Cisco Visual Networking Index: Forecast and Trends, 2017–2022

This forecast is part of the Cisco® Visual Networking Index™ (Cisco VNI™), an ongoing initiative to track and forecast the impact of visual networking applications. This document presents the details of the Cisco VNI global IP traffic forecast, key trends and the underlying methodology. For more global, regional and select country-level projections, refer to the VNI Forecast Highlights tool.

Executive summary

Global traffic projections

Annual global IP traffic will reach 4.8 ZB per year by 2022, or 396 Exabytes (EB) per month. In 2017, the annual run rate for global IP traffic was 1.5 ZB per year, or 122 EB per month.

Global IP traffic will increase threefold over the next 5 years. Overall, IP traffic will grow at a Compound Annual Growth Rate (CAGR) of 26 percent from 2017 to 2022. Monthly IP traffic will reach 50 GB per capita by 2022, up from 16 GB per capita in 2017.

Busy hour Internet traffic is growing more rapidly than average Internet traffic. Busy hour (or the busiest 60minute period in a day) Internet traffic will increase by a factor of 4.8 between 2017 and 2022, and average Internet traffic will increase by a factor of 3.7.

Global internet users and devices/Connections

The number of devices connected to IP networks will be more than three times the global population by 2022. There will be 3.6 networked devices per capita by 2022, up from 2.4 networked devices per capita in 2017. There will be 28.5 billion networked devices by 2022, up from 18 billion in 2017.

M2M connections will be more than half of the global connected devices and connections by 2022. The share of M2M connections will grow from 34 percent in 2017 to 51 percent by 2022. There will be 14.6 billion M2M connections by 2022.

Smartphone traffic will exceed PC traffic. In 2018, PCs accounted for 41 percent of total IP traffic, but by 2022 PCs will account for only 19 percent of IP traffic. Smartphones will account for 44 percent of total IP traffic by 2022, up from 18 percent in 2017.

Contents

Global network access/Connectivity trends (Fixed/Mobile/Wi-Fi)

Traffic from wireless and mobile devices will account for 71 percent of total IP traffic by 2022. By 2022, wired devices will account for 29 percent of IP traffic, and Wi-Fi and mobile devices will account for 71 percent of IP traffic. In 2017, also, wired devices accounted for less than half of the global IP traffic, at 48 percent.

Globally, mobile data traffic will increase sevenfold between 2017 and 2022. Mobile data traffic will grow at a CAGR of 46 percent between 2017 and 2022, reaching 77.5 exabytes per month by 2022.

Global mobile data traffic will grow nearly twice as fast as fixed IP traffic from 2017 to 2022. Fixed IP traffic will grow at a CAGR of 24 percent between 2017 and 2022, while mobile traffic grows at a CAGR of 46 percent. Global mobile data traffic was 9 percent of total IP traffic in 2017 and will be 20 percent of total IP traffic by 2022.

Global application trends

Globally, IP video traffic will be 82 percent of all IP traffic (both business and consumer) by 2022, up from 75 percent in 2017. Global IP video traffic will grow four-fold from 2017 to 2022, a CAGR of 29 percent. Internet video traffic will grow fourfold from 2017 to 2022, a CAGR of 33 percent.

Live Internet video will account for 17 percent of Internet video traffic by 2022. Live video will grow 15-fold from 2017 to 2022.

Internet video surveillance traffic will increase sevenfold between 2017 to 2022. Globally, 3 percent of all Internet video traffic will be due to video surveillance by 2022, up from 2 percent in 2017.

Virtual Reality (VR) and Augmented Reality (AR) traffic will increase 12-fold between 2017 and 2022 globally, a CAGR of 65 percent.

Internet video to TV will increase threefold between 2017 to 2022. Internet video to TV will be 27 percent of fixed consumer Internet video traffic by 2022.

Consumer Video-on-Demand (VoD) traffic will nearly double by 2022. The amount of VoD traffic by 2022 will be equivalent to 10 billion DVDs per month.

Internet gaming traffic will grow ninefold from 2017 to 2022, a CAGR of 55 percent. Globally, Internet gaming traffic will be 4 percent of global IP traffic by 2022, up from 1 percent in 2017.

Global network performance

Broadband speeds will nearly double by 2022. By 2022, global fixed broadband speeds will reach 75.4 Mbps, up from 39 Mbps in 2017.

Global traffic topology

Content Delivery Networks (CDNs) will carry 72 percent of Internet traffic by 2022 up from 56 percent in 2017.

Thirty-three percent of service provider network capacity will be within a metro network by 2022, up from 27 percent in 2017.

Global 5G mobile highlights

5G devices and connections will be over 3 percent of global mobile devices and connections by 2022. By 2022, global mobile devices will grow from 8.6 billion in 2017 to 12.3 billion by 2022 – over 422 million of those will be 5G capable.

Nearly twelve percent of global mobile traffic will be on 5G cellular connectivity by 2022. Globally, the average 5G connection will generate 21 GB of traffic per month by 2022.

Regional highlights

IP traffic is growing fastest in the Middle East and Africa, followed by Asia Pacific. Traffic in the Middle East and Africa will grow at a CAGR of 41 percent between 2017 and 2022.

Summary of regional growth rates:

- IP traffic in Asia Pacific will reach 172.7 EB per month by 2022, growing at a CAGR of 32 percent.
  - By 2022, APAC will have 2.6 billion Internet users (62 percent of population), up from 1.7 billion (41 percent of population) in 2017.
  - By 2022, APAC will have 13.1 billion networked devices/connections, up from 8.6 billion in 2017.
  - By 2022, APAC's average fixed broadband speed will reach 98.8 Mbps, 2.1-fold growth from 2017 (46.2 Mbps)
- IP traffic in North America will reach 108.4 EB per month by 2022, growing at a CAGR of 21 percent.
  - By 2022, NA will have 353 million Internet users (94 percent of population), up from 331 million (92 percent of population) in 2017.
  - By 2022, NA will have 5.0 billion networked devices/connections, up from 2.9 billion in 2017.
  - By 2022, NA's average fixed broadband speed will reach 94.2 Mbps, 2.2-fold growth from 2017 (43.2 Mbps)
- IP traffic in Western Europe will reach 49.9 EB per month by 2022, growing at a CAGR of 22 percent.
  - By 2022, WE will have 380 million Internet users (89 percent of population), up from 358 million (85 percent of population) in 2017.
  - By 2022, WE will have 4.0 billion networked devices/connections, up from 2.3 billion in 2017.
  - By 2022, WE's average fixed broadband speed will reach 76.0 Mbps, 2.0-fold growth from 2017 (37.9 Mbps)
    IP traffic in Central and Eastern Europe will reach 25.3 EB per month by 2022, growing at a CAGR of 26 percent.
  - By 2022, CEE will have 364 million Internet users (73 percent of population), up from 332 million (68 percent of population) in 2017.
  - By 2022, CEE will have 2.0 billion networked devices/connections, up from 1.2 billion in 2017.
  - By 2022, CEE's average fixed broadband speed will reach 46.7 Mbps, 1.4-fold growth from 2017 (32.8 Mbps)

- IP traffic in the Middle East and Africa will reach 20.9 EB per month by 2022, growing at a CAGR of 41 percent.
  - By 2022, MEA will have 549 million Internet users (32 percent of population), up from 388 million (23 percent of population) in 2017.
  - By 2022, MEA will have 2.5 billion networked devices/connections, up from 1.7 billion in 2017.
  - By 2022, MEA's average fixed broadband speed will reach 20.2 Mbps, 2.0-fold to 2.6-fold growth from 2017 (7.8 Mbps)
- IP traffic in Latin America will reach 18.8 EB per month by 2022, growing at a CAGR of 21 percent.
  - By 2022, LATAM will have 465 million Internet users (69 percent of population), up from 368 million (57 percent of population) in 2017.
  - By 2022, LATAM will have 2.0 billion networked devices/connections, up from 1.4 billion in 2017.
  - By 2022, LATAM's average fixed broadband speed will reach 28.1 Mbps, 2.4-fold growth from 2017 (11.7 Mbps).

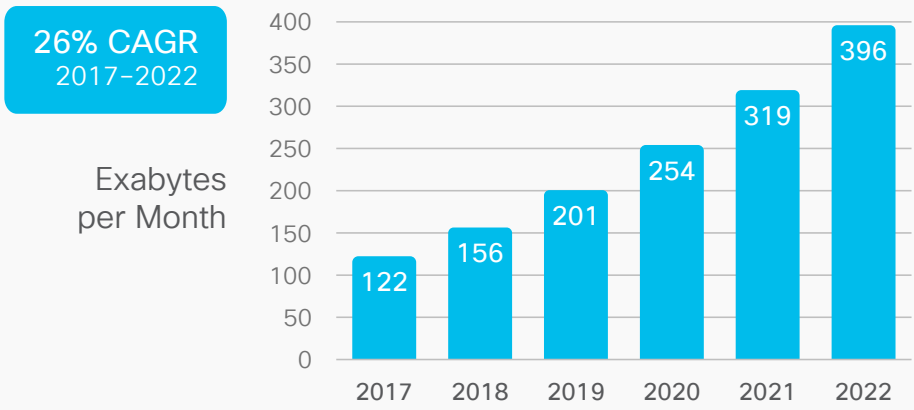
Forecast overview

The current Cisco Visual Networking Index (VNI) forecast projects global IP traffic to nearly triple from 2017 to 2022. The appendix offers a detailed summary.

Overall IP traffic is expected to grow to 396 EB per month by 2022, up from 122 EB per month in 2017, a CAGR of 26 percent (Figure 1). This growth represents a slight increase in expectations over last year's forecast, which projected a CAGR of 24 percent from 2016 to 2021, driven by an increase in the growing share of mobile traffic as a percentage of the total IP traffic.

Also, of note in the recent forecast is the growing number of countries whose fixed traffic growth rivals that of their mobile traffic growth. United States is the outlier, with a fixed growth of 26 percent in 2017 and a mobile growth of 23 percent over the same time period. Japan, Korea, Canada, Germany and Sweden, all have fixed growth that is only slightly lower than their mobile growth. The majority of countries still have significantly higher growth rates for mobile than for fixed.

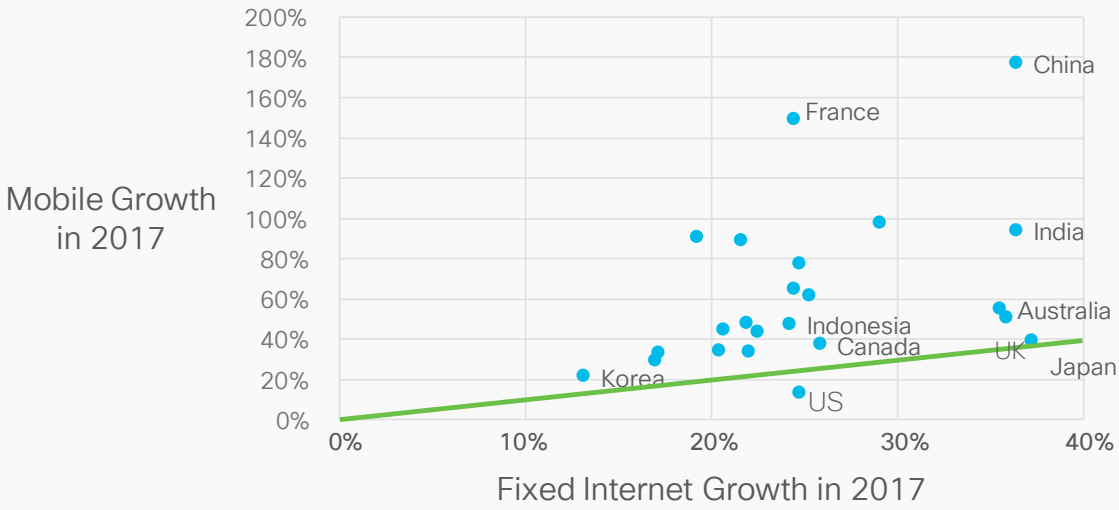
Figure 1. Cisco VNI forecasts 396 EB per month of IP traffic by 2022



Source: Cisco VNI Global IP Traffic Forecast, 2017–2022

For more details about Cisco's forecasting methodology, refer to the appendix.

Figure 2. Fixed and mobile Internet traffic growth rates, 2017



Source: Cisco VNI Global IP Traffic Forecast, 2017–2022

Total Internet traffic has experienced dramatic growth in the past two decades. More than 20 years ago, in 1992, global Internet networks carried approximately 100 GB of traffic per day. Ten years later, in 2002, global Internet traffic amounted to 100 Gigabytes per second (GB/second). In 2017, global Internet traffic reached more than 45,000 GB/second. Table 1 provides a view of the historical benchmarks for total Internet traffic.

Table 1. The Cisco VNI forecast: historical Internet context

Year	Global internet traffic
1992	100 GB per day
1997	100 GB per hour
2002	100 GB per second
2007	2,000 GB per second
2017	46,600 GB per second
2022	150,700 GB per second

Source: Cisco VNI, 2018.

Per capita IP and Internet traffic growth has followed a similarly steep growth curve over the past decade. Globally, monthly IP traffic will reach 50 GB per capita by 2022, up from 16 GB per capita in 2017, and Internet traffic will reach 44 GB per capita by 2022, up from 13 GB per capita in 2017. Ten years ago, in 2007, per capita Internet traffic was well under 1 GB per month. In 2000, per capita Internet traffic was 10 Megabytes (MB) per month.

The sections that follow explore the trends contributing to the continued growth of global IP traffic.

Trends

Trend 1: Continued shifts in mix of devices and connections

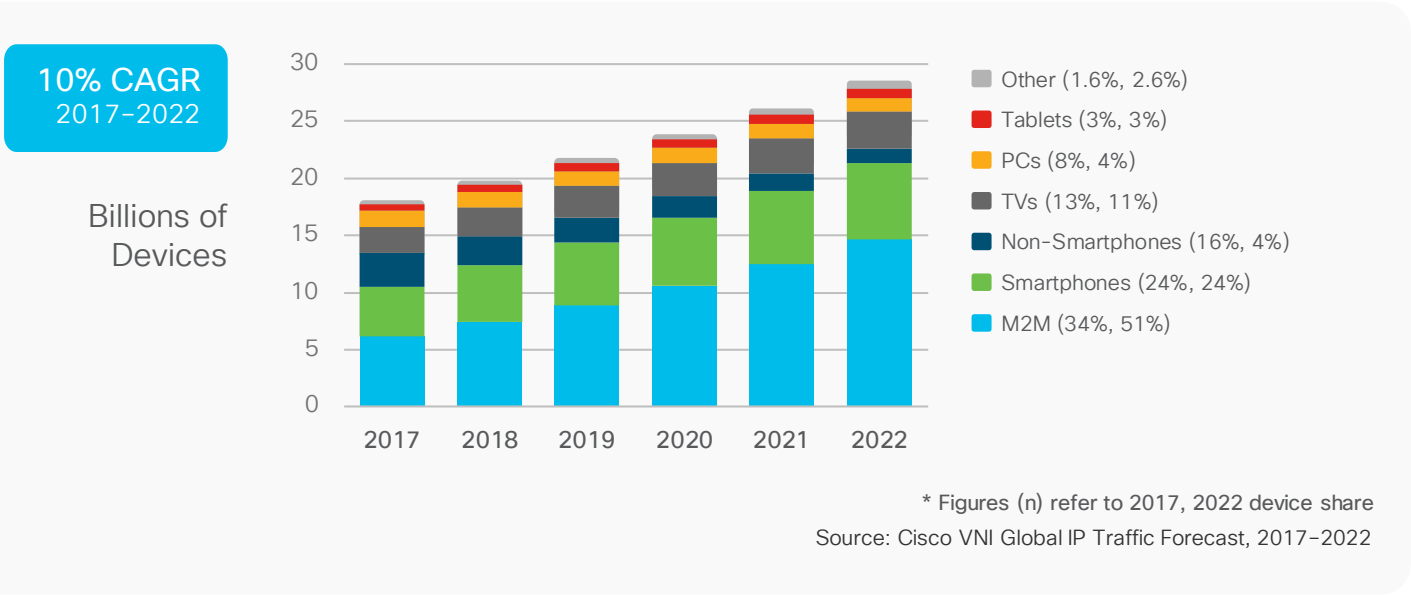
Globally, devices and connections are growing faster (10 percent CAGR) than both the population (1.0 percent CAGR) and Internet users (7 percent CAGR). This trend is accelerating the increase in the average number of devices and connections per household and per capita. Each year, various new devices in different form factors with increased capabilities and intelligence are introduced and adopted in the market. A growing number of M2M applications, such as smart meters, video surveillance, healthcare monitoring, transportation, and package or asset tracking, are contributing in a major way to the growth of devices and connections. By 2022, M2M connections will be 51 percent of the total devices and connections.

M2M connections will be the fastest-growing category, growing nearly 2.4-fold during the forecast period, at 19 percent CAGR, to 14.6 billion connections by 2022.

Smartphones will grow the second fastest, at a 9 percent CAGR (increasing by a factor of 1.6). Connected TVs (which include flat-panel TVs, set-top boxes, digital media adapters [DMAs], Blu-ray disc players, and gaming consoles) will grow next fastest at 7 percent CAGR, to 3.2 billion by 2022. PCs will continue to decline (a 2.5 percent decline) over the forecast period. However, there will more PCs than tablets throughout the forecast period and by the end of 2022 (1.2 billion PCs vs. 790 million tablets).

By 2022, the consumer share of the total devices, including both fixed and mobile devices, will be 72 percent, with business claiming the remaining 28 percent. Consumer share will grow at a slightly slower rate, at an 8.8 percent CAGR relative to the business segment, which will grow at a 12.0 percent CAGR.

Figure 3. Global devices and connections growth



* Figures (n) refer to 2017, 2022 device share

Source: Cisco VNI Global IP Traffic Forecast, 2017–2022

Globally, the average number of devices and connections per capita will grow from 2.4 in 2017 to 3.6 by 2022 (Table 2).

Among the countries that will have the highest average of per capita devices and connections by 2022 are the United States (13.6), South Korea (11.8), and Canada (11.0).

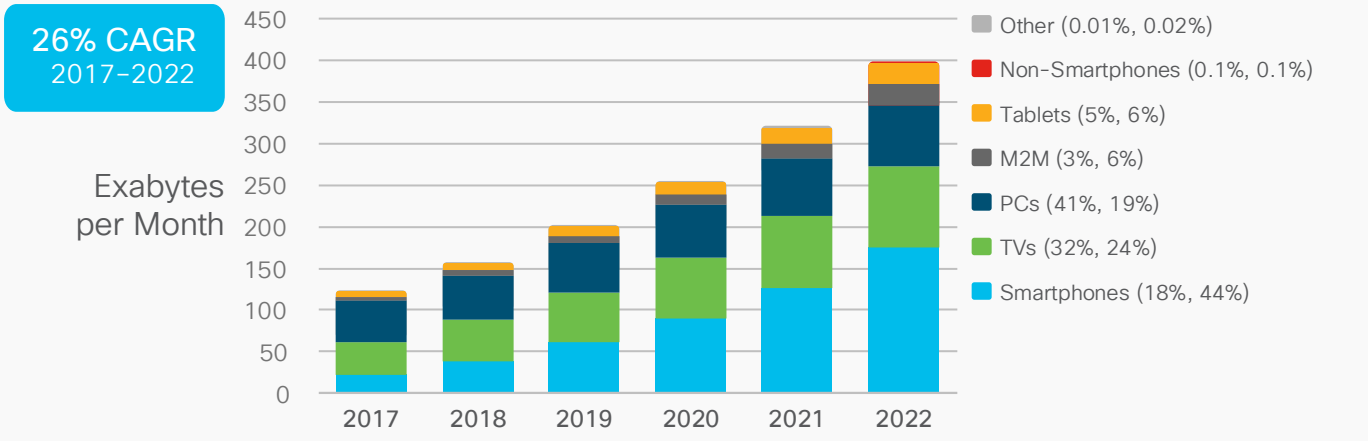
Table 2. Average number of devices and connections per capita

	2017	2022
Asia Pacific	2.1	3.1
Central and Eastern Europe	2.5	3.9
Latin America	2.1	2.9
Middle East and Africa	1.1	1.4
North America	8.0	13.4
Western Europe	5.4	9.4
Global	2.4	3.6

Source: Cisco VNI, 2018.

The changing mix of devices and connections and growth in multidevice ownership affects traffic and can be seen in the changing device contribution to total IP traffic. At the end of 2017, 59 percent of IP traffic and 51 percent of Internet traffic originated from non-PC devices. By 2022, 81 percent of IP traffic and Internet traffic will originate from non-PC devices (Figure 4).

Figure 4. Global IP traffic by devices

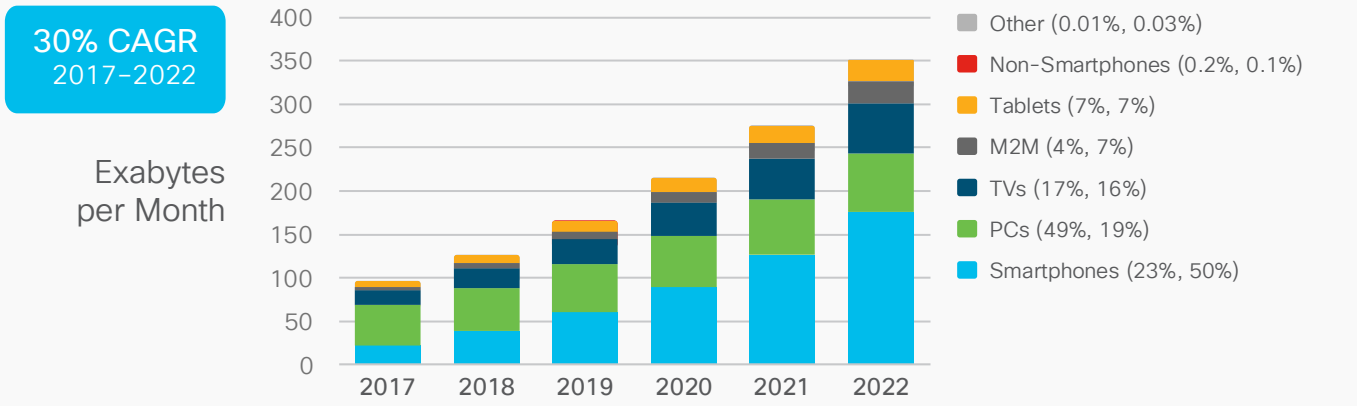


* Figures (n) refer to 2017, 2022 traffic share

Source: Cisco VNI Global IP Traffic Forecast, 2017–2022

As in the case of mobile networks, video devices can have a multiplier effect on traffic. An Internet-enabled HD television that draws 2 hours of content per day from the Internet would generate as much Internet traffic as an entire household today. With the growth of video viewing on smartphones and tablets, traffic from these devices is growing as a percentage of total Internet traffic. Share of PCs to total global Internet traffic will decline to 19 percent by 2022, down from 49 percent in 2017. Smartphones will account for 50 percent of total global Internet traffic by 2022, up from 23 percent in 2017 (Figure 5).

Figure 5. Global internet traffic by device type

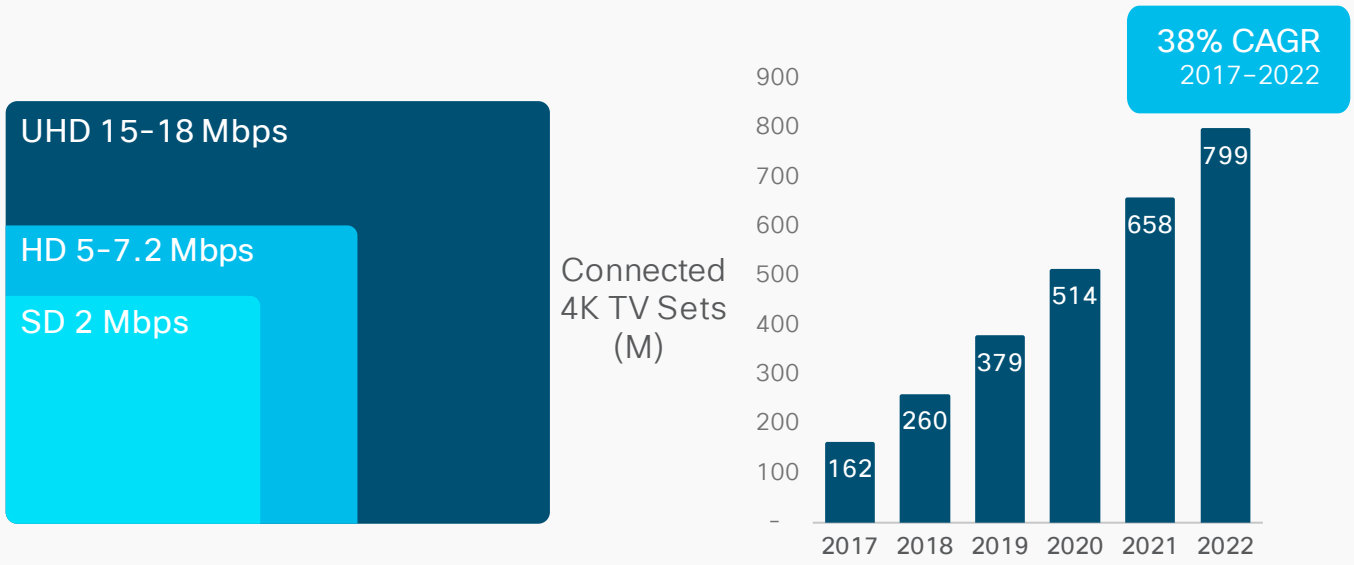


* Figures (n) refer to 2017, 2022 traffic share

Source: Cisco VNI Global IP Traffic Forecast, 2017–2022

The video effect of the devices on the traffic is more pronounced because of the introduction of Ultra-High- Definition (UHD), or 4K, video streaming. This technology has such an effect because the bit rate for 4K video at about 15 to 18 Mbps is more than double the HD video bit rate and nine times more than Standard-Definition (SD) video bit rate. We estimate that by 2022, nearly two-thirds (62 percent) of the installed flat-panel TV sets will be UHD, up from 23 percent in 2017 (Figure 6).

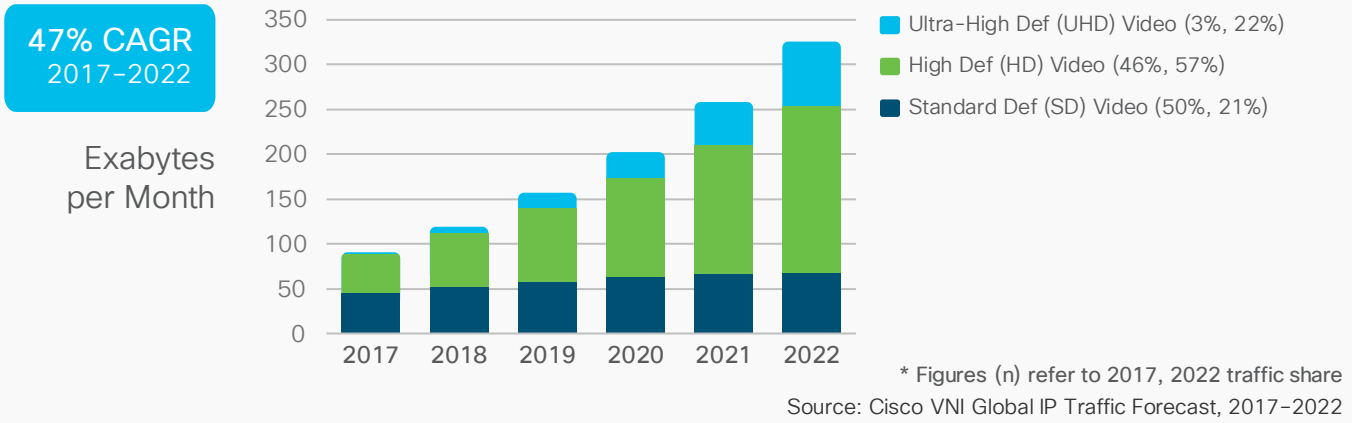
Figure 6. Increasing video definition: By 2022, 62 percent of connected Flat-Panel TV sets will be 4K



Source: Cisco VNI Global IP Traffic Forecast, 2017–2022

UHD (or 4K) IP VoD will account for 22 percent of global IP Video traffic by 2022 (Figure 7). UHD as a percentage of IP VoD traffic will be higher at 35 percent by 2022.

Figure 7. Global UHD IP video traffic



* Figures (n) refer to 2017, 2022 traffic share

Source: Cisco VNI Global IP Traffic Forecast, 2017–2022

Trend 2: IPv6 adoption enables Internet of Things (IoT) connectivity

The transition from an IPv4 environment to an IPv6 environment is making excellent progress, with increases in IPv6 device capabilities, content enablement, and operators implementing IPv6 in their networks. These developments are particularly important because Asia, Europe, North America, and Latin America have already exhausted their IPv4 allotments, and Africa is expected to exhaust its allotment by 2019.

Table 3 shows the projected exhaustion dates as of October 2018, according to the IPv4 Exhaustion Counter and Regional Internet Registries (RIR).

Table 3. IPv4 address exhaustion dates

Regional Internet Registries	Exhaustion Date
Asia Pacific Network Information Centre (APNIC)	April 15, 2011 (actual)
Réseaux IP Européens Network Coordination Centre (RIPE NCC)	September 14, 2012 (actual)
Latin America and Caribbean Network Information Centre (LACNIC)	June 10, 2014 (actual)
American Registry for Internet Numbers (ARIN)	September 24, 2015 (actual)
African Network Information Center (AFRINIC)	May 23, 2019 (projected)

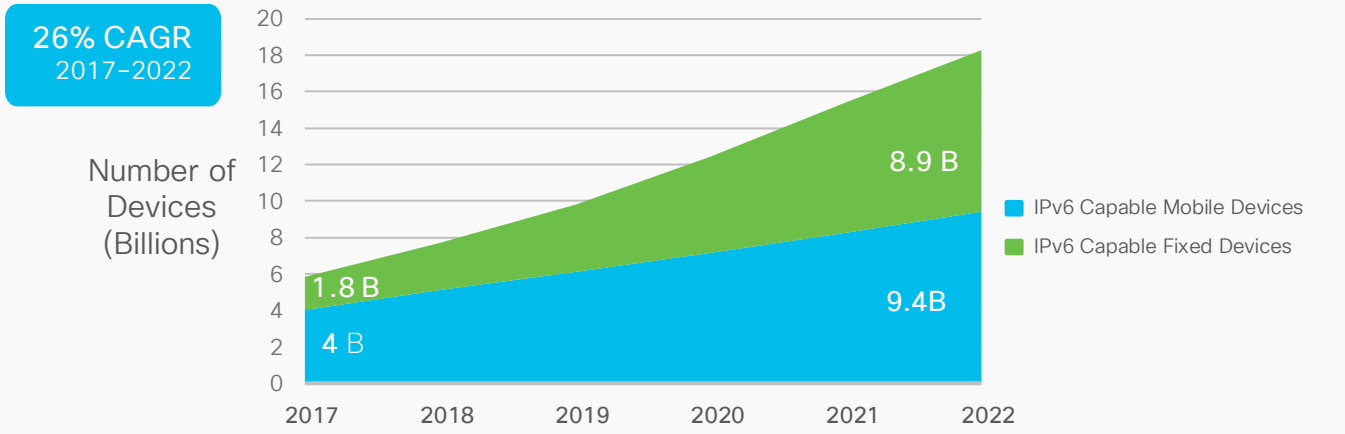
Building on the Cisco VNI IPv6-capable devices analysis, the forecast estimates that globally there will be nearly 18.3 billion IPv6-capable fixed and mobile devices by 2022, up from nearly 6 billion in 2017, a CAGR of 26 percent. In terms of percentages, 64 percent of all fixed and mobile networked devices will be IPv6-capable by 2022, up from 32 percent in 2017 (Figure 8).

This estimate is based on the capability of the device and the network connection to support IPv6 and is not a projection of active IPv6 connections. Mobile-device IPv6 capability is assessed based on OS support of IPv6 and estimations of the types of mobile network infrastructure to which the device can connect (3.5-generation [3.5G] or later). Fixed-device IPv6 capability is assessed based on device support of IPv6 and an estimation of the capability of the residential Customer Premises Equipment (CPE) or business routers to support IPv6, depending on the device end-user segment.

Globally, fixed and mobile network operators are broadly deploying the IPv6 protocol and supporting significant volumes of IPv6 traffic as a percentage of their overall IP traffic. The range of examples include France's Free Telecom (40%), KDDI (46%), AT&T (63%), Comcast (64%), Verizon Wireless (86%), Reliance Jio (88%), and T-Mobile (94%) [Source: **World IPv6 Launch Organization**, September 2018]. Per Google, in Sept 2018, the percentage of users who access Google via IPv6 is nearly 25%; up from 11% in May 2017 [Source: Google Statistics September 2018]

Amid these industry developments, the Cisco VNI forecast is undertaking an effort to estimate the potential IPv6 network traffic that could be generated if a percentage of IPv6-capable devices become actively connected to an IPv6 network, given the estimated global average for monthly traffic per device type.

Figure 8. Global IPv6-capable devices and connections forecast, 2017–2022



Source: Cisco VNI Global IP Traffic Forecast, 2017–2022

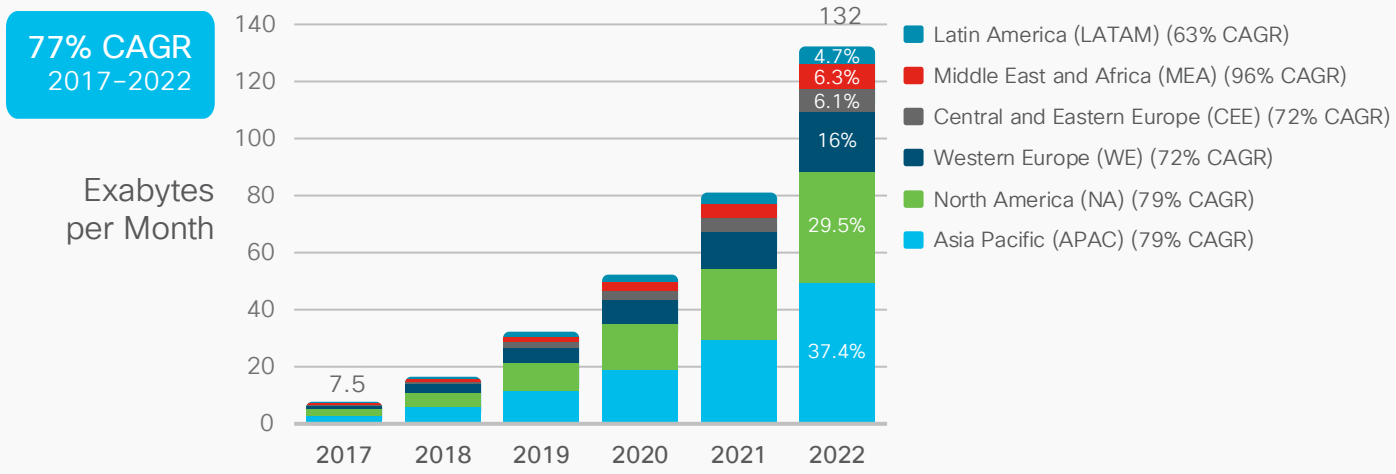
Looking to 2022, if 60 percent of IPv6-capable devices are actively connected to an IPv6 network, the forecast estimates that globally IPv6 traffic would amount to 132 EB per month, or 38 percent of total Internet traffic (Figure 9).

This initial estimation of potential IPv6 traffic is based on the assumptions that IPv6 device capability, IPv6 content enablement, and IPv6 network deployment will keep pace with current trends and may even accelerate during the forecast period. Considering the interdependence of these variables, forecast assumptions could be subject to refinement as our analysis continues.

Content providers are also moving to increase the IPv6 enablement of their sites and services. According to Cisco® IPv6 labs, by 2022 the content available over IPv6 will be about 51 percent. There can be, however, variation depending on the popularity of websites across regions and countries. In addition, specific country initiatives and content-provider deployments have positively affected local IPv6 content reachability.

Overall, the likelihood that a significant portion of Internet traffic will be generated over IPv6 networks holds considerable opportunity for network operators, content providers, and end users seeking to gain the scalability and performance benefits of IPv6 and enable the Internet of Things (IoT).

Figure 9. Projected global fixed and mobile IPv6 traffic forecast, 2017–2022

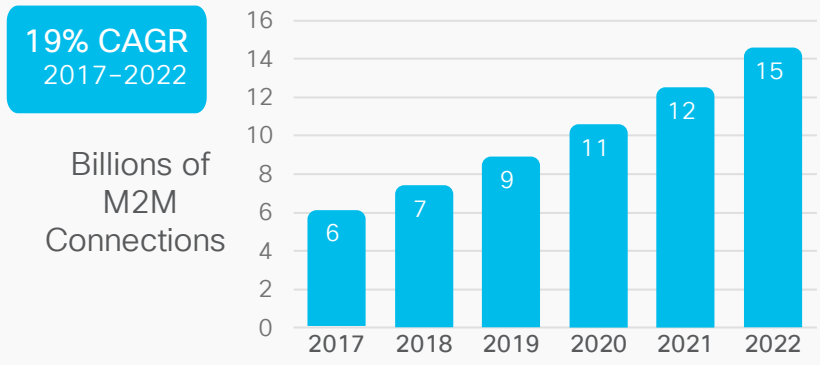


Source: Cisco VNI Global IP Traffic Forecast, 2017–2022

Trend 3: M2M applications across many industries accelerate IoT growth

Internet of Things (IoT) is no longer a phenomenon, but it has become a prevalent system in which people, processes, data, and things connect to the Internet and each other. Globally, M2M connections will grow 2.4-fold, from 6.1 billion in 2017 to 14.6 billion by 2022 (Figure 10). There will be 1.8 M2M connections for each member of the global population by 2022.

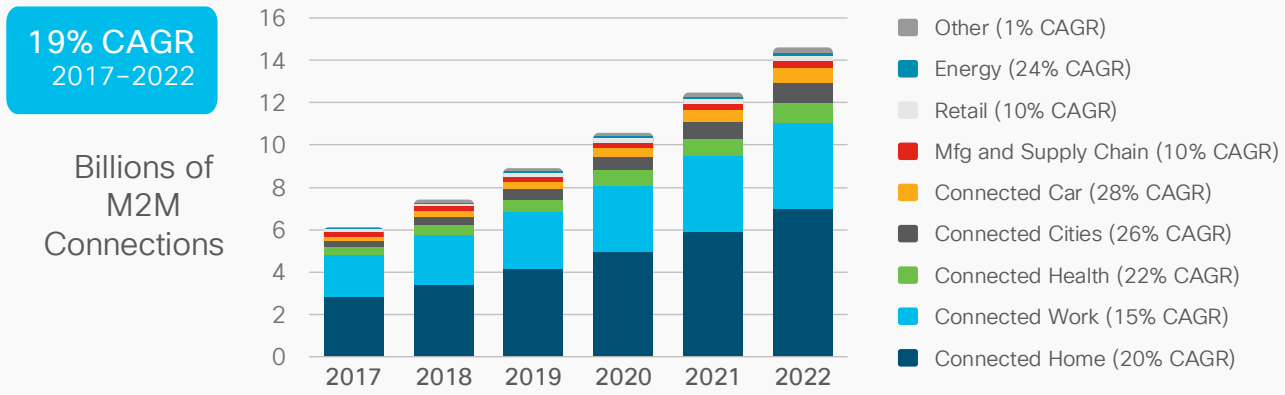
Figure 10. Global M2M connection growth



Source: Cisco VNI Global IP Traffic Forecast, 2017–2022

Connected home applications, such as home automation, home security and video surveillance, connected white goods, and tracking applications, will represent 48 percent, or nearly half, of the total M2M connections by 2022, showing the pervasiveness of M2M in our lives (Figure 11). Connected car, with applications such as fleet management, in-vehicle entertainment and Internet access, roadside assistance, vehicle diagnostics, navigation, and autonomous driving, will be the fastest-growing industry segment, at a 28 percent CAGR. Connected cities applications will have the second-fastest growth, at a 26 percent CAGR each.

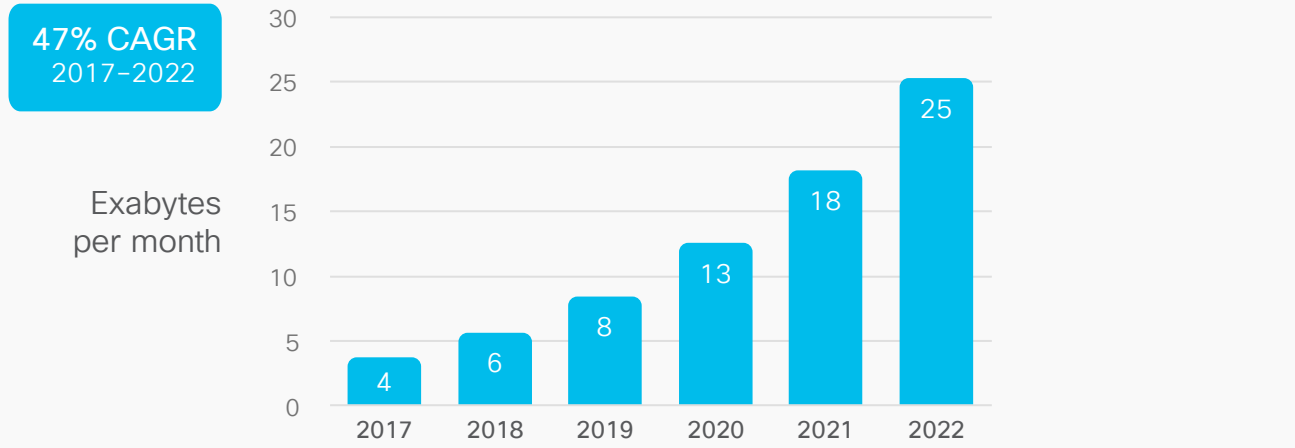
Figure 11. Global M2M connection growth by industries



Source: Cisco VNI Global IP Traffic Forecast, 2017–2022

Although the number of connections is growing 2.4-fold, global M2M IP traffic will grow more than sevenfold over this same period, from 3.7 EB per month in 2017 (3 percent of global IP traffic) to more than 25 EB by 2022 (6 percent of global IP traffic; refer to Figure 12). The amount of traffic is growing faster than the number of connections because of the increase of deployment of video applications on M2M connections and the increased use of applications, such as telemedicine and smart car navigation systems, which require greater bandwidth and lower latency.

Figure 12. Global M2M traffic growth

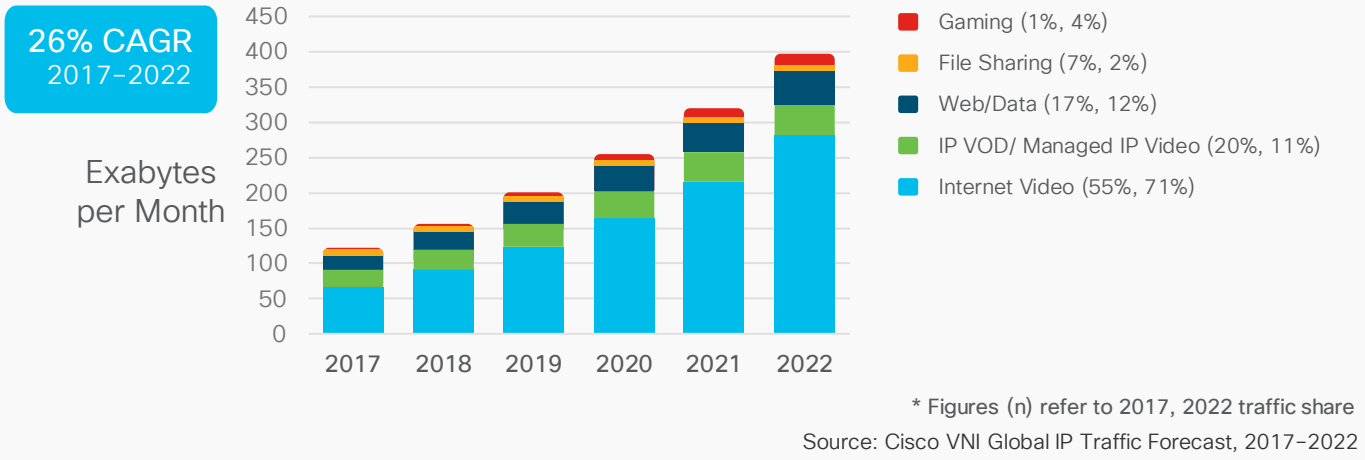


Source: Cisco VNI Global IP Traffic Forecast, 2017–2022

Trend 4: Applications traffic growth

The sum of all forms of IP video, which includes Internet video, IP VoD, video files exchanged through file sharing, video-streamed gaming, and video conferencing, will continue to be in the range of 80 to 90 percent of total IP traffic. Globally, IP video traffic will account for 82 percent of traffic by 2022 (Figure 13).

Figure 13. Global IP traffic by application category



* Figures (n) refer to 2017, 2022 traffic share

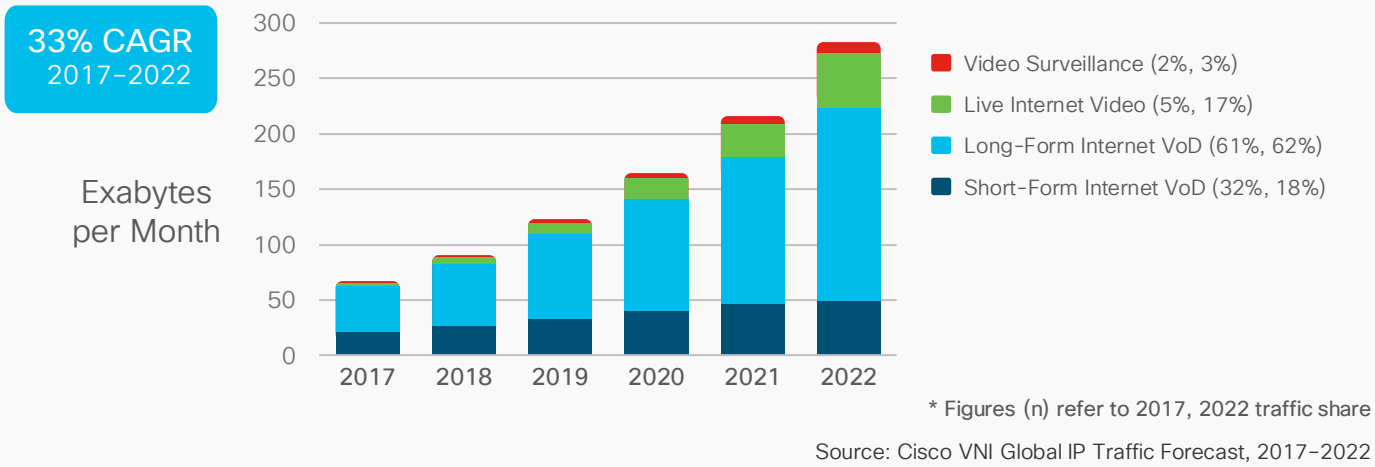
Source: Cisco VNI Global IP Traffic Forecast, 2017–2022

The implications of video growth are difficult to overstate. With video growth, Internet traffic is evolving from a relatively steady stream of traffic (characteristic of Peer-to-Peer [P2P] traffic) to a more dynamic traffic pattern.

In the past few years, service providers have observed a pronounced increase in traffic associated with gaming downloads. Newer consoles such as the Xbox One and PlayStation 4 have sufficient onboard storage to enable gamers to download new games rather than buy them on disc. These graphically intense games are large files, and gaming traffic will reach 4 percent of all IP traffic by 2022. Furthermore, these downloads tend to occur during peak usage periods, with gaming downloads reaching up to 8 percent of busy hour traffic. We expect the growth of gaming traffic to continue, and gaming is one of the forms of traffic that will limit the likelihood that video traffic will exceed the projected 82 percent by 2022.

There are shifts within Internet video traffic itself as well (Figure 14). In particular, live Internet video has the potential to drive large amounts of traffic as it replaces traditional broadcast viewing hours. Live video already accounts for 5 percent of Internet video traffic and will grow 15-fold to reach 17 percent by 2022. Also, of note is the growth of video surveillance traffic (dropcams). This traffic is of a very different nature than live or on-demand streaming and represents a steady stream of upstream video camera traffic, uploaded continuously from homes and small businesses to the cloud.

Figure 14. Global internet video by subsegment



* Figures (n) refer to 2017, 2022 traffic share

Source: Cisco VNI Global IP Traffic Forecast, 2017–2022

Effects of video on traffic symmetry

With the exception of short-form video and video calling, most forms of Internet video do not have a large upstream component. As a result, traffic is not becoming more symmetric, a situation that many expected when user-generated content first became popular. The emergence of subscribers as content producers is an extremely important social, economic, and cultural phenomenon, but subscribers still consume far more video than they produce. Upstream traffic has been slightly declining as a percentage for several years.

It appears likely that residential Internet traffic will remain asymmetric for the next few years. However, numerous scenarios could result in a move toward increased symmetry; for example:

- Content providers and distributors could adopt P2P as a distribution mechanism. There has been a strong case for P2P as a low-cost Content-Delivery System (CDS) for many years, yet most content providers and distributors have opted for direct distribution, with the exception of applications such as PPStream and PPLive in China, which offer live video streaming through P2P and have had great success. If content providers in other regions follow suit, traffic could rapidly become highly symmetric.
- High-end video communications could accelerate, requiring symmetric bandwidth. PC-to-PC video calling is gaining momentum, and the nascent mobile video calling market appears to have promise. If high-end video calling becomes popular, traffic could move toward greater symmetry.

Generally, if service providers provide ample upstream bandwidth, applications that use upstream capacity will begin to appear.

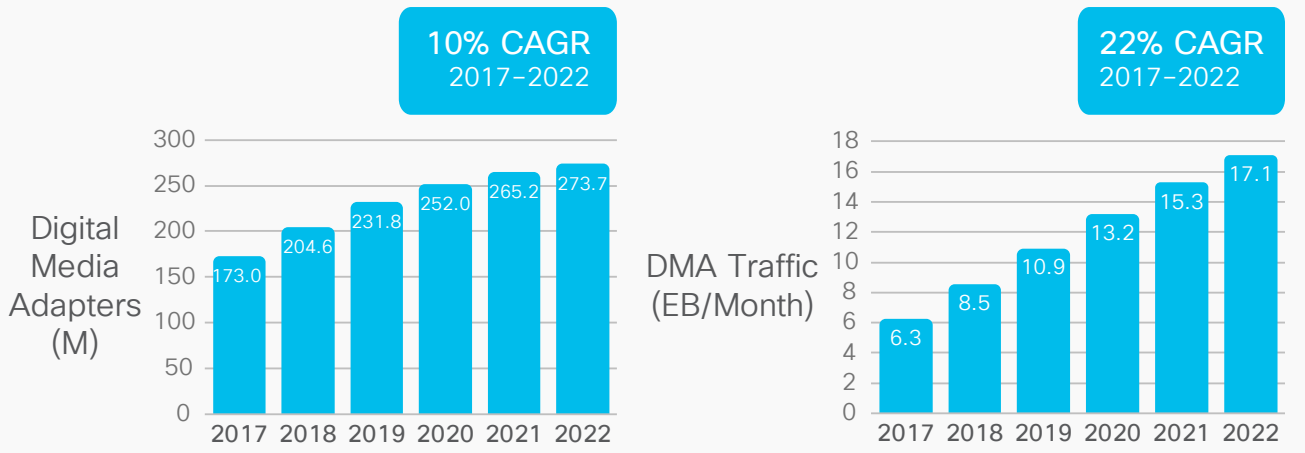
Trend 5: “Cord-Cutting” analysis

In the context of the Cisco VNI Forecast, “cord cutting” refers to the trend in which traditional and subscription television viewing is increasingly being supplanted by other means of video viewing, such as online and mobile video, which are available to viewers through fixed and mobile Internet connections.

We are seeing a trend in which the growth in digital television service that denotes television viewing across all digital platforms (cable, IPTV, satellite, etc.) is growing much more slowly relative to mobile video. Also, in emerging regions mobile video growth rates are even higher because these regions are bypassing fixed connectivity.

Also, if we look at Internet devices such as Digital Media Adapters (DMAs), we find that although they will represent only 9 percent of all Internet connected TVs—including, service provider STBs, gaming consoles, and directly connected Internet TV sets—by 2022 they will represent 18 percent of global Internet connected TV traffic. This trend again shows that there is increasingly less reliance on STBs managed by service providers for Internet access in general and for video specifically (Figure 15).

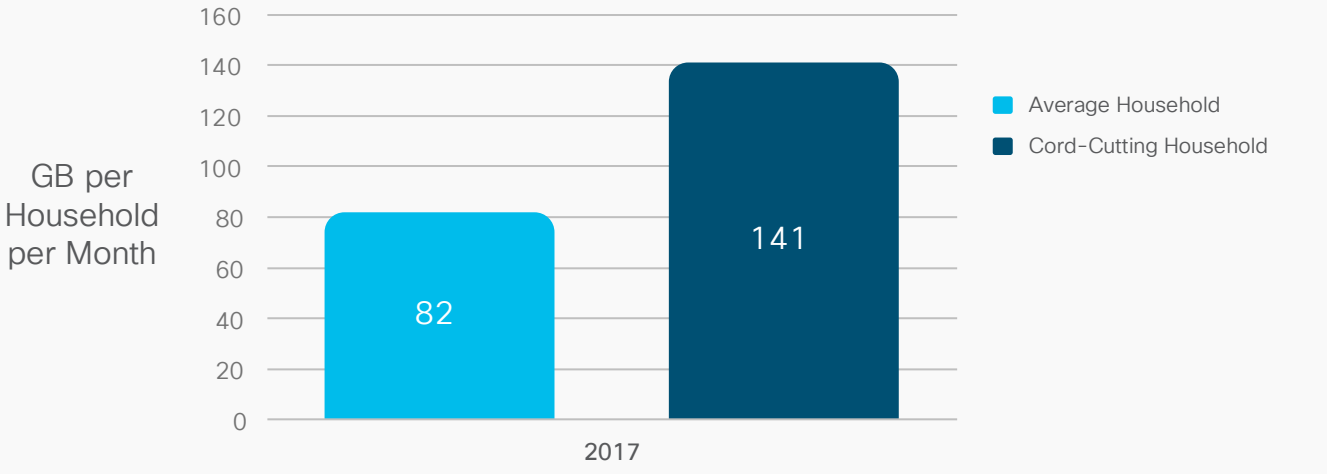
Figure 15. Growth in global digital media adapters



* DMAs include devices such as Roku, Apple TV, Chromecast
Source: Cisco VNI Global IP Traffic Forecast, 2017–2022

From a traffic perspective, we expect that on average a household that is still on linear TV will generate much less traffic than a household that has "cut the cord" and is relying on Internet video (Figure 16). A cord-cutting household generated 141 GB per month in 2017, compared to 82 GB per month for an average household. This difference occurs because linear television generates much less traffic (one stream of video shared across numerous linear-TV households) than Internet video, which is unicast to each Internet video device.

Figure 16. Global cord cutting generates 72 percent higher traffic



Source: Cisco VNI Global IP Traffic Forecast, 2017–2022

Trend 6: Security analysis

Users expect their online experience to be always available and always secure—and their personal and business assets to be safe. The last several years have been easily the most eventful period from a security threat perspective, with many serious data breaches that have been discussed widely in the media. Given the scope of the monetary and brand damage associated with data breaches, cybersecurity is treated as a business risk rather than merely an IT issue. Advances in technology is the main driver for economic growth but has also led to a higher incidence of cyberattacks. The leading trends such as ecommerce, mobile payments, cloud computing, Big Data and analytics, IoT, AI, machine learning, and social media, all increase cyber risk for users and businesses. Compounding the problem, the nature of the threats is becoming more diverse. The list includes Distributed Denial-of-Service (DDoS), ransomware, Advanced Persistent Threats (APTs), viruses, worms, malware, spyware, botnets, spam, spoofing, phishing, hacktivism and potential state-sanctioned cyberwarfare.

There were a total of 864 breaches with a total of nearly 34.2 million records exposed as of the month of September in 2018. The number of records exposed per data breach averaged 39,554 year-to-date in 2018, according to 2018 Identity Theft Resource Center, with the highest number of records exposed in the business category. Average cost of a lost or stolen record continues to increase, according to the IBM Security and Ponemon Institute 2018 Cost of Data Breach Study and it is globally $148 in 2018 compared to an average of $141 in 2017. The extensive use of IoT devices increased cost by $5 per compromised record. The United States and Canada have the highest per capita costs of data breaches, at $233 and $202. India and Brazil have the lowest per capita costs, at $68 and $67 respectively.

There are many methods to breaching, according to the Verizon 2018 data breach investigations report. 76 percent of breaches were financially motivated and 48 percent of the breaches featured hacking Almost three-quarters (73%) of cyberattacks were perpetrated by outsiders. Members of organized criminal groups were behind half of all breaches, with nation-state or state-affiliated actors involved in 12%.

A Distributed-Denial-of-Service (DDoS) attack occurs when multiple systems flood the bandwidth or resources of a targeted system, usually one or more web servers. Such an attack is often the result of multiple compromised systems flooding the targeted system with traffic. DDoS attacks represent the dominant threat observed by the vast majority of service providers. Infrastructure outages also continue to be a threat with over half of operators experiencing this issue. Peak DDoS attack size was 600 Gbps in 2017, down from 841 Gbps in 2016, according to Arbor Networks 13th Annual Infrastructure Security report. But 1H 2018 told a different tale, the peak DDoS attack size was a dramatic 1.7 Tbps, a 179 percent increase from 1H 2017. This was due to cybercriminals exploiting vulnerabilities in the Memcached protocol, resulting in record breaking amplification attacks. This has become a method that is increasingly popular since it does not require malware driven botnets. Average DDoS attack size in 2017 was 990 Mbps, a slight decrease from 1,133 Mbps in 2016, enough to take most organizations completely offline. However, since Memcached appeared, average attack size has increased 37 percent from 1H 2017 to 1H 2018.

DDoS attacks can represent up to 25 percent of a country's total Internet traffic while they are occurring (Figure 18). In 2017 the top motivation behind DDoS attacks was criminals demonstrating attack capabilities, with gaming and criminal extortion attempts in second and third place, respectively. The events from 2017 and the first quarter of 2018 once again demonstrated that the attackers are increasing their computing resources to perform DDoS attacks. Amplification attackers, who have tools for carrying out a DDoS attack, exploit vulnerabilities in the network and compute resources. Security vendors continue to make sure these attacks are financially unviable for the cybercriminals.

Figure 17. DDoS Attack Size and Traffic Increasing

DDoS Attack Size and Traffic Increasing

Peak attack size increased **174% Y/Y.***

DDoS attacks can represent up to **25%** of a country's total Internet traffic while they are occurring.

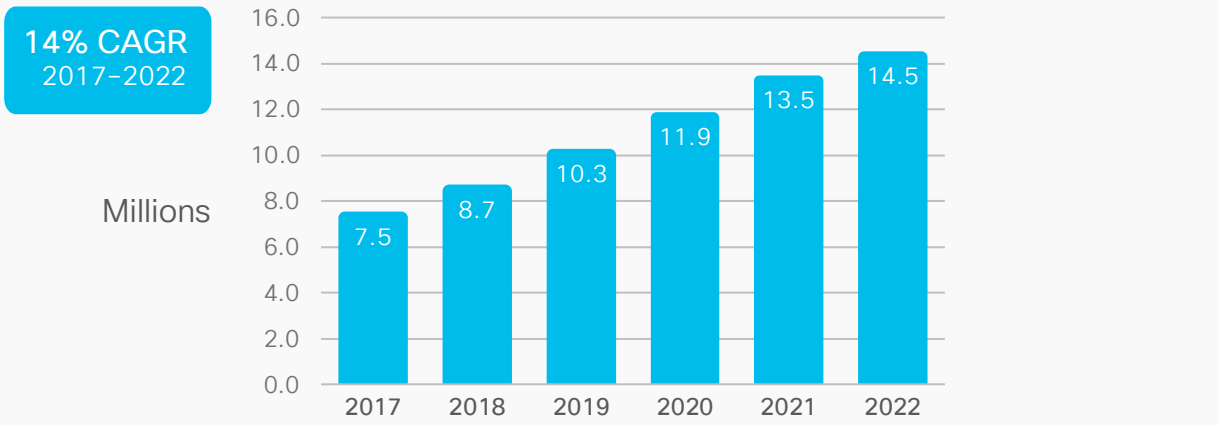
Average DDoS attack size between 1-2 Gbps increased **37% Y/Y** which is faster than Internet traffic at **33% Y/Y**.

* 1H2017-1H2018

Source: Arbor Networks, Cisco VNI Global IP Traffic Forecast, 2017–2022

Globally the total number of DDoS attacks will double to 14.5 million by 2022 (Figure 18).

Figure 18. Global DDoS attacks forecast, 2017-2022



Source: Cisco VNI Global IP Traffic Forecast, 2017–2022

The modern ransomware attack was born from two innovations in the early part of this decade: encryption and bitcoin. Mirai Botnet, WannaCry, Petya, NotPetya attacks were launched one after the other in 2017. With the Mirai Botnet attack in 2017, compromises and hacking took mainstage with exposing vulnerabilities in IoT in relation to home monitoring and devices. However, the concern is beyond the home as well. Vulnerabilities in smartphone apps can also be used to introduce malware. Vehicle-to-vehicle (V2V) communication and vehicle-to-everything (V2X) communication are being enabled with smart cities and next-generation mobile and Wi-Fi standards. Key fob scanning, taking control over air bag systems, and anti-collision systems are all possibilities. Security will remain a key part of the IoT deployment and proliferation.

Trend 7: Effects of accelerating speeds on traffic growth

Fixed speeds

Broadband speed is a crucial enabler of IP traffic. Broadband-speed improvements result in increased consumption and use of high-bandwidth content and applications. The global average broadband speed continues to grow and will double from 2017 to 2022, from 39.0 Mbps to 75.4 Mbps. Table 4 shows the projected broadband speeds from 2017 to 2022. Several factors influence the fixed broadband-speed forecast, including the deployment and adoption of Fiber To The Home (FTTH), high-speed DSL, and cable broadband adoption, as well as overall broadband penetration. Among the countries covered by this study, Japan, South Korea, and Sweden lead within the Cisco VNI countries in terms of broadband speed largely because of their wide deployment of FTTH.

Table 4. Fixed broadband speeds (in Mbps), 2017–2022

Region	2017	2018	2019	2020	2021	2022	CAGR (2017–2022)
Global	39.0	45.9	52.9	60.4	67.9	75.4	14%
Asia Pacific	46.2	62.8	79.4	87.5	92.7	98.8	16%
Latin America	11.7	15.7	19.7	22.0	25.0	28.1	19%
North America	43.2	56.6	70.1	79.6	87.9	94.2	17%
Western Europe	37.9	45.6	53.2	60.8	68.4	76.0	15%
Central and Eastern Europe	32.8	35.0	37.2	40.8	43.7	46.7	7%
Middle East and Africa	7.8	9.7	11.7	15.7	17.6	20.2	21%

Source: Cisco VNI, 2018.

Consider how long it takes to download an HD movie at these speeds: at 10 Mbps, it takes 20 minutes; at 25 Mbps, it takes 9 minutes; but at 100 Mbps, it takes only 2 minutes. High-bandwidth speeds will be essential to support consumer cloud storage, making the download of large multimedia files as fast as a transfer from a hard drive. Table 5 shows the percentage of broadband connections that will be faster than 10 Mbps, 25 Mbps, and 50 Mbps by region.

Table 5. Broadband speed greater than 10 Mbps, 2017–2022

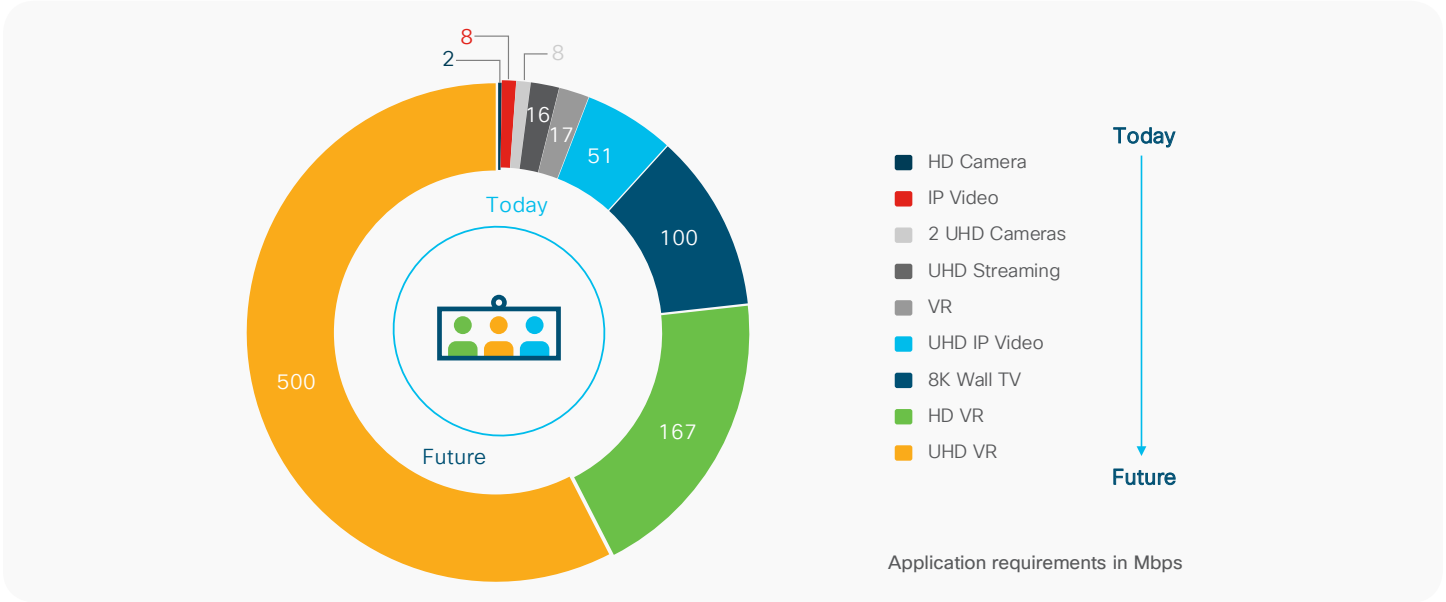
Region	Greater Than 10 Mbps					
	2017	2018	2019	2020	2021	2022
Global	69%	74%	79%	84%	89%	95%
Asia Pacific	77%	82%	87%	93%	95%	98%
Latin America	35%	43%	52%	58%	65%	72%
North America	78%	81%	84%	88%	91%	95%
Western Europe	66%	71%	75%	80%	85%	90%
Central and Eastern Europe	66%	67%	67%	69%	71%	72%

Region	Greater Than 25 Mbps					
	2017	2018	2019	2020	2021	2022
Global	42%	51%	60%	65%	72%	79%
Asia Pacific	50%	61%	71%	79%	86%	93%
Latin America	13%	20%	26%	28%	32%	36%
North America	51%	59%	66%	73%	81%	88%
Western Europe	41%	48%	54%	59%	66%	72%
Central and Eastern Europe	38%	41%	45%	48%	51%	54%
Middle East and Africa	6%	9%	11%	12%	13%	14%
Middle East and Africa	19%	25%	31%	35%	40%	45%
Region	**Greater Than 50 Mbps**					
	2017	2018	2019	2020	2021	2022
Global	29%	37%	44%	50%	56%	63%
Asia Pacific	36%	46%	56%	65%	74%	83%
Latin America	6%	8%	11%	11%	13%	14%
North America	34%	41%	48%	55%	62%	69%
Western Europe	25%	29%	34%	38%	42%	47%
Central and Eastern Europe	24%	25%	26%	26%	27%	28%
Middle East and Africa	2%	3%	4%	4%	4%	4%

Source: Cisco VNI, 2018.

A few countries also have users that currently experience greater than 125 Mbps, paving the path for the future demands of video. Video continues to be of enormous demand in today's home, but there will be significant bandwidth demands with the video application requirements of the future, even beyond the forecast period of 2022. In Figure 19, a scenario with video applications of the future is explored; today's bandwidth needs are a sliver of the future needs.

Figure 19. Significant demand for video in the home of the future



Mobile speeds

Globally, the average mobile network connection speed in 2017 was 8.7 Mbps. The average speed will more than triple and will be 28.5 Mbps by 2022.

Anecdotal evidence supports the idea that overall use increases when speed increases, although there is often a delay between the increase in speed and the increased use, which can range from a few months to several years. The reverse can also be true with the burstiness associated with the adoption of tablets and smartphones, where there is a delay in experiencing the speeds that the devices can support. The Cisco VNI 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 6).

Table 6. Projected average mobile network connection speeds (in Mbps) by region and country

	2017	2018	2019	2020	2021	2022	CAGR (2017–2022)
Global							
Global speed: All handsets	8.7	13.2	17.7	21.0	24.8	28.5	27%
Western Europe	16.0	23.6	31.2	37.2	43.8	50.5	26%
Central and Eastern Europe	10.1	12.9	15.7	19.5	22.8	26.2	21%
Middle East and Africa	4.4	6.9	9.4	11.2	13.2	15.3	28%
North America	16.3	21.6	27.0	31.9	36.9	42.0	21%
Asia Pacific	10.6	14.3	18.0	21.7	25.3	28.8	22%
Latin America	4.9	8.0	11.2	13.0	15.3	17.7	30%

Source: Cisco VNI, 2018.

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

A crucial factor promoting the increase in mobile speeds over the forecast period is the increasing proportion of fourth-generation (4G) mobile connections. The effect of 4G connections on traffic is significant, because 4G connections, which include mobile WiMAX and Long-Term Evolution (LTE), generate a disproportionate amount of mobile data traffic.

Wi-Fi speeds from mobile devices

Globally, Wi-Fi connection speeds originated from dual-mode mobile devices will more than double by 2022. The average Wi-Fi network connection speed (24.4 Mbps in 2017) will exceed 54.2 Mbps by 2022. North America will experience the highest Wi-Fi speeds, 83.8 Mbps, by 2022 (Table 7).

Wi-Fi speeds inherently depend on the quality of the broadband connection to the premises. The speed also depends on the Wi-Fi standard in the CPE device.

The latest standard, IEEE 802.11ac and 802.11 ad, are considered to be a true wired complement and can enable higher definition video streaming and services that require higher data rates. Also, an important factor in the use of Wi-Fi technology is the number and availability of hotspots.

Table 7. Projected average Wi-Fi network connection speeds (in Mbps) by region and country

Region	2017	2018	2019	2020	2021	2022	CAGR (2017–2022)
Global	24.4	30.3	36.3	42.2	48.2	54.2	17%
Asia Pacific	26.7	34.5	42.2	47.6	56.0	63.3	19%
Latin America	9.0	10.6	12.1	13.8	15.2	16.8	13%
North America	37.1	46.9	56.8	63.6	74.4	83.8	18%
Western Europe	25.0	30.8	36.3	37.7	44.6	49.5	15%
Central and Eastern Europe	19.5	22.6	24.1	27.4	30.1	32.8	11%
Middle East and Africa	6.2	7.0	7.9	9.6	10.2	11.2	13%

Source: Cisco VNI, 2018.

Trend 8: Mobility (Wi-Fi) continues to gain momentum

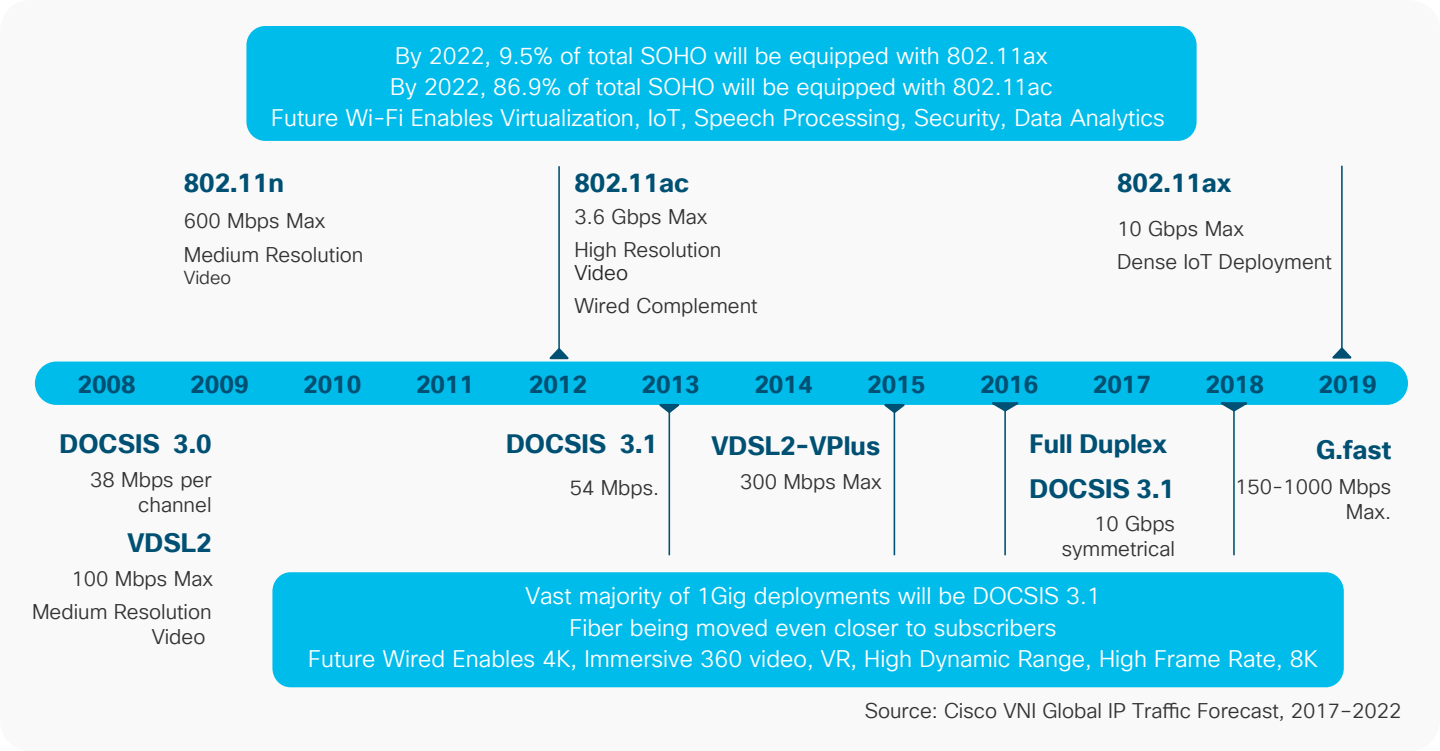
One of the main contributing factors to growing traffic is consumer video use. One of the main solutions to meet the demands of the increasing demand for bandwidth has long been leveraging Wi-Fi networks, which enables operators to scale capacity to meet their subscribers' needs. Globally, there will be nearly 549 million public Wi-Fi hotspots by 2022, up from 124 million hotspots in 2017, a fourfold increase. Western Europe had the highest number of hotspots, with 48 percent of the world's Wi-Fi hotspots in 2017. By 2022, Asia Pacific will have the highest percentage of 47 percent. Public Wi-Fi along with community hotspots are included in the forecast. Community hotspots or homespots 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. The homespots may be provided by a broadband or other provider directly or through a partner. Asia Pacific will lead in adoption of homespots. By 2022, China will lead in total number of homespots, followed by the United States and Japan.

Hotels, cafes, and restaurants will have the highest number of hotspots by 2022 globally, and the fastest growth is in healthcare facilities (hospitals), where hotspots will triple over the forecast period. The primary objective of Wi-Fi in hospitals is to improve the delivery of healthcare services and staff productivity, with a secondary benefit being Internet access for patients, their families, and their guests.

Integral to these verticals and looking into the future are the game-changing IoT devices and connections. According to the WBA Alliance, there is a need to find a dynamic way for IoT devices to search for a computable network and automatically roam between Wi-Fi and mobile networks at scale without intervention. Additionally, interest in Wi-Fi advertising and location services is growing as service providers search for new ways to monetize Wi-Fi and generate new revenue streams. It's also clear there is a growing awareness and acceptance among consumers that data on their location, movement and behavior can be exchanged for free Wi-Fi.

Critical enablers of Hotspot 2.0 adoption are higher speed Wi-Fi gateways and the adoption of the IEEE 802.11ac and the latest 802.11ax standards. Globally, the prevalence of IEEE 802.11ac, the latest Wi-Fi standard, will gain momentum from 2017 through 2022. By 2022, 86.9 percent of all Small Office Home Office (SOHO) Wi-Fi routers will be equipped with 802.11ac. IEEE 802.11n, which was ratified in 2007, provides a range of speeds that allow users to view medium-resolution video streaming because of the higher throughput. IEEE 802.11ac, with very high theoretical speeds, is considered a true wired complement and can enable higher definition video streaming and services with use cases that require higher data rates. The latest 802.11ax also called the High-Efficiency Wireless (HEW), has the goal of improving the average throughput per user by a factor of at least four times in dense user environments It will enable dense IoT deployments. By 2022, 9.5% of total SOHO routers will be equipped with 802.11ax. (Figure 20).

Figure 20. Future of Wired and Wireless Technologies

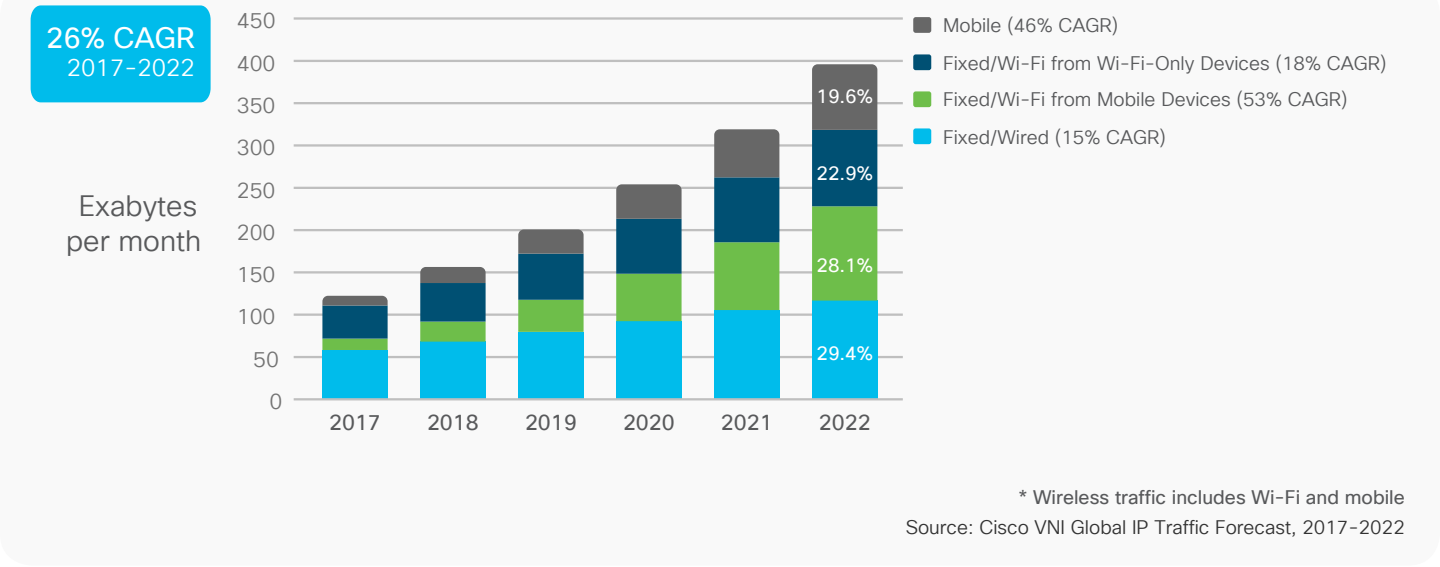


Source: Cisco VNI Global IP Traffic Forecast, 2017–2022

Wi-Fi has a powerful role to play alongside other small cell technologies in delivering key use cases going forward in the 5G Era.

The rapid growth of mobile data traffic has been widely recognized and reported. The trend toward mobility carries over into the realm of fixed networks as well, in that an increasing portion of traffic will originate from portable or mobile devices. Figure 21 shows the growth in Wi-Fi and mobile traffic in relation to traffic from wired devices. By 2022, wired networks will account for 29 percent of IP traffic, and Wi-Fi and mobile networks will account for 71 percent of IP traffic. In 2017, wired networks accounted for 48 percent of IP traffic; Wi-Fi accounted for 43 percent; and mobile or cellular networks accounted for 9 percent of total global IP traffic.

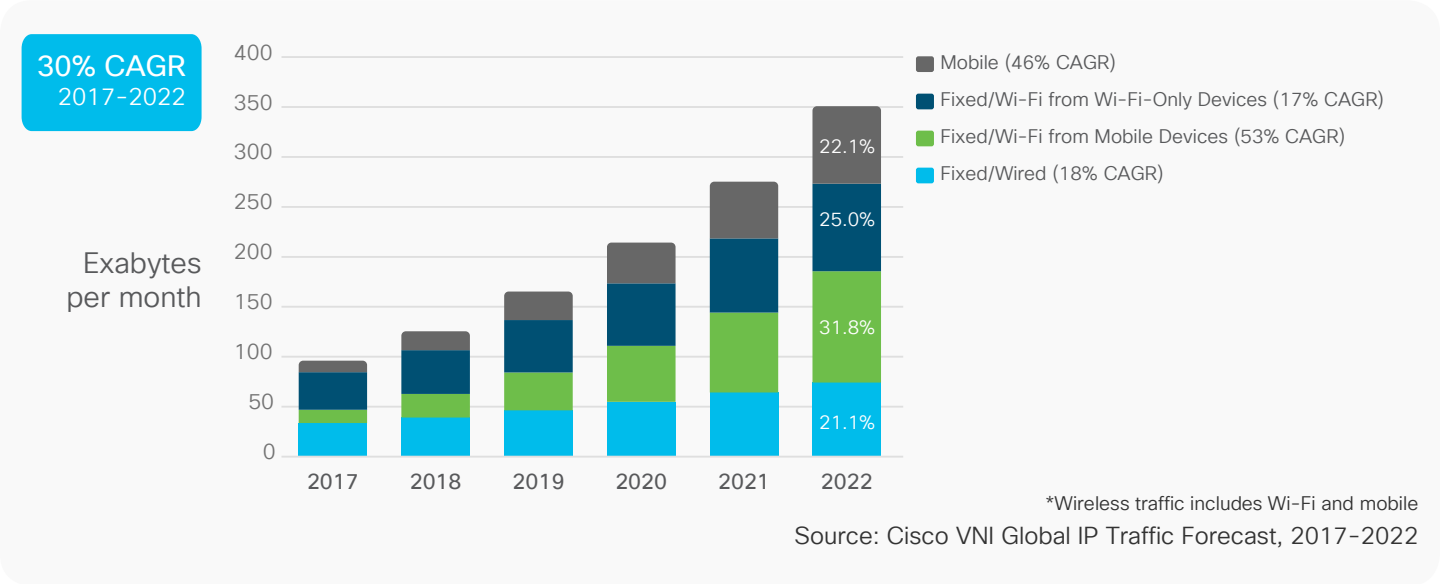
Figure 21. Global IP traffic, wired and wireless*



* Wireless traffic includes Wi-Fi and mobile
Source: Cisco VNI Global IP Traffic Forecast, 2017-2022

Narrowing the focus to Internet traffic and excluding managed IP traffic yields a more pronounced trend. By 2022, wired devices will account for 21 percent of Internet traffic, and Wi-Fi and mobile devices will account for 79 percent of Internet traffic (Figure 22). In 2017, wired devices accounted for 35 percent of Internet traffic.

Figure 22. Global internet traffic, wired and wireless



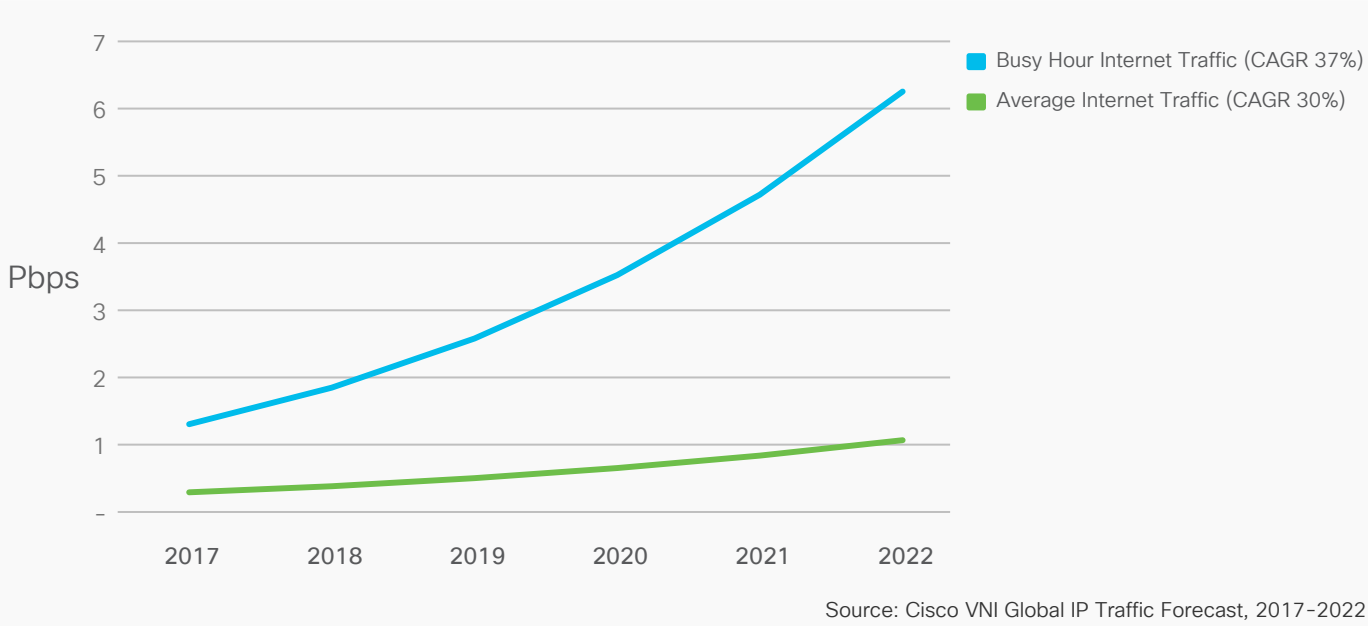
*Wireless traffic includes Wi-Fi and mobile
Source: Cisco VNI Global IP Traffic Forecast, 2017-2022

Trend 9: Traffic-pattern analysis (peak compared to average, CDN uptake and SD-WAN)

Although average Internet traffic has settled into a steady growth pattern, busy hour traffic (or traffic in the busiest 60 minute period of the day) continues to grow more rapidly than average Internet traffic. Service providers plan network capacity according to peak rates rather than average rates. Between 2017 and 2022, global busy hour Internet use will grow at a CAGR of 37 percent, compared with 30 percent for average Internet traffic (Figure 23).

Video is the underlying reason for accelerated busy hour traffic growth. Unlike other forms of traffic, which are spread evenly throughout the day (such as web browsing and file sharing), video tends to have a "prime time." Because of video consumption patterns, the Internet now has a much busier busy hour. Because video has a higher peak-to-average ratio than data or file sharing, and because video is gaining traffic share, peak Internet traffic will grow faster than average traffic. The growing gap between peak and average traffic is amplified further by the changing composition of Internet video. Real-time video such as live video, ambient video, and video calling has a peak-to-average ratio that is higher than on-demand video.

Figure 23. Busy hour compared with average Internet traffic growth

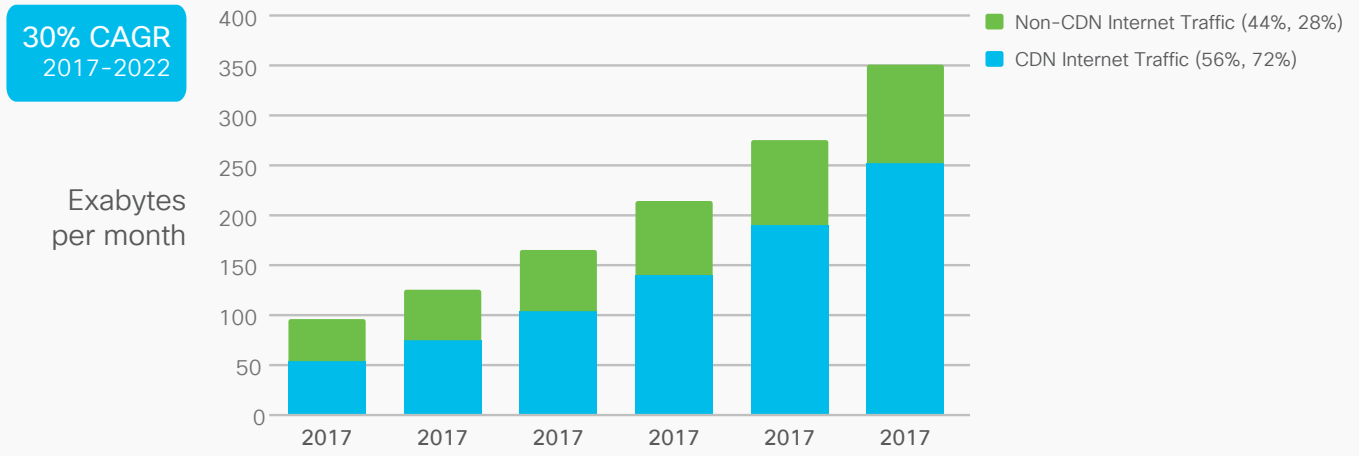


Source: Cisco VNI Global IP Traffic Forecast, 2017-2022

Changes in traffic topology are being brought about by the increasing role of Content Delivery Networks (CDNs) in data delivery. CDNs will carry 72 percent of total Internet traffic by 2022 (Figure 24), up from 56 percent in 2017. Although network performance is usually attributed to the speeds and latencies offered by the service provider, the delivery algorithms used by CDNs have an equal if not more significant bearing on video quality.

Much CDN traffic is carried by private CDNs rather than third-party CDNs. Private CDNs are those built and operated by content providers for their own content, and only their content. Private CDN capacity is not available to other content providers for purchase. Large private CDN operators include Google, Amazon, Facebook, and Microsoft.

Figure 24. Global content delivery network Internet traffic, 2017 and 2022

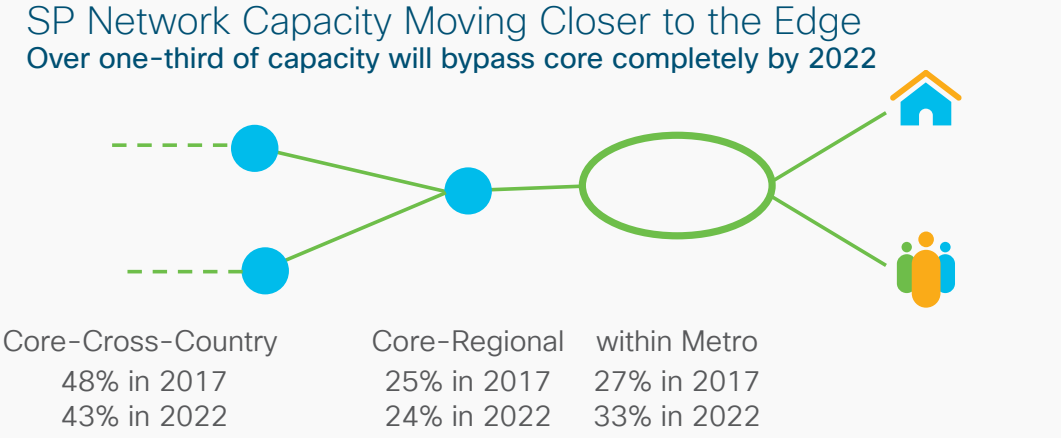


* Figures (n) refer to 2017, 2022 traffic share

Source: Cisco VNI Global IP Traffic Forecast, 2017-2022

CDNs will carry traffic closer to the end user, but presently much CDN traffic is deposited onto regional core networks. However, metro-capacity of the service provider networks is growing faster than core-capacity and will account for a third or 33 percent of total service provider network capacity by 2022, up from 27 percent in 2017 (Figure 25).

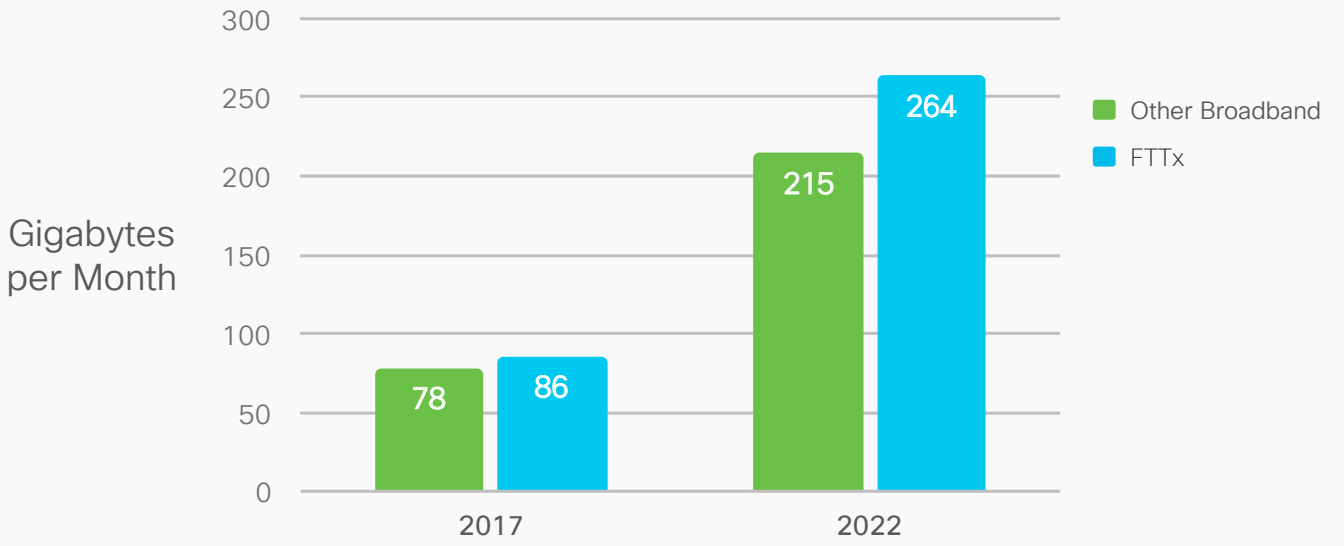
Figure 25. Internet traffic moving closer to the edge



Source: Cisco VNI Global IP Traffic Forecast, 2017-2022

Speed is a critical factor in Internet traffic. When speed increases, users stream and download greater volumes of content, and adaptive bit-rate streaming increases bit rates automatically according to available bandwidth. Service providers find that users with greater bandwidth generate more traffic. By 2022, households with high-speed fiber connectivity will generate 23 percent more traffic than households connected by DSL or cable broadband, globally (Figure 26). The average FTTH household generated 86 GB per month in 2017 and will generate 264 GB per month by 2022.

Figure 26. Fiber-Connected households generate more traffic than households with other sources of broadband



Source: Cisco VNI Global IP Traffic Forecast, 2017–2022

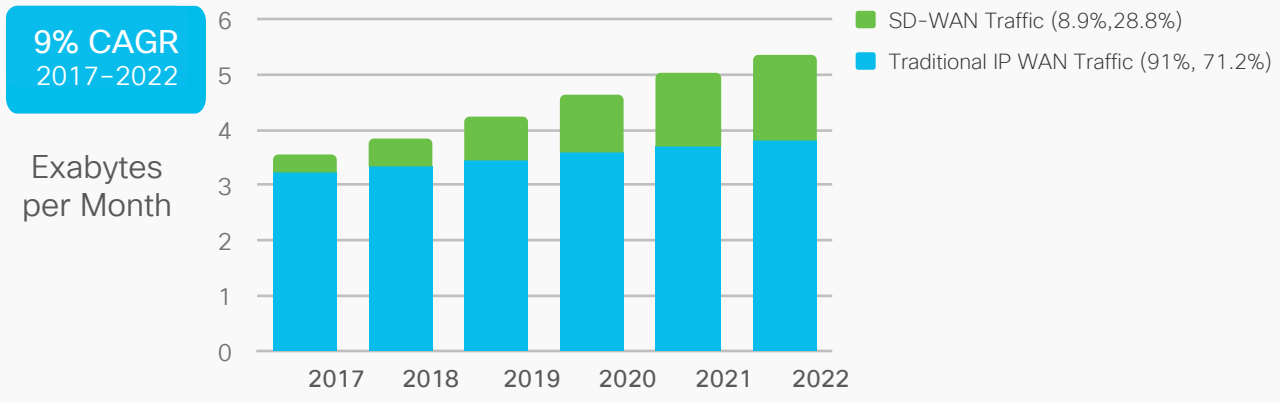
To limit the volume of traffic, service providers can institute use-based tiered pricing and data caps.

Mobile operators have increased the amount of data they offer consumers with plans in 2018. Some of these plans include data caps in excess of 25GB. Competition is fueling the increase, as operators like to keep up with their peers in offering "the most data" for marketing purposes. With mobile penetration reaching a saturation point in many countries across all regions, the strategy until 2017 was the implementation of tiered plans as a way to monetize data and effectively manage or throttle the top users of traffic. While the top 1 percent of the users continue to consume less data in comparison to five years ago, there has been a resurgence in unlimited plans. In general, data caps affect a larger percentage of mobile users than fixed users. On the fixed networks, data caps continue to increase to match subscribers' growing appetite for video. In parallel, fixed broadband operators in most countries offered higher broadband speed tiers in 2018 compared with 2017. Chinese operators in particular have hiked fixed broadband speeds, offering in the hundreds of megabits; one even offers 1 Gbps. In the United States, most providers are offering 1 Gbps and one operator offers 2 Gbps. While 10 Gbps offers are elusive to most, fixed operators in Japan, Sweden, Switzerland, UAE and Qatar are offering these higher speed services.

In several countries, Netflix has a sizable percentage of the Internet video minutes and traffic. Wildcard traffic generators such as Twitch.TV, a live streaming service in which video gamers watch each other play, has established itself on many fixed networks around the world.

A final trend relating to the technology coordinating traffic flow is the adoption of SD-WAN in the enterprise (Figure 27). SD-WAN traffic will grow at a CAGR of 37 percent compared to 3 percent for traditional MPLS-based WAN. SD-WAN will increase 5-fold and will be 29 percent of WAN traffic by 2022.

Figure 27. Global enterprise SD-WAN traffic



* Figures (n) refer to 2016, 2021 traffic share
Source: Cisco VNI Global IP Traffic Forecast, 2017–2022

Other trends to watch

Cisco's approach to forecasting IP traffic has been characterized as conservative. Emerging trends and innovations in network architectures, device/connection deployments, and application adoption/usage have the potential to increase the outlook for traffic volumes, shapes and characteristics significantly. Based on our perspective and analysis, the following topics warrant consideration as future "wildcards" in the forecasting process.

Infrastructure/Network Architecture Transformation

- **Edge networking** continues to gain more intelligence and capacity to support evolving network demands and superior network experiences. Increasingly, global service providers are making networking investments and architectural transformations to bolster the capabilities at the network edge. Based on our analysis, 33 percent of global service provider network capacity will be within a metro network by 2022 (up from 27 percent in 2017). Comparatively, 24 percent of global service provider network capacity will be in regional backbones by 2022 (down from 25 percent in 2017) and 43 percent of global service provider network capacity will be in cross-country backbones by 2022 (down from 48 percent in 2017).
- **5G roll-outs** provide mobility innovation and new levels of fixed/mobile convergence. By 2022, 22 percent of global Internet traffic will come from mobile (cellular) networks (up from 12 percent in 2017). By 2022, about 3 percent of global mobile devices/connections will be 5G-capable (and nearly 12 percent of global mobile traffic will come from 5G). As expected, mobile carriers from around the world are beginning to introduce trial 5G networks (see 5G Availability Around the World from Lifewire). Many industry experts believe that large-scale 5G deployments will begin to take shape in 2020, when mobile spectrum, standards, profitable business plans and other operational issues are more fully fleshed out.

Device/Connection Shifts

- **Dominance of smartphones** as the "communications hub" for social media, video consumption, tracking IoT/digitization applications (et al.), as well as traditional voice. Smartphones will represent 44 percent of global IP traffic by 2022 (up from 18 percent in 2017). This trend demonstrates the effect that smartphones have on how consumers and businesses users access and use the Internet and IP networks.
- **Quantifiable impact of IoT connections and applications** is creating new network demands and requirements. IoT connections will represent more than half (14.6 billion) of all global connected devices and connections (28.5 billion) by 2022. While IoT includes a wide variety of low-bandwidth to high-bandwidth applications (from smart meters to smart cars), the segment will represent more than 6 percent of global IP traffic by 2022 (up from just over 3 percent in 2017). In addition to traffic growth ramifications, IoT is also a catalyst for fixed/mobile convergence network innovations and comprehensive network security improvements.

Application Adoption and Usage

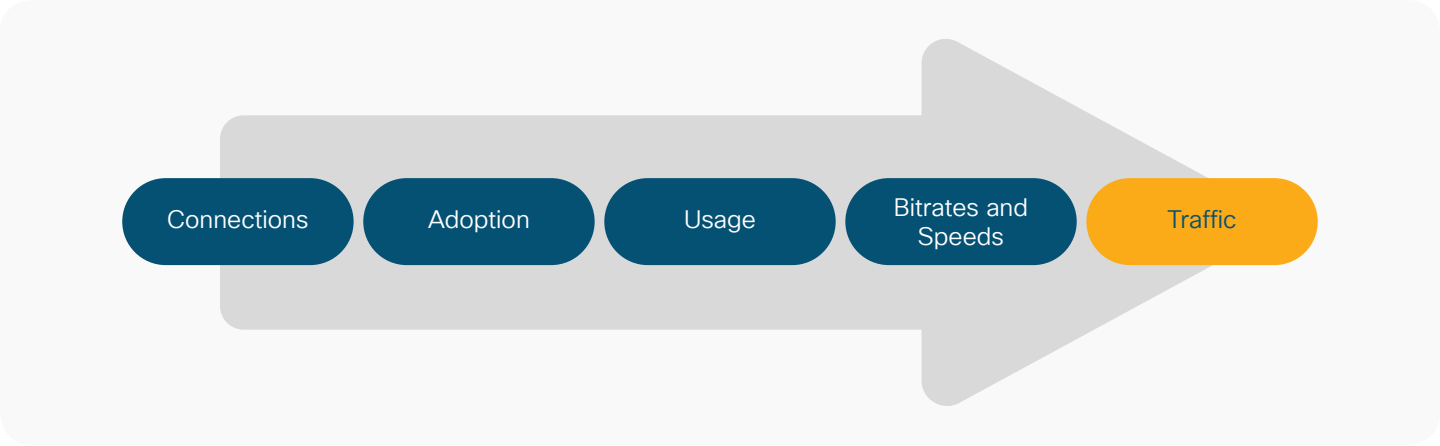
- **Internet gaming** is seeing a resurgence—the traffic will grow 9-fold between 2017 and 2022. Gaming on demand and streaming gaming platforms have been in development for several years, with many newly released in the last couple of years. With traditional gaming, graphical processing is performed locally on the gamer's computer or console. With cloud gaming, game graphics are produced on a remote server and transmitted over the network to the gamer. As cloud gaming becomes popular, gaming could become one of the largest Internet traffic categories.
- **Virtual reality and augmented reality:** With new hardware available to individuals, and a growing body of content to consume, VR and AR are expected to continue a high growth trajectory through this forecast period (2017 – 2022). Traffic associated with virtual and augmented reality applications is poised to grow 12-fold over the next five years (65 percent CAGR). This growth stems mainly from the download of large virtual reality content files and applications, but a significant wild card is the potential adoption of virtual reality streaming, which could raise our prediction of high-growth even higher.
- **Video surveillance:** New Internet-connected video surveillance cameras upload a constant video stream to the cloud for remote viewing. With a steady flow of video traffic from each camera, video surveillance is already having an effect on overall Internet traffic. It accounts for 2 percent of Internet video traffic today and will grow 7-fold to reach 3 percent by 2022. If such devices become mass market in the next five years, we could see video cameras generating a significantly higher volume of traffic, since Internet-enabled cameras can produce up to 300 GB per camera per month for full HD-resolution monitoring of high-activity areas.

Appendices

Appendix A: Overview of VNI methodology

The Cisco Visual Networking Index Forecast methodology has been developed based on a combination of analyst projections, in-house estimates and forecasts, and direct data collection. The analyst projections for broadband connections, video subscribers, mobile connections, and Internet application adoption come from SNL Kagan, Ovum, IDC, Gartner, Ookla Speedtest.net, Strategy Analytics, Dell'Oro Group, Synergy, comScore, Nielsen, Maravedis, ACG Research, ABI Research, Media Partners Asia, IHS, International Telecommunications Union (ITU), CTIA, UN, telecommunications regulators, and others. Upon this foundation are layered Cisco's own estimates for application adoption, minutes of use, and kilobytes per minute. The adoption, usage, and bit-rate assumptions are tied to fundamental enablers such as broadband speed and computing speed. All usage and traffic results are then validated using data shared with Cisco from service providers. Figure 1 shows the forecast methodology.

Figure 28. Cisco VNI forecast methodology incorporates fundamental enablers of adoption and usage



Following is the methodology through each step for a single application category (in this case, Internet video) where the estimation process is illustrated.

Step 1: Number of users

The forecast for Internet video begins with estimations of the number of consumer fixed Internet users. Even such a basic measure as consumer fixed Internet users can be difficult to assess, because few analyst firms segment the number of users by both segment (consumer versus business) and network (mobile versus fixed). The number of consumer fixed Internet users was not taken directly from an analyst source but was estimated from analyst forecasts for consumer broadband connections, data on hotspot users from a variety of government sources, and population forecasts by age segment. The number of Internet video users was collected and estimated from a variety of sources, and the numbers were then reconciled with the estimate of overall Internet users.

Step 2: Application adoption

After the number of Internet video users has been established, the number of users for each video subsegment must be estimated. It was assumed that all Internet video users view short-form video in addition to other forms of video they may watch. The number of Internet video users who watch long-form video (based partially on comScore Video Metrix figures for video sites whose average viewing time is longer than 5 minutes), live video, ambient video, and Internet Personal Video Recorder (PVR) is estimated.

Step 3. Minutes of use

For each application subsegment, Minutes of Use (MOU) are estimated. Multiple sources are used to determine MOU. Special care is taken to help ensure that the total number of Internet video minutes is well within the total number of video minutes (including television broadcast) for each user. For example, if the average individual watches a total of 4 hours of video content per day, the sum of Internet, managed IP, and mobile video hours should be a relatively small portion of the total 4 hours.

Step 4. Bit rates

After MOU have been estimated for each sub segment of video, the next step is to apply kilobytes (KB) per minute. To calculate KB per minute, first the regional and country average broadband speeds are estimated for the years 2017 through 2022. For each application category, a representative bit rate is established, and this representative bit rate grows at approximately the same pace as the broadband speed. For video categories, a 7 percent annual compression gain is applied to the bit rate. Local bit rates are then calculated based on how much the average broadband speed in the country differs from the global average, the digital screen size in the country, and the computing power of the average device in the country. Combining these factors yields bit rates that are then applied to the MOU.

Step 5: Rollup

The next step in the methodology is to multiply the bit rates, MOU, and users together to get average PB per month.

Step 6: Traffic migration assessment

The next step is to reconcile the Internet, managed IP, and mobile segments of the forecast. The portion of mobile data traffic that has migrated from the fixed network is subtracted from the fixed forecast, and the amount of mobile data traffic offloaded onto the fixed network through dual-mode devices and femtocells is added back to the fixed forecast.

The sections that follow present quantitative results of the forecast and details of the methodology for each segment and type. Due to rounding, numbers presented in this document may not add up precisely to the totals.

Appendix B: Global IP traffic growth, 2017–2022

Table 8 shows the top-line forecast. According to this forecast, global IP traffic in 2017 stands at 122 EB per month and will triple by 2022, to reach 366 EB per month. Consumer IP traffic will reach 333 EB per month and business IP traffic will be 63 EB per month by 2022.

Table 8. Global IP traffic, 2017–2022

IP Traffic, 2017–2022	2017	2018	2019	2020	2021	2022	CAGR (2017–2022)
By Type (Petabytes [EB] per Month)							
Fixed Internet	85	107	137	174	219	273	26%
Managed IP	26	31	35	40	44	45	11%
Mobile data	12	19	29	41	57	77	46%
By Segment (EB per Month)							
Consumer	100	129	167	212	267	333	27%
Business	22	27	34	42	52	63	23%
By Geography (EB per Month)							
Asia Pacific	43	59	80	105	136	173	32%
North America	42	52	63	77	92	108	21%
Western Europe	18	22	27	33	41	50	22%
Central and Eastern Europe	8	10	12	15	20	25	26%
Middle East and Africa	7	9	11	13	16	19	21%
Latin America	4	5	7	10	15	21	41%
Total (EB per Month)							
Total IP traffic	122	156	201	254	319	396	26%

Source: Cisco VNI, 2018

Definitions

- **Consumer:** Includes fixed IP traffic generated by households, university populations, and Internet cafés
- **Business:** Includes fixed IP WAN or Internet traffic generated by businesses and governments
- **Mobile:** Includes mobile data and Internet traffic generated by handsets, notebook cards, and mobile broadband gateways
- **Internet:** Denotes all IP traffic that crosses an Internet backbone
- **Managed IP:** Includes corporate IP WAN traffic and IP transport of TV and VoD

The following tables show cross-tabulations of end-user segment and network type for the final year of the forecast period (2022). Consumer Internet remains the primary generator of IP traffic, but mobile data has the highest growth rate and begins to generate significant traffic by 2022 (Table 9).

Table 9. Exabytes per month as of year-end 2022

	Consumer	Business	Total
Internet	225	49	273
Managed IP	40	5	45
Mobile data	68	9	77
Total	333	63	396

Source: Cisco VNI, 2018

Table 10 shows the same data as Table 2, but in terms of annual traffic run rates. These run rates are based on the monthly traffic at the end of 2022.

Table 10. Exabytes per year as of year-end 2022

	Consumer	Business	Total
Internet	2,694	585	3,279
Managed IP	479	64	543
Mobile data	819	111	930
Total	3,993	760	4,752

Source: Cisco VNI, 2018

Consumer and business traffic are both dominated by Internet traffic (Table 11).

Table 11. Traffic share by end-user segment as of year-end 2022

	Consumer	Business
Internet	67%	77%
Managed IP	12%	8%
Mobile data	21%	15%
Total	100%	100%

Source: Cisco VNI, 2018

Consumer traffic accounts for the majority of IP traffic in every network type segment. Consumer traffic will be 82 percent of all fixed Internet traffic, 88 percent of all of managed IP traffic, and 88 percent of all mobile data traffic (Table 12).

Table 12. Traffic share by network type as of year-end 2022

	Consumer	Business	Total
Internet	82%	18%	100%
Managed IP	88%	12%	100%
Mobile data	88%	12%	100%
Total	84%	16%	100%

Source: Cisco VNI, 2018

Consumer Internet traffic will represent more than half of all IP traffic, followed by consumer-mobile data, which will represent 17 percent of traffic (Table 13).

Table 13. Overall traffic share as of year-end 2022

	Consumer	Business	Total
Internet	57%	12%	69%
Managed IP	10%	1%	11%
Mobile data	17%	2%	20%
Total	84%	16%	100%

Source: Cisco VNI, 2018

Appendix C: Consumer IP traffic, 2017–2022

As shown in Table 14, global consumer IP traffic is expected to reach 333 EB per month by 2022. Most of today's consumer IP traffic is Internet traffic.

Table 14. Global consumer IP traffic, 2017–2022

Consumer IP Traffic, 2017–2022	2017	2018	2019	2020	2021	2022	CAGR (2017–2022)
By Type (EB per Month)							
Internet	67	86	111	141	179	225	27%
Managed IP	23	27	31	35	39	40	12%
Mobile data	10	16	25	36	50	68	47%
By Geography (EB per Month)							
Asia Pacific	35	49	67	89	116	147	33%
North America	35	43	53	64	76	90	21%
Western Europe	15	18	22	27	33	41	23%
Central and Eastern Europe	6	7	9	12	16	20	28%
Middle East and Africa	6	7	9	11	13	16	22%
Latin America	3	4	6	9	13	18	45%
Total (EB per Month)							
Total IP traffic	100	129	167	212	267	333	27%

Source: Cisco VNI, 2018

Appendix D: Consumer internet traffic, 2017–2022

This category encompasses consumer IP traffic that crosses the Internet and is not confined to a single service provider's network. Internet video streaming and downloads are beginning to take a larger share of bandwidth and will grow to more than 82 percent of all consumer Internet traffic by 2022 (Table 15).

Table 15. Global consumer internet traffic, 2017–2022

Consumer Internet Traffic, 2017–2022	2017	2018	2019	2020	2021	2022	CAGR (2017–2022)
By Type (EB per Month)							
Fixed	67	86	111	141	179	225	27%
Mobile	10	16	25	36	50	68	47%
By Subsegment (EB per Month)							
Internet video	56	77	105	140	184	240	34%
Web, email, and data	12	15	19	23	27	31	22%
Online gaming	1	3	4	7	11	15	59%
File sharing	8	7	7	7	7	7	-3%
By Geography (EB per Month)							
Asia Pacific	27	38	54	74	99	130	37%
North America	25	32	40	50	61	74	25%
Western Europe	12	15	19	24	30	37	25%
Central and Eastern Europe	5	7	9	11	15	19	29%
Middle East and Africa	3	4	6	9	13	18	46%
Latin America	5	6	8	9	11	14	21%
Total (EB per Month)							
Consumer Internet traffic	77	102	136	177	229	293	31%

Source: Cisco VNI, 2018

Definitions

- **Web, email, and data:** Includes web, email, instant messaging, and other data traffic (excludes file sharing)
- **File sharing:** Includes peer-to-peer traffic from all recognized Peer-to-Peer (P2P) systems such as BitTorrent and eDonkey, as well as traffic from web-based file-sharing systems
- **Gaming:** Includes casual online gaming, networked console gaming, and multiplayer virtual-world gaming
- **Internet video:** Includes short-form Internet video (for example, YouTube), long-form Internet video (for example, Hulu), live Internet video, Internet video to TV (for example, Netflix through Roku), online video purchases and rentals, webcam viewing, and web-based video monitoring (excludes P2P video file downloads)

Appendix E: Content delivery network traffic, 2017–2022

With the emergence of popular video-streaming services that deliver Internet video to the TV and other device endpoints, CDNs have prevailed as a dominant method to deliver such content. Globally, 72 percent of all Internet traffic will cross CDNs by 2022, up from 56 percent in 2017 (Table 16).

Table 16. Global content delivery network internet traffic, 2017–2022

CDN Traffic, 2017–2022	2017	2018	2019	2020	2021	2022	CAGR (2017–2022)
By Geography (EB per Month)							
Asia Pacific	15	22	33	47	70	97	46%
North America	24	33	44	56	70	85	29%
Western Europe	11	14	18	24	31	39	30%
Central and Eastern Europe	2	3	4	6	9	13	41%
Latin America	2	2	3	4	7	9	40%
Middle East and Africa	1	1	2	3	5	8	64%
Total (EB per Month)							
CDN Internet traffic	54	75	104	140	190	252	36%

Source: Cisco VNI, 2018

Appendix F: Consumer-managed IP traffic, 2017–2022

Consumer managed IP video is IP traffic generated by traditional commercial TV services (Table 17). This traffic remains within the footprint of a single service provider, so it is not considered Internet traffic. (For Internet video delivered to the set-top box, refer to Internet video to TV in the section “Internet Video”.)

Table 17. Global consumer-managed IP traffic, 2017–2022

Consumer-Managed IP Traffic, 2017–2022	2017	2018	2019	2020	2021	2022	CAGR (2017–2022)
By Network (EB per Month)							
Fixed	22.80	27.02	31.12	35.17	38.76	39.91	12%
By Geography (EB per Month)							
Asia Pacific	8.46	10.80	13.09	15.26	17.32	17.13	15%
North America	10.49	11.71	12.85	13.99	14.86	15.69	8%
Western Europe	2.57	2.86	3.14	3.43	3.67	3.81	8%
Latin America	0.70	0.91	1.15	1.41	1.66	1.92	23%
Central and Eastern Europe	0.42	0.54	0.67	0.79	0.91	1.01	19%
Middle East and Africa	0.15	0.19	0.24	0.29	0.33	0.35	19%
Total (EB per Month)							
Managed IP video traffic	22.80	27.02	31.12	35.17	38.76	39.91	12%

Source: Cisco VNI, 2018

Appendix G: Business IP traffic

The enterprise forecast is based on the number of network-connected computers worldwide. In our experience, this basis provides the most accurate measure of enterprise data usage (Table 18).

Table 18. Business IP traffic, 2017–2022

Business IP Traffic, 2017–2022	2017	2018	2019	2020	2021	2022	CAGR (2017–2022)
By network type (EB per month)							
Business Internet traffic	17.25	20.90	25.89	32.15	39.70	48.74	23%
Business managed IP traffic	3.56	3.86	4.25	4.65	5.02	5.35	9%
Business mobile data	1.62	2.54	3.68	5.11	6.93	9.22	42%
By geography (EB per month)							
Asia Pacific	8.02	9.95	12.71	16.07	20.25	25.30	26%
North America	6.52	8.27	10.31	12.82	15.50	18.48	23%
Western Europe	3.62	4.25	5.14	6.19	7.47	9.06	20%
Central and Eastern Europe	2.12	2.36	2.72	3.25	3.99	4.97	19%
Latin America	1.24	1.42	1.68	2.04	2.51	3.08	20%
Middle East and Africa	0.90	1.04	1.25	1.53	1.92	2.42	22%
Total (EB per month)							
Business IP traffic	22.43	27.29	33.82	41.90	51.65	63.31	23%

Source: Cisco VNI, 2018

Definitions

- Business Internet traffic: All business traffic that crosses the public Internet
- Business IP traffic: All business traffic that is transported over IP but remains within the corporate WAN
- Business mobile data traffic: All business traffic that crosses a mobile access point

Appendix H: Mobile data traffic

Mobile data traffic includes handset-based data traffic, such as text messaging, multimedia messaging, and handset video services (Table 19). Mobile Internet traffic is generated by wireless cards for portable computers and handset-based mobile Internet usage.

Table 19. Mobile data and internet traffic, 2017–2022

Mobile data and internet traffic, 2017–2022	2017	2018	2019	2020	2021	2022	CAGR (2017–2022)
By Geography (EB per month)							
Asia Pacific	5.88	10.35	15.91	22.81	31.81	43.17	49%
Middle East and Africa	1.22	2.05	3.25	5.01	7.56	11.17	56%
Central and Eastern Europe	1.38	2.15	3.12	4.32	5.83	7.75	41%
North America	1.26	1.80	2.50	3.41	4.48	5.85	36%
Western Europe	1.02	1.47	2.06	2.81	3.80	5.12	38%
Latin America	0.75	1.18	1.72	2.42	3.31	4.44	43%
Total (EB per month)							
Mobile data and Internet	11.51	19.01	28.56	40.77	56.80	77.49	46%

Source: Cisco VNI, 2018

For more information

Several interactive tools are available to help you create custom highlights and forecast charts by region, by country, by application, and by end-user segment (refer to the Cisco VNI Forecast Highlights tool). Inquiries can be directed to traffic-inquiries@cisco.com.