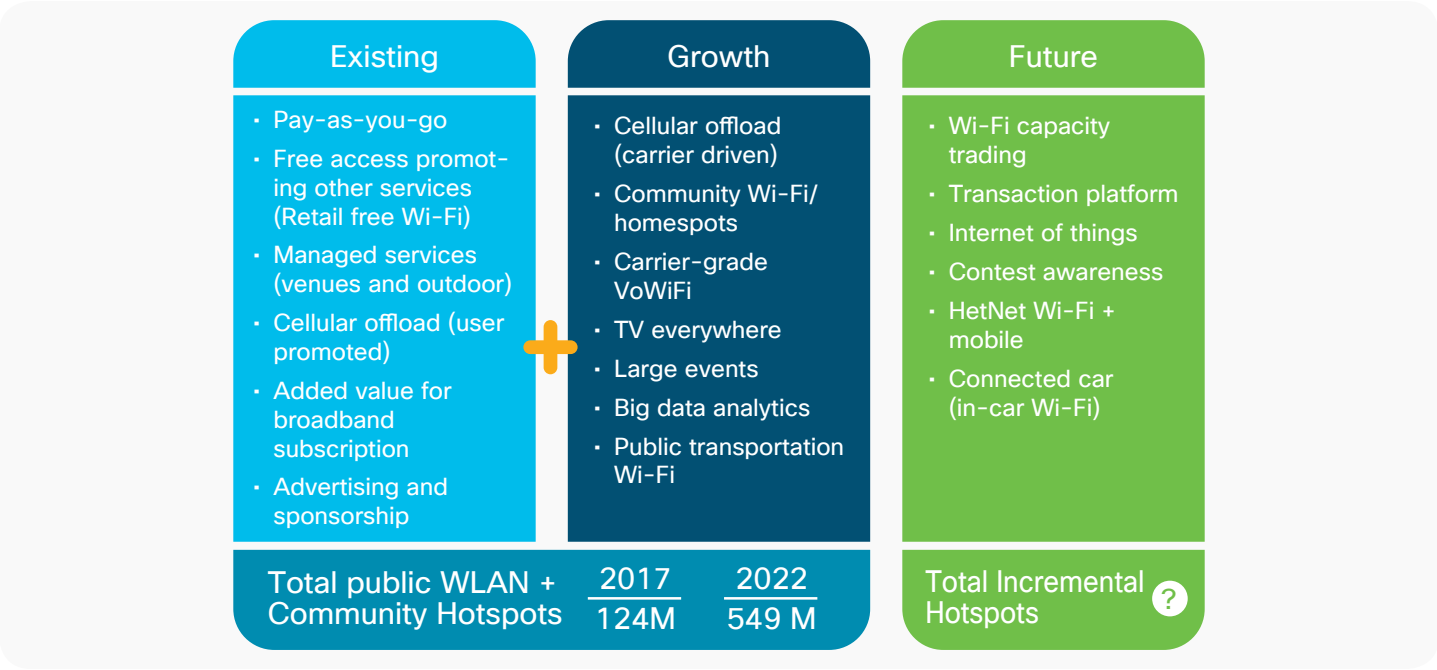


Note: Offload pertains to traffic from dual-mode devices (excluding laptops) over Wi-Fi or small-cell networks.
Source: Cisco VNI Mobile, 2019

Growth of Wi-Fi Hotspots

Globally, total public Wi-Fi hotspots (including homespots) will grow four-fold from 2017 to 2022, from 124 million in 2017 to 549 million by 2022 (Figure 18). Total Wi-Fi homespots will grow from 115 million in 2017 to 532 million by 2022. Homespots or community hotspots are a significant part of the public Wi-Fi strategy. The public Wi-Fi hotspots include public Wi-Fi commercial hotspots and homespots.

Figure 18. Global Wi-Fi Hotspot Strategy and 2017–2022 Forecast



Source: Maravedis, Cisco VNI Mobile, 2019

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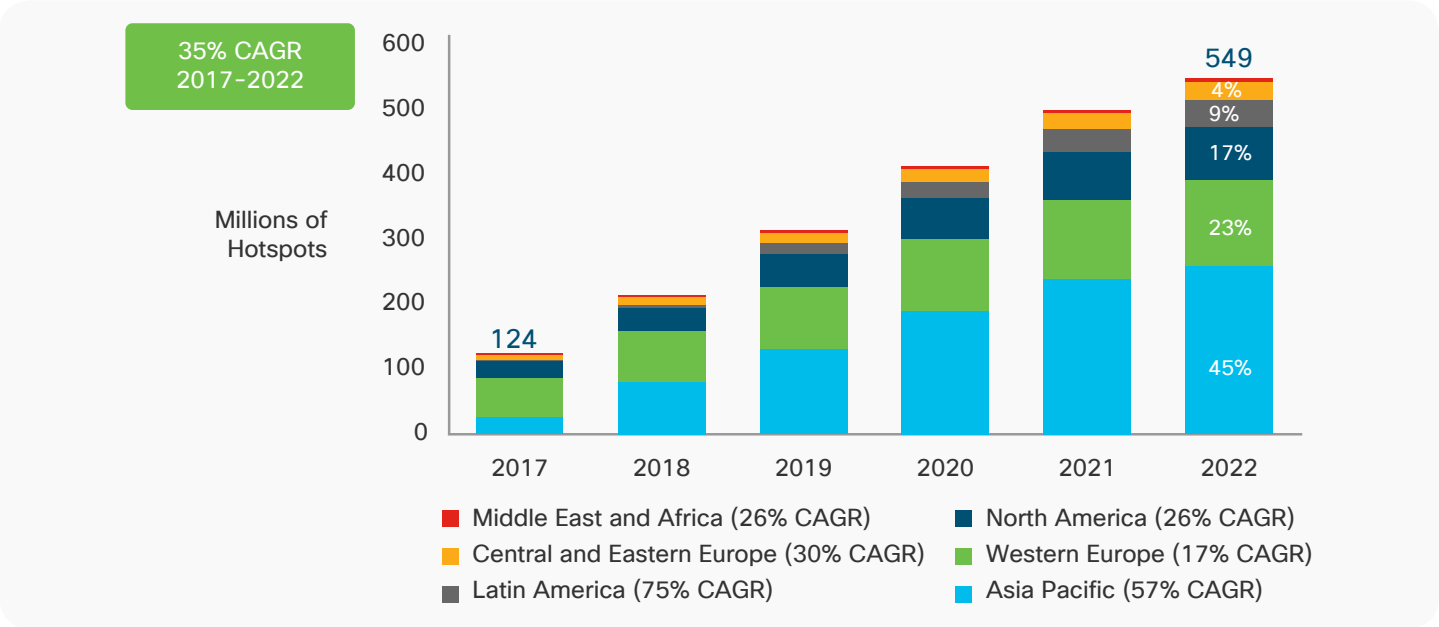
Commercial hotspots include fixed and MNO hotspots that are purchased or installed for a monthly fee or commission. Commercial hotspots can be set up to offer both fee-based and free Internet Wi-Fi access. Hotspots are installed to offer public Wi-Fi at cafés and restaurants, retail chains, hotels, airports, planes, and trains for customers and guests. Cafés, retail shops, public venues, and offices usually provide a free Wi-Fi Service Set Identifier (SSID) for their guests and visitors. Commercial hotspots are a smaller subset of the overall public Wi-Fi hotspot forecast and will grow from 9.8 Million in 2017 to 17.2 Million by 2022.

Homespots or community hotspots have emerged as a potentially significant element of the public Wi-Fi landscape. In this model, subscribers allow part of the capacity of their residential gateway to be open to casual use. Homespots have dual SSIDs and operators download software to a subscriber's home gateway, allowing outside users to use one of the SSIDs like a hotspot. This model is used to facilitate guest Wi-Fi and mobile offload, as well as other emerging models of community use of Wi-Fi (Figure 19).

Figure 19. Global Public Wi-Fi Hotspots: Asia Pacific Leads with 45 Percent Hotspots Worldwide by 2022



Note: *Middle East and Africa represents 1 percent of global public Wi-Fi hotspots by 2022.
Source: Maravedis, Cisco VNI Mobile, 2018

Wi-Fi access has had widespread acceptance by MNOs globally, and it has evolved as a complementary network for traffic offload purposes—offloading from expensive cellular networks on to lower-cost-per-bit Wi-Fi networks. If we draw a parallel from data to voice, we can foresee a similar evolution where VoWiFi is evolving as a supplement to cellular voice, extending the coverage of cellular networks through Wi-Fi for voice within the buildings and other areas that have a wider and more optimum access to Wi-Fi hotspots.

Overall Wi-Fi Traffic Growth

A broader view of Wi-Fi traffic (inclusive of traffic from Wi-Fi-only devices) shows that Wi-Fi and mobile are both growing faster than fixed traffic (traffic from devices connected to the network through Ethernet). Fixed traffic will fall from 48 percent of total IP traffic in 2017 to 29 percent by 2022. Mobile and offload from mobile devices together will account for 48 percent of total IP traffic by 2022, a testament to the significant growth and impact of mobile devices and lifestyles on overall traffic. Wi-Fi traffic from both mobile devices and Wi-Fi-only devices together will account for more than half (51 percent) of total IP traffic by 2022, up from 43 percent in 2017 (Figure 20).

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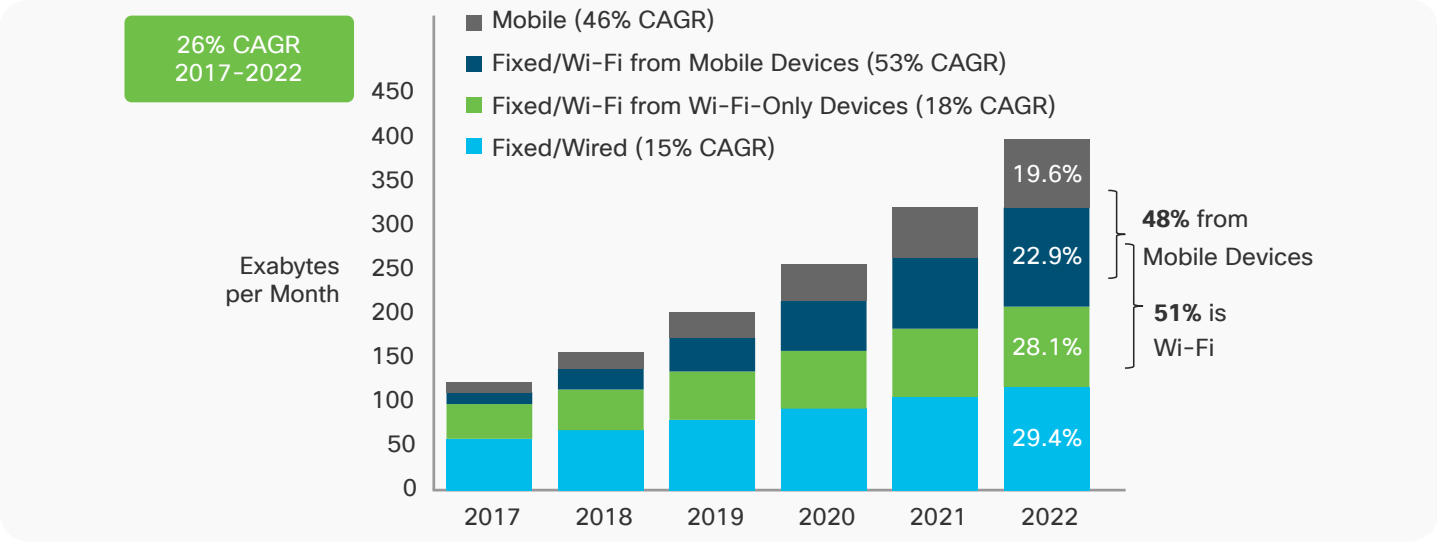
Figure 20. IP Traffic by Access Technology

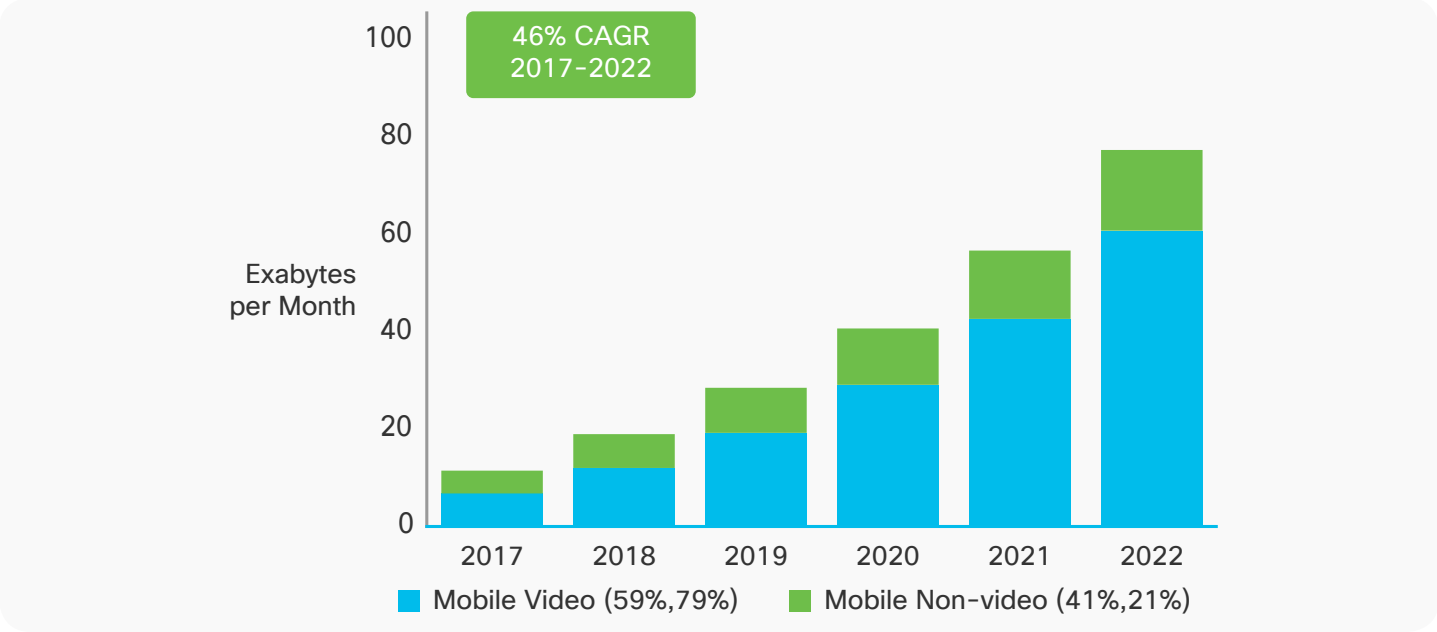


Note: Fixed/Wi-Fi from Mobile Devices may include a small amount of Fixed/Wired from Mobile Devices
Source: Cisco VNI Mobile, 2019

Trend 5: Identifying New Mobile Applications and Requirements

Because mobile video content has much higher bit rates than other mobile content types, mobile video will generate much of the mobile traffic growth through 2022. Mobile video will grow at a CAGR of 55 percent between 2017 and 2022, higher than the overall average mobile traffic CAGR of 46 percent. Of the 77 exabytes per month crossing the mobile network by 2022, nearly 61 exabytes will be due to video (Figure 21). Mobile video represented more than half of global mobile data traffic beginning in 2012.

Figure 21. Mobile Video Will Generate Nearly Four-Fifths of Mobile Data Traffic by 2022



Note: Figures in parentheses refer to 2017 and 2022 traffic share.
Source: Cisco VNI Mobile, 2019

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One consequence of the growth of video in both fixed and mobile contexts is the resulting acceleration of busy- hour traffic in relation to average traffic growth. Video usage tends to occur during evening hours and has a “prime time,” unlike general web usage that occurs throughout the day. As a result, more video usage means more traffic during the peak hours of the day.

Virtual Reality (VR) and Augmented Reality (AR)

Virtual reality immerses users in a simulated environment and augmented reality is an overlay of technology on the real world. Both are equally appealing to a creative mind and have their own set of specific applications.

Both VR and AR are poised to be the next set of the biggest trends in mobile technology. The evolution of edge computing and advancements in wireless networking ranging from the imminent roll out of 5G to highly efficient mobile connectivity solutions coupled with access to smarter mobile and wearable devices have all contributed to providing a rich environment for the proliferation and growth of AR and VR.

Figure 22. All the Realities: VR, AR, Mixed and Extended

Extended reality (XR) is a term referring to all real-and-virtual combined environments and human-machine interactions generated by computer technology and wearables. Examples: flying drones, underwater exploration.

Mixed Reality: Mixed reality (MR), sometimes referred to as hybrid reality, is the merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time. Examples: entertainment industry.

Virtual reality (VR) is an immersive multimedia or computer simulated environment which allows one to interact with it. Examples: complete immersive gaming, virtual aviation training, medical/ surgical training, mental treatment.

Augmented reality (AR) is a view of a real-world environment whose elements are supplemented and enhanced by computer-generated sensory input such as sound, video, or graphics Examples: tourism, retail- furniture visualizers, clothes visualizer.

The accelerated acquisition of smartphones, tablets and wearable devices is significantly contributing to the development of AR and VR markets. Globally, smartphones will be 54.7% of device connections by 2022 (CAGR of 9 percent), and 93% of total traffic growing at a CAGR of 48 percent. AR and VR market development is expected to follow a similar trend.

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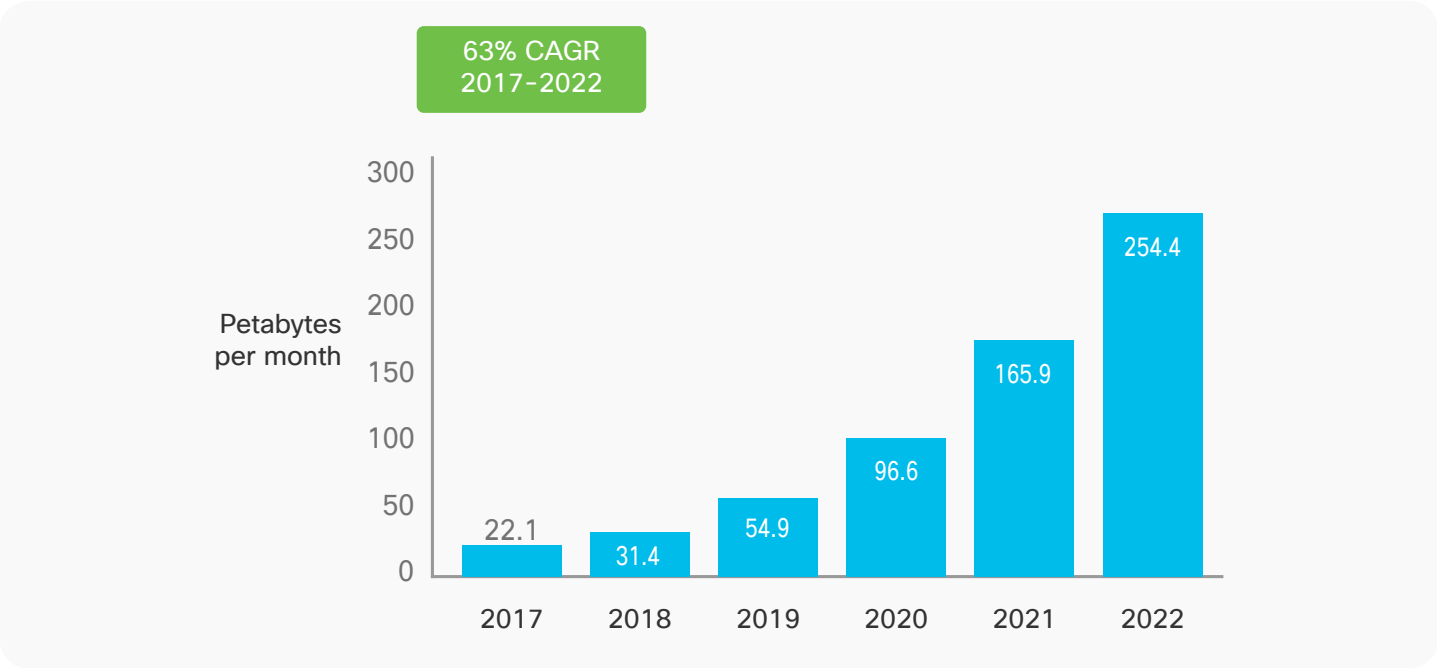
	Adoption Accelerators	Key Inhibitors and Dependencies
VR and AR	• Investment from sports, gaming and entertainment industry • Ease of access to consumers through fast and efficient networks and new smart devices • Development of software components and proliferation of different VR and AR platforms • Accelerating adoption of VR by early adopters in the gaming industry • Vast applicability of AR in many different industry segments	• Lack of rich content • Short battery life • Dependency on the impending roll out of 5G • Dependency on rollout of IoT or Tactile Internet

Source: Cisco VNI Mobile, 2019

While gaming is one of the key applications driving VR, AR is primarily been driven by industrial applications such as retail, medicine, education, tourism, retail shopping (furniture, clothes comparison, etc.) – just to name a few. In comparison to VR, currently AR seems to be growing at a slower rate but with its multiple applications in different industries it stands a chance to become more popular than VR. The jury is still out as things have just started evolving in this fascinating space.

All these innovations in AR and VR will place new demands on the network in terms of its quality and performance. Bandwidth and latency requirements will become increasingly imperative for a high quality VR and AR experience and service providers will need to take a note of this new demand. Globally, augmented and virtual reality traffic will grow nearly 12-fold from 22 petabytes per month in 2017, to 254 petabytes per month in 2022. (See Figure 23).

Figure 23. AR and VR Mobile Data Traffic



Source: Cisco VNI Mobile, 2019

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This is a tremendous opportunity for service providers to jump in at and provide their distribution and GTM (Go To Market) muscle to further drive the adoption of VR and AR. VR and AR ecosystems are just forming now, Service providers can catch some of these early developments and gain significantly by owning or helping develop some of the AR and VR ecosystems that will ultimately drive their network connectivity offerings. Whether AR trumps VR or VR grows faster than AR remains to be seen- what is unmistakable is that there will be a resounding impact with this new technological advance.

Trend 6: Comparing Mobile Network Speed Improvements

Globally, the average mobile network connection speed in 2017 was 8.7 Mbps. The average speed will grow at a CAGR of 26.7 percent, and will reach 28.5 Mbps by 2022. Smartphone speeds, generally 3G and higher, will be on par with the overall average mobile connection by 2022. Smartphone speeds will more than triple by 2022, reaching 41.6 Mbps.

Anecdotal evidence supports the idea that usage increases when speed increases, although there is often a delay between the increase in speed and the increased usage, which can range from a few months to several years. However, in mature markets with strong data caps implementation, evidence points to the fact that the increase in speed may not lead to the increase in usage of mobile data. The Cisco VNI Mobile Forecast relates application bit rates to the average speeds in each country. Many of the trends in the resulting traffic forecast can be seen in the speed forecast, such as the high growth rates for developing countries and regions relative to more developed areas (Table 3).

	2017	2018	2019	2020	2021	2022	CAGR 2017–2022
Global							
Global speed: All Connections	8.7	13.2	17.7	21.0	24.8	28.5	26.7%
Global speed: Smartphones	13.5	14.9	22.1	25.9	34.8	41.6	25.2%
Global speed: Tablets	22.6	24.5	25.9	32.9	40.5	57.2	20.4%
By Region							
Asia Pacific	10.6	14.3	18.0	21.7	25.3	28.8	22.1%
Latin America	4.9	8.0	11.2	13.0	15.3	17.7	29.6%
North America	16.3	21.6	27.0	31.9	36.9	42.0	20.9%
Western Europe	16.0	23.6	31.2	37.2	43.8	50.5	25.8%
Central and Eastern Europe	10.1	12.9	15.7	19.5	22.8	26.2	21.0%
Middle East and Africa	4.4	6.9	9.4	11.2	13.2	15.3	28.0%

Note: Current and historical speeds are based on data from Ookla's Speedtest. Forward projections for mobile data speeds are based on third-party forecasts for the relative proportions of 2G, 3G, 3.5G, 4G and 5G among mobile connections through 2022.

Source: Cisco VNI Mobile, 2019

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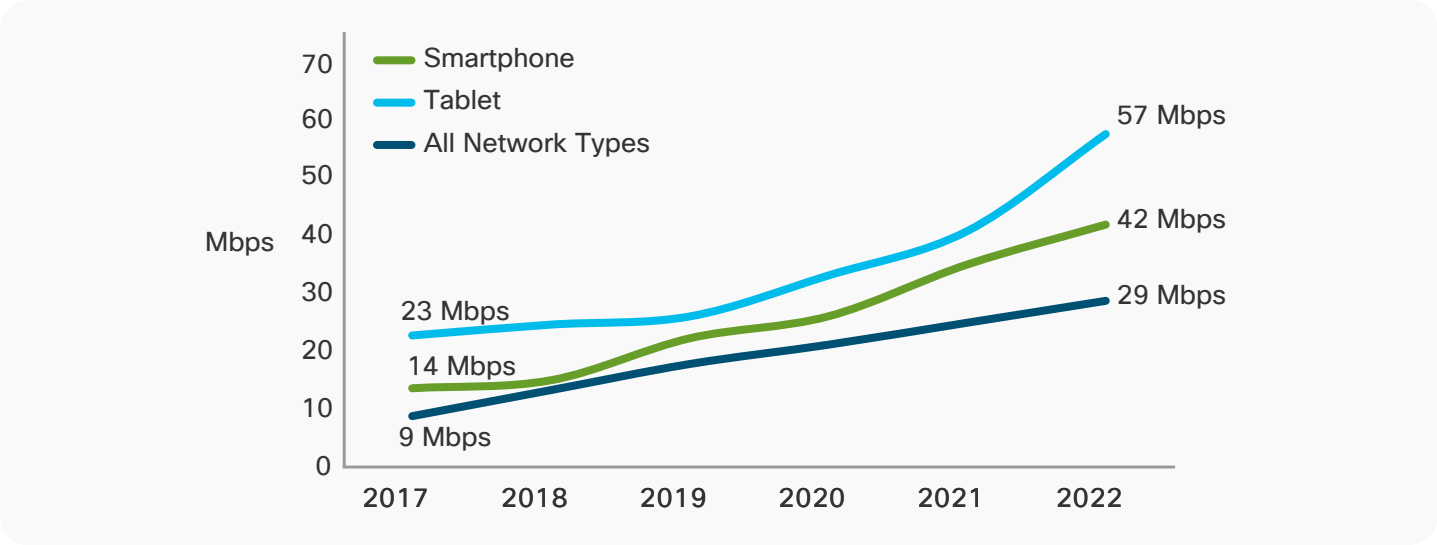
The speed at which data can travel to and from a mobile device can be affected in two places: the infrastructure speed capability outside the device and the connectivity speed from the network capability inside the device (Figure 24).

These speeds are actual and modeled end-user speeds and not theoretical speeds that the devices, connection, or technology is capable of providing. Several variables affect the performance of a mobile connection: rollout of 2G, 3G, and 4G, and now 5G in various countries and regions, technology used by the cell towers, spectrum availability, terrain, signal strength, standard ratifications and number of devices sharing a cell tower. The type of application the end user uses is also an important factor. Increase in speeds by 2022 is due to the expected rollout and commercial deployment of 5G.

Download speed, upload speed, and latency characteristics vary widely depending on the type of application, be it video, radio, or instant messaging.

Figure 24. Mobile Speeds by Device



Source: Cisco VNI Mobile, 2019

By 2022, 4G speeds will be nearly double than that of an average mobile connection. In comparison, an average mobile connection will surpass by over 2-fold over 3G speeds by 2022. Average 5G speeds will increase from 76 Mbps in 2019 to 170 Mbps by 2022. 5G is expected to be in its infancy by 2022, globally, 5G connections will be 3.4% of total mobile connections. (Figure 25).

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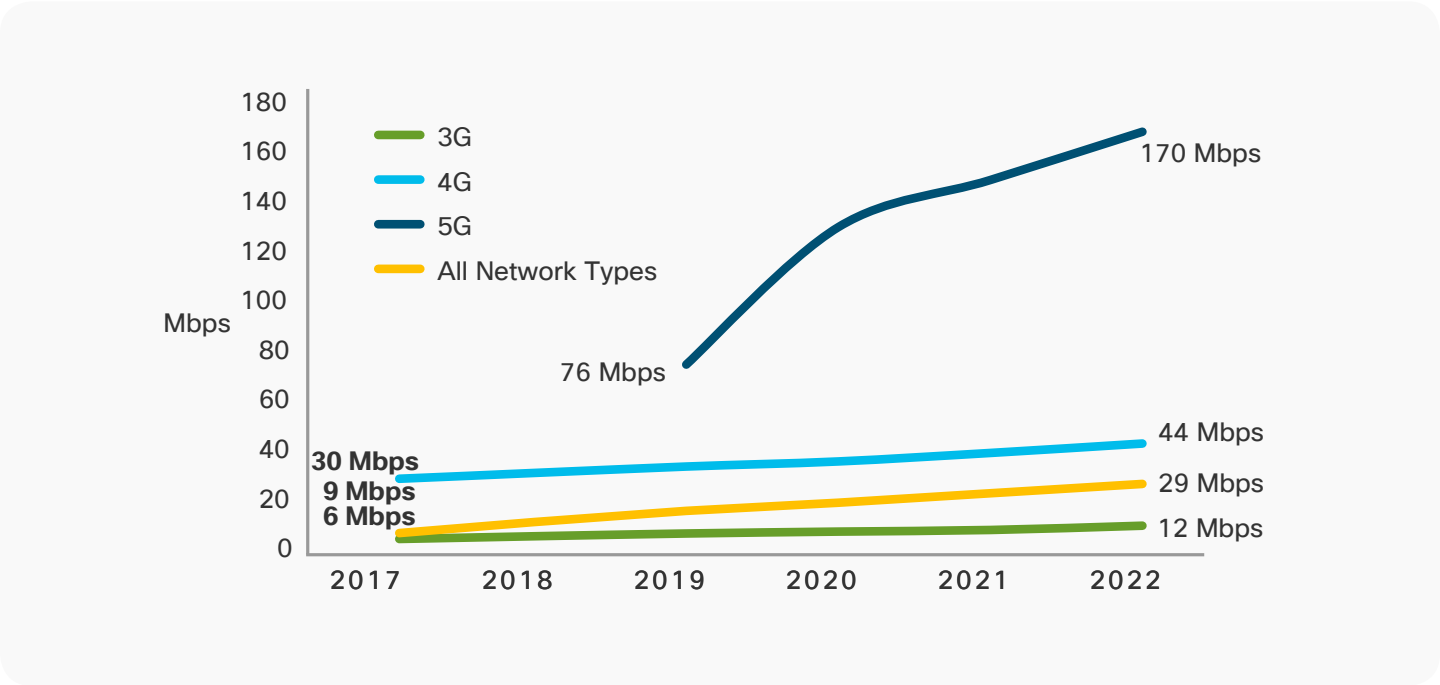
Figure 25. Mobile Speeds by Technology: 2G Versus 3G Versus 4G



Source: Cisco VNI Mobile, 2019; Ookla Speedtest.net

A slow expansion of 5G means that being first to market with 5G is less important than having a long-term strategy for 5G investment that creates value for customers. The rollout of 4G holds some important lessons. Because the quality of the mobile broadband experience relies heavily on network capability and capacity, network tests and consumer mobile broadband satisfaction tests will be even more important in the 5G world than for 4G or 3G. 5G devices will take time to roll out and become affordable. The most successful LTE operators by subscriptions either quickly moved to price LTE at the same level as 3G after the first launch of the network, or launched LTE at no premium to 3G. Tiered pricing and managing top users will remain a priority.

Trend 7: Reviewing Tiered Pricing—Unlimited Data and Shared Plans

An increasing number of service providers worldwide are moving from unlimited data plans to tiered mobile data packages. To make an estimate of the impact of tiered pricing on traffic growth, we repeated a case study based on the data of several tier 1 and tier 2 North American service providers. The study tracks data usage from the timeframe of the introduction of tiered pricing 6 years ago. The findings in this study are based on Cisco's analysis of data provided by a third-party data-analysis firm. This firm maintains a panel of volunteer participants who have given the company access to their mobile service bills, including GB of data usage. The data in this study reflects usage associated with devices (from January 2010 and August 2018) and also refers to the study from the previous update for longer-term trends. The overall study spans 7 years. Cisco's analysis of the data consists of categorizing the pricing plans, operating systems, devices, and data usage by users; incorporating additional third-party information about device characteristics; and performing exploratory and statistical data analysis. The results of the study represent actual data from a few tier 1 and tier 2 mobile data operators from North American markets, global forecasts that include emerging markets and more providers may lead to lower estimates.

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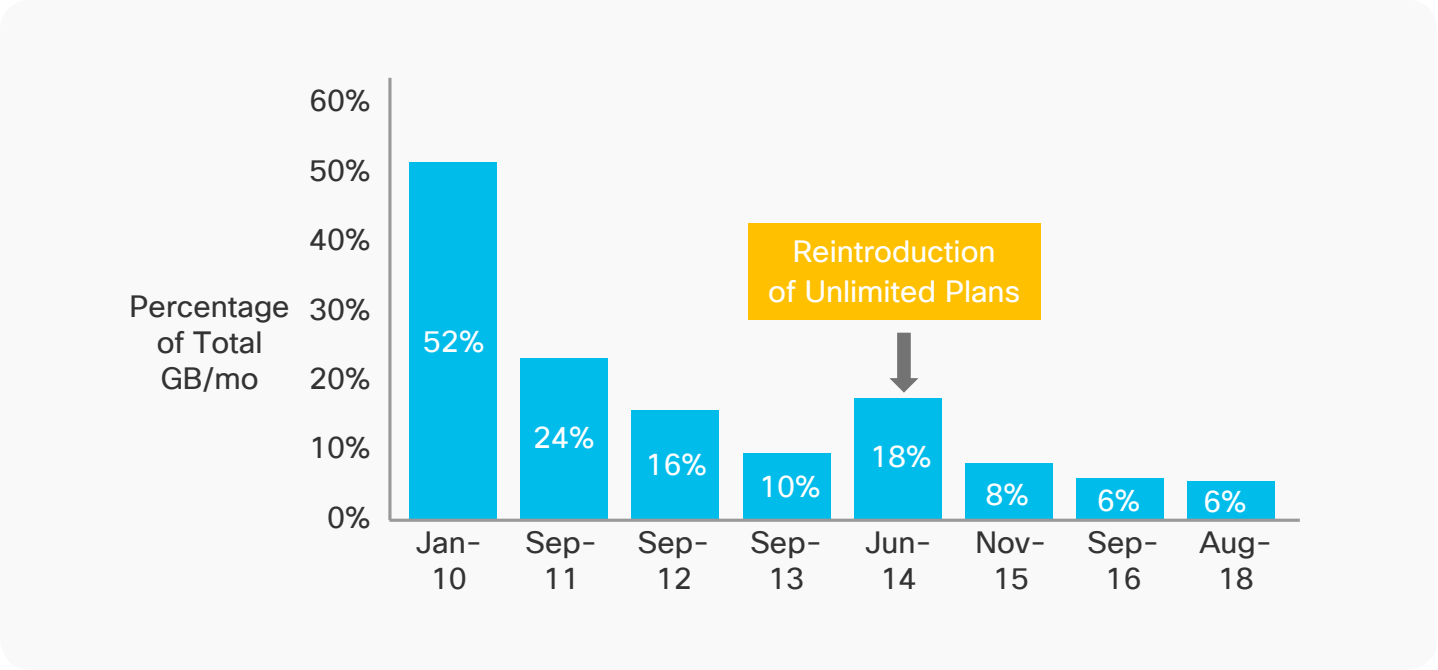
Unlimited plans had made a temporary resurgence from October 2013 to June 2014 with the increased number of unlimited plan offerings by tier 2 operators. In September 2016, 61 percent of the data plans were tiered and 39 percent of the data plans were unlimited. By August 2018, 66% of the plans were unlimited within the study. The gigabyte consumption of both tiered and unlimited plans per line has increased. On an average, usage on a device with a tiered plan grew from 1.1 GB in June 2014 to 2.9 GB in September 2016 to 3.5 in August 2018 Unlimited plans consumption grew at a faster rate, from 2.6 GB in June 2014 to 7.0 GB in September 2016 to 14.7 GB by August 2018.Tiered pricing plans are often designed to constrain the heaviest mobile data users, especially the top 1 percent of mobile data consumers.

The usage per month of the average top 1 percent of mobile data users has been steadily decreasing compared to that of overall usage. At the beginning of the 6-year study, 52 percent of the traffic was generated by the top 1 percent. With the reintroductions and promotions of unlimited plans by tier 2 operators in the study, the top 1 percent generated 18 percent of the overall traffic per month by June 2014. By August 2018, just 6 percent of the traffic was generated by the top 1 percent of users. This rate has been steady since 2016. (Figure 26).

Figure 26. Top 1 Percent Generates 52% of Monthly Data Traffic in January 2010 Compared to 6% in August 2018



Source: Cisco VNI Mobile, 2019

The top 20 percent of mobile users generate 62 percent of mobile data traffic and the top 5 percent of users consume 27 percent of mobile data traffic in the study (Figure 27).

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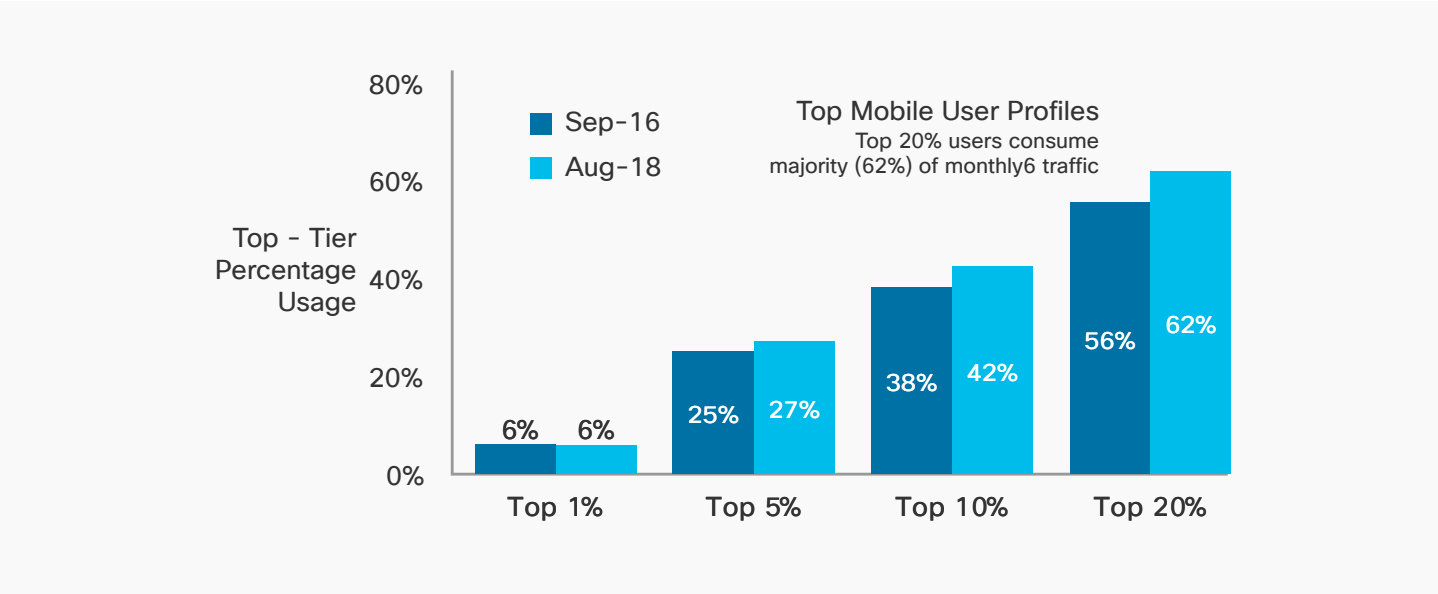
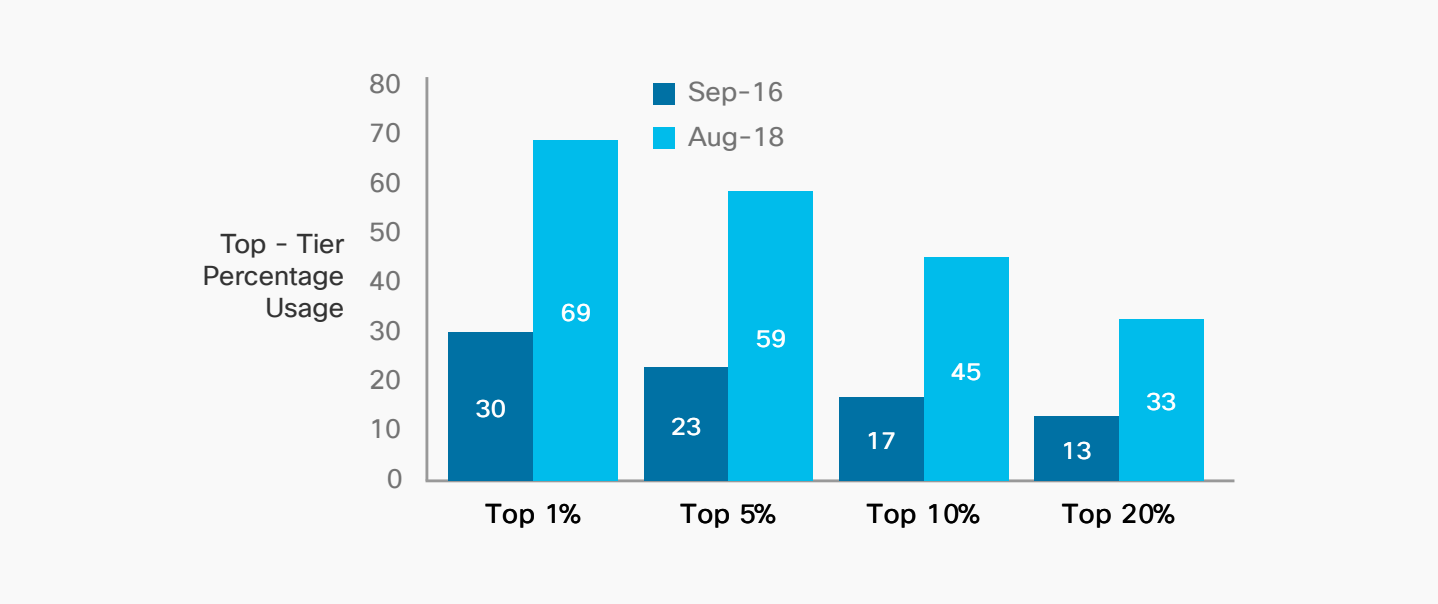
Figure 27. Top 20 Percent Consumes Nearly 62 Percent of Mobile Data Traffic



Source: Cisco VNI Mobile, 2019

With the introduction of new, larger-screen smartphones and tablets with all mobile-data-plan types, there is a continuing increase in usage in terms of gigabytes per month per user in all the top tiers (Figure 28).

Figure 28. Top 20 Percent of Average Users Consumes 33 Gigabytes per Month



Note: Study based on North American Tier 1 and Tier 2 operators.
Source: Cisco VNI Mobile, 2019

The proportion of mobile users who generated more than 2 gigabytes per month was 65 percent of users at the by September 2016, and 10 percent of the users consumed more than 10 gigabytes per month of mobile data (Figure 29) in the study. The top 10% users consume 45 GB/month as of August 2018.

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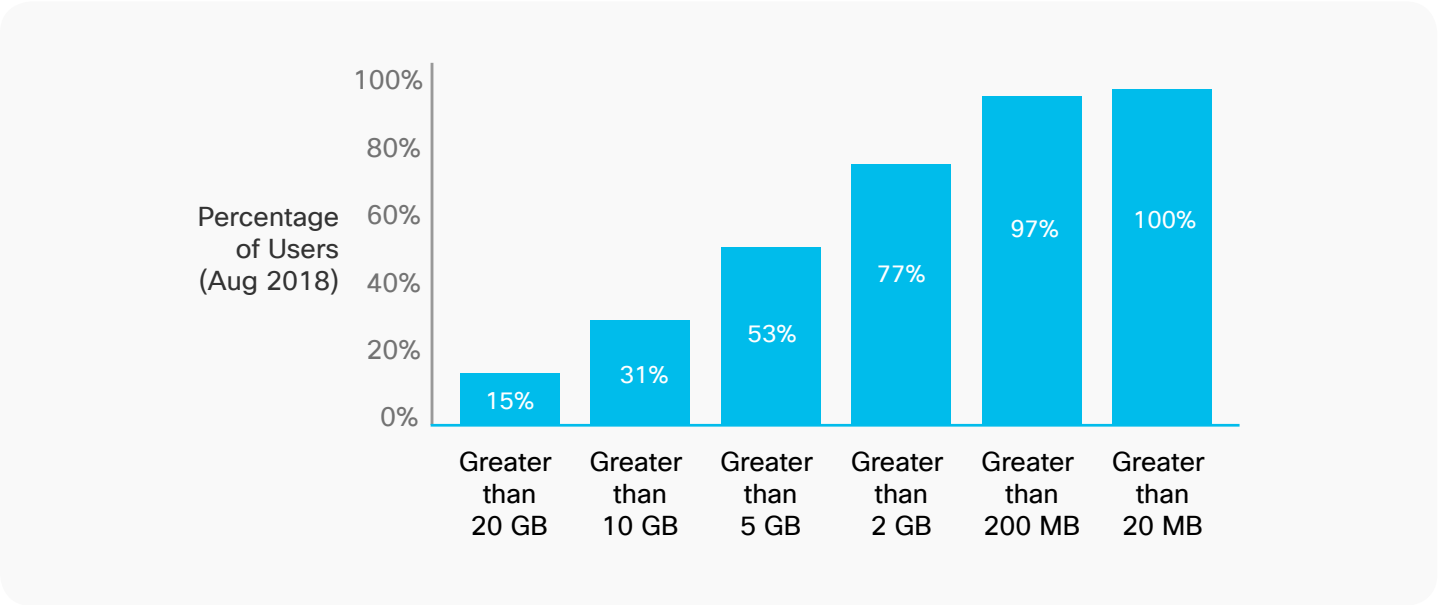
Figure 29. 65 Percent of Mobile Users Consume More Than 2 GB per Month

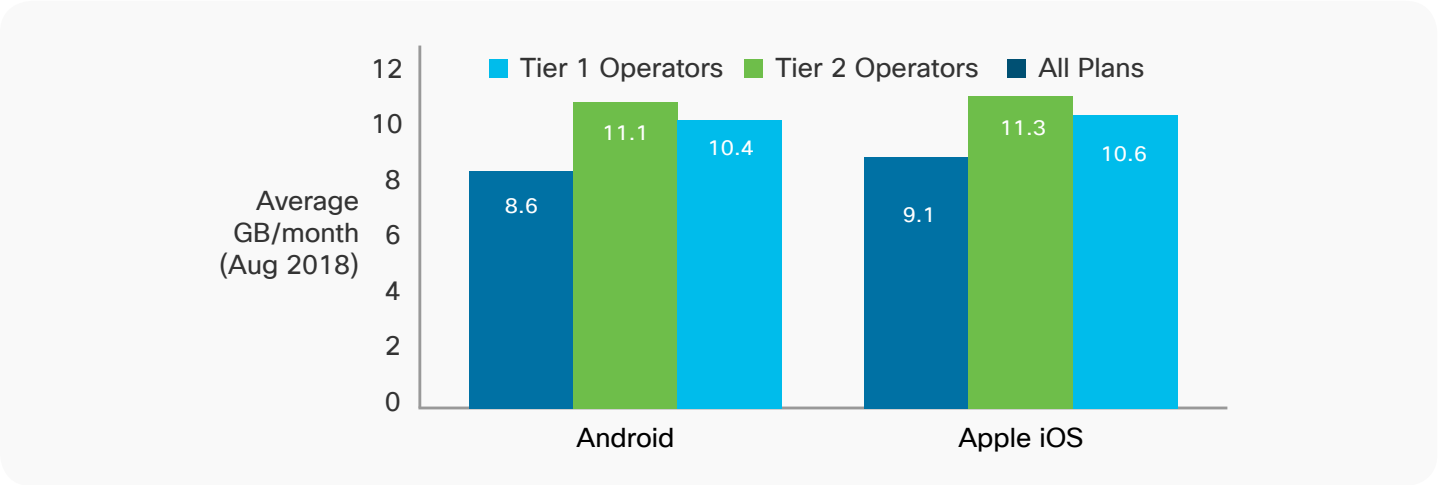


Note: Study based on North American Tier 1 and Tier 2 operators.
Source: Cisco VNI Mobile, 2019

iOS Marginally Surpasses Android in Data Usage

At the beginning of the 7-year tiered-pricing case study, Android data consumption was equal to, if not higher than, that of other smartphone platforms. However, Apple-based devices have since caught up, and their data consumption is marginally higher than that of Android devices in terms of gigabytes per month per connection usage (Figure 30).

Figure 30. Gigabytes per Month by Operating System



Note: Study based on North American Tier 1 and Tier 2 operators.
Source: Cisco VNI Mobile, 2019

Tiered plans outnumber unlimited plans; unlimited plans continue to lead in data consumption. Although the number of unlimited plans with tier 1 operators is declining, users with tier 1 operators have a higher average usage in gigabytes/month with unlimited plans (Figure 31).

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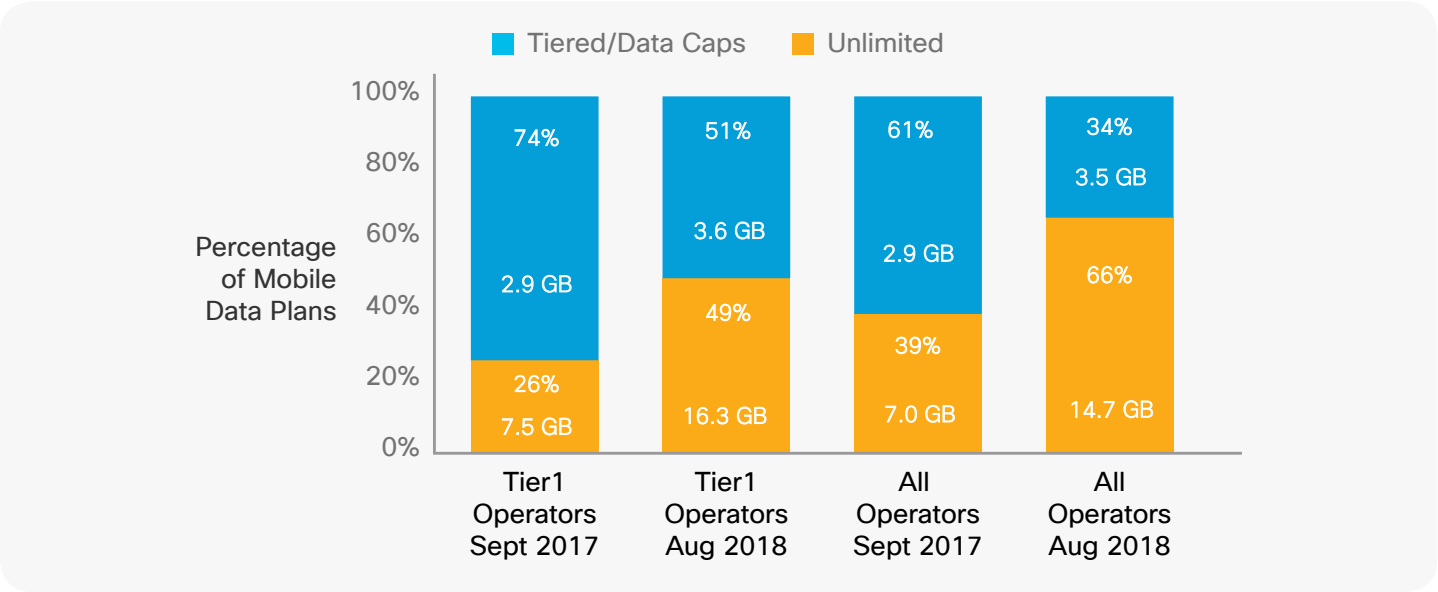
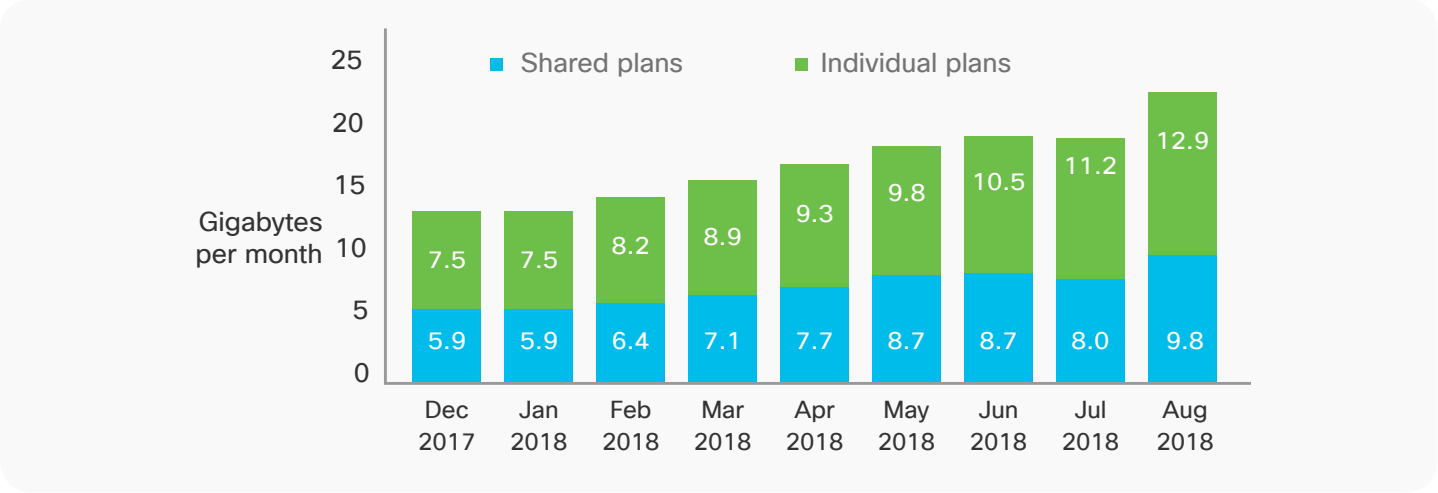
Figure 31. Tiered vs. Unlimited Plans



Note: Study based on to North American Tier 1 and Tier 2 operators.
Source: Cisco VNI Mobile, 2019

The number of shared plans is now a majority (76%) as compared to that of individual plans. The average data usage for shared plans is approaching that of individual plans (Figure 32).

Figure 32. Shared vs. Individual Data Plans



Note: Study based on to North American Tier 1 and Tier 2 operators.
Source: Cisco VNI Mobile, 2019

Besides mainstream mobile devices, billions of IoT connections will be added over next 5 years. These connections are predominantly either on Wi-Fi and/or on cellular networks. There are immense implications on the network design and readiness front with the slew of IoT devices coming on to the network, be it Wi-Fi or mobile. Mobile data plans will need to evolve to accommodate the large mix and types of connections for end consumers and subscribers.

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Conclusion

Mobile connectivity has become essential for many network users. Most people already consider mobile voice service a necessity, and mobile voice, data, and video services are fast becoming an integral part of consumers and business users' lives. Used extensively by consumer as well as enterprise segments, with impressive uptakes in both developed and emerging markets, mobility has proved to be transformational. The number of mobile subscribers has grown rapidly, and bandwidth demand for data and video content continues to increase. Mobile M2M connections represent the fastest growing device/connection category in our forecast. The next 5 years are projected to provide unabated mobile video adoption. Backhaul capacity and efficiency must increase so mobile broadband, data access, and video services can effectively support consumer usage trends and keep mobile infrastructure costs in check.

We continue to see evolution of mobile networks. While 4G or LTE connectivity is forecasted to have the primary share of the market, there are field trials currently underway for 5G in some countries. Deploying next-generation mobile networks requires greater service portability and interoperability. With the proliferation of mobile and portable devices, there is an imminent need for networks to allow all these devices to be connected transparently, with the network providing high-performance computing and delivering enhanced real-time video and multimedia. New network capabilities have generated uptake of newer advanced mobile services such as augmented reality and virtual reality. We find that this continuous evolution towards enhanced bandwidth, latency, security and openness of mobile networks will broaden the range of applications and services that can be deployed, creating a highly enhanced mobile broadband experience. The expansion of wireless access (both cellular and Wi-Fi) will increase the number of consumers who can access and subsequently rely on mobile networks, creating a need for greater economies of scale and lower cost per bit.

As many business models emerge with new forms of advertising; media and content partnerships; and mobile services including M2M, live gaming, and augmented and virtual reality, a mutually beneficial situation needs to be developed for service providers and over-the-top providers. New partnerships, ecosystems, and strategic consolidations are expected to further transform the wireless networking landscape as mobile operators, content providers, application developers, and others seek to monetize the content, services, and communications that traverse mobile networks. Operators must solve the challenge of effectively monetizing video traffic while developing profitable business cases that support capital infrastructure expenditures needed for 5G. They must become more agile and able to change course quickly and provide innovative services to engage and retain a wide range of customers from technology savvy to technology agnostic. While the net neutrality regulatory process and business models of operators evolve, there is an unmet demand from consumers for the highest quality and speeds. There is a definite move towards wireless technologies becoming seamless with wired networks for ubiquitous connectivity and experiences. The next few years will be critical for operators and service providers to plan future network deployments that will create an adaptable environment in which the multitude of mobile-enabled devices and applications of the future can be deployed.

For More Information

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Appendix A: The Cisco VNI Global Mobile Data Traffic Forecast

Table 4 shows detailed data from the Cisco VNI Global Mobile Data Traffic Forecast. This forecast includes only cellular traffic and excludes traffic offloaded onto Wi-Fi and small cell from dual-mode devices. The "other portable devices" category includes readers, portable gaming consoles, and other portable devices with embedded cellular connectivity. Wearables are included in the "M2M" category.

Table 4. Global Mobile Data Traffic, 2017–2022

	2017	2018	2019	2020	2021	2022	CAGR 2017–2022
By Application Category (PB per Month)							
Video	6,821	12,051	19,279	29,149	42,734	60,889	55%
Non-Video	4,691	6,959	9,281	11,621	14,064	16,604	29%
By Device Type (PB per Month)							
Smartphones	10,132	17,172	26,122	37,548	52,560	71,975	48%
Tablets and PCs	1,021	1,311	1,675	2,140	2,744	3,525	28%
M2M	211	346	549	840	1,234	1,725	52%
Nonsmartphones	147	180	214	242	260	268	13%
Other portable devices	0.43	0.36	0.31	0.29	0.33	0.38	-3%
By Region (PB per Month)							
Asia Pacific	5,877	10,351	15,908	22,815	31,807	43,166	49%
Middle East and Africa	1,222	2,052	3,251	5,009	7,564	11,171	56%
Central and Eastern Europe	1,379	2,153	3,119	4,317	5,834	7,752	41%
North America	1,261	1,804	2,500	3,405	4,485	5,846	36%
Western Europe	1,022	1,471	2,062	2,807	3,801	5,120	38%
Latin America	752	1,178	1,720	2,418	3,308	4,439	43%
Total (PB per Month)							
Total Mobile Data Traffic	11,512	19,009	28,560	40,770	56,799	77,493	46%

Source: Cisco Mobile VNI, 2019

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The Cisco VNI Global Mobile Data Traffic Forecast relies in part upon data published by Ovum, Strategy Analytics, Infonetics, Gartner, IDC, Dell'Oro, Synergy, ACG Research, Nielsen, comScore, the International Telecommunications Union (ITU), CTIA, and telecommunications regulators in each of the countries covered by VNI.

The Cisco VNI methodology begins with the number and growth of connections and devices, applies adoption rates for applications, and then multiplies the application user base by Cisco's estimated minutes of use and KB per minute for that application. The methodology has evolved to link assumptions more closely with fundamental factors, to use data sources unique to Cisco, and to provide a high degree of application, segment, geographic, and device specificity.

- **Inclusion of fundamental factors:** As with the fixed IP traffic forecast, each Cisco VNI Global Mobile Data Traffic Forecast update increases the linkages between the main assumptions and fundamental factors such as available connection speed, pricing of connections and devices, computational processing power, screen size and resolution, and even device battery life. This update focuses on the relationship of mobile connection speeds and the KB-per-minute assumptions in the forecast model.
- **Device-centric approach:** As the number and variety of devices on the mobile network continue to increase, it becomes essential to model traffic at the device level rather than the connection level. This Cisco VNI Global Mobile Data Traffic Forecast update details traffic to smartphones; nonsmartphones; laptops, tablets, and netbooks; e-readers; digital still cameras; digital video cameras; digital photo frames; in-car entertainment systems; and handheld gaming consoles.
- **Estimation of the impact of traffic offload:** The Cisco VNI Global Mobile Data Traffic Forecast model now quantifies the effect of dual-mode devices and femtocells on handset traffic. Data from the USC Institute for Communication Technology Management's annual mobile survey was used to model offload effects.

Appendix B: Global 4G Networks and Connections

Tables 5 and 6 show the regional 4G and 5G connections for 2022 and wearable devices growth, respectively.

Table 5. Regional 4G and 5G Connections by 2022

	Number of 4G Connections (M)	% of Regional Connections	Number of 5G Connections (M)	% of Regional Connections
Asia Pacific	3,850	61%	229	4%
Central and Eastern Europe	579	63%	5	0.5%
Latin America	559	58%	10	1%
Middle East and Africa	419	23%	3	0.2%
North America	589	51%	102	9%
Western Europe	678	58%	74	6%
Global	6,675	54%	422	3%

Source: Cisco Mobile VNI, 2019

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Table 6. Regional Wearable Devices Growth

	2017		2022	
	Number of 4G Connections (M)	% of Regional Connections	Number of 5G Connections (M)	% of Regional Connections
Asia Pacific	155	29%	311	28%
Central and Eastern Europe	28	5%	68	6%
Latin America	18	3%	49	4%
Middle East and Africa	21	4%	46	4%
North America	217	41%	439	40%
Western Europe	88	17%	192	17%
Global	526	100%	1,105	100%

Source: Cisco Mobile VNI, 2019

Appendix C: IPv6-Capable Devices, 2017–2022

Table 7 provides regional IPv6-capable forecast details.

Table 7. IPv6-Capable Devices by Region, 2017–2022

	2017	2018	2019	2020	2021	2022	CAGR 2017–2022
Global	4,036	5,098	6,101	7,129	8,262	9,403	18%
Asia Pacific	1,891	2,406	2,865	3,373	3,926	4,413	18%
Central and Eastern Europe	418	501	570	603	655	716	11%
Latin America	387	479	548	629	701	803	16%
Middle East and Africa	452	657	886	1,102	1,279	1,467	27%
North America	416	507	591	694	862	1,057	21%
Western Europe	472	547	640	728	840	947	15%

Source: Cisco Mobile VNI, 2019

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