White Paper

Cisco Global Cloud Index: Forecast and Methodology, 2014–2019

What You Will Learn

The Cisco® Global Cloud Index (GCI) is an ongoing effort to forecast the growth of global data center and cloud-based IP traffic. The forecast includes trends associated with data center virtualization and cloud computing. This document presents the details of the study and the methodology behind it.

Forecast Overview

Global Data Center Traffic

- Annual global data center IP traffic will reach 10.4 zettabytes (863 exabytes [EB] per month) by the end of 2019, up from 3.4 zettabytes (ZB) per year (287 EB per month) in 2014.
- Global data center IP traffic will grow 3-fold over the next 5 years. Overall, data center IP traffic will grow at a compound annual growth rate (CAGR) of 25 percent from 2014 to 2019.

Data Center Virtualization and Cloud Computing Growth

- By 2019, more than four-fifths (86 percent) of workloads will be processed by cloud data centers; 14 percent will be processed by traditional data centers.
- Overall data center workloads will more than double (2.5-fold) from 2014 to 2019; however, cloud workloads will more than triple (3.3-fold) over the same period.
- The workload density (that is, workloads per physical server) for cloud data centers was 5.1 in 2014 and will grow to 8.4 by 2019. Comparatively, for traditional data centers, workload density was 2.0 in 2014 and will grow to 3.2 by 2019.

Public vs. Private Cloud

- By 2019, 56 percent of the cloud workloads will be in public cloud data centers, up from 30 percent in 2014. (CAGR of 44 percent from 2014 to 2019).
- By 2019, 44 percent of the cloud workloads will be in private cloud data centers, down from 70 percent in 2014. (CAGR of 16 percent from 2014 to 2019).

Global Cloud Traffic

- Annual global cloud IP traffic will reach 8.6 ZB (719 EB per month) by the end of 2019, up from 2.1 ZB per year (176 EB per month) in 2014.
- Global cloud IP traffic will more than quadruple (4.1-fold) over the next 5 years. Overall, cloud IP traffic will grow at a CAGR of 33 percent from 2014 to 2019.
- Global cloud IP traffic will account for more than four-fifths (83 percent) of total data center traffic by 2019.

Cloud Service Delivery Models

- By 2019, 59 percent of the total cloud workloads will be Software-as-a-Service (SaaS) workloads, up from 45 percent in 2014.
- By 2019, 30 percent of the total cloud workloads will be Infrastructure-as-a-Service (IaaS) workloads, down from 42 percent in 2014.
- By 2019, 11 percent of the total cloud workloads will be Platform-as-a-Service (PaaS) workloads, down from 13 percent in 2014.

Internet of Everything Potential Impact on Cloud

- Globally, the data created by Internet of Everything (IoE) devices will reach 507.5 ZB per year (42.3 ZB per month) by 2019, up from 134.5 ZB per year (11.2 ZB per month) in 2014.
- Globally, the data created by IoE devices will be 269 times higher than the amount of data being transmitted to data centers from end-user devices and 49 times higher than total data center traffic by 2019.

Consumer Cloud Storage

- By 2019, 55 percent (2 billion) of the consumer Internet population will use personal cloud storage, up from 42 percent (1.1 billion users) in 2014.
- Globally, consumer cloud storage traffic per user will be 1.6 Gigabytes per month by 2019, compared to 992 megabytes per month in 2014.

Multiple-Device and -Connection Ownership

- North America (7.3), followed by Western Europe (5.5), had the highest average number of devices or connections per user in 2014, followed by Middle East and Africa (5.4), Latin America (4.7) Central and Eastern Europe (4.5), and Asia Pacific (4.5).
- By 2019, North America (13.6), followed by Western Europe (9.9), will have the highest average number of devices or connections per user, followed by Central and Eastern Europe (6.2), Latin America (5.2), Middle East and Africa (5.0), and Asia Pacific (5.0).

IPv6 Adoption Fosters Cloud Growth

- Globally 32 percent of Internet users will be IPv6-capable by 2019.
- Globally, by 2019, nearly 41 percent of all fixed and mobile devices and connections will be IPv6-capable.
- Increased cloud provider deployments have had a positive impact on IPv6 content and its availability. From October 2014 to October 2015, there has been nearly a 4-percent increase in the number of websites that are IPv6-capable.

Regional Cloud Readiness

Internet Ubiquity

- North America and Western Europe led in Internet access penetration (fixed and mobile) in 2014 and will continue to lead in this category through 2019. However, all regions will show measurable improvement in broadband access to their respective populations throughout the forecast period.

Network Speeds and Latency

- Central and Eastern Europe leads all regions with an average fixed download speed of 28.3 Mbps. Asia Pacific follows with an average fixed download speed of 28.1 Mbps. Central and Eastern Europe and Asia Pacific also lead all regions in average fixed upload speeds with 20.9 Mbps and 16.0 Mbps, respectively.
- Central and Eastern Europe leads all regions in average fixed network latency with 33 ms, followed by Asia Pacific with 35 ms.
- North America leads all regions with an average mobile download speed of 16.3 Mbps. Western Europe follows with an average mobile download speed of 13.8 Mbps. Central and Eastern Europe and North America lead all regions in average mobile upload speeds with 7.7 Mbps and 6.5 Mbps, respectively.
- North America and Western Europe lead all regions in average mobile network latency with 63 ms and 70 ms, respectively.

Top Five Data Center and Cloud Networking Trends

Over the last few years, the telecommunications industry has seen cloud adoption evolve from an emerging technology to an established networking solution that is gaining widespread acceptance and deployment. Enterprise and government organizations are moving from test environments to placing more of their mission-critical workloads into the cloud. For consumers, cloud services offer ubiquitous access to content and services, on multiple devices, delivered to almost anywhere network users are located.

The following sections identify five important trends in data center and cloud networking that are accelerating traffic growth, changing the end-user experience, and placing new requirements and demands on data center and cloud-based infrastructures.

1. Growth of Global Data Center Relevance and Traffic
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    - Data Center Traffic Destinations: Most Traffic Remains Within the Data Center
    - Global Data Center and Cloud IP Traffic Growth
    - SDN/NFV Architecture Impact—Wild Card
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Trend 1: Growth of Global Data Center Relevance and Traffic

The main qualitative motivators for cloud adoption include faster delivery of services and data, increased application performance, and improved operational efficiencies. Although security and integration with existing IT environments continue to represent concerns for some potential cloud-based applications, a growing range of consumer and business cloud services are currently available. Today's cloud services address varying customer requirements (for example, privacy, mobility, and multiple device access) and support near-term opportunities as well as long-term strategic priorities for network operators, both public and private.

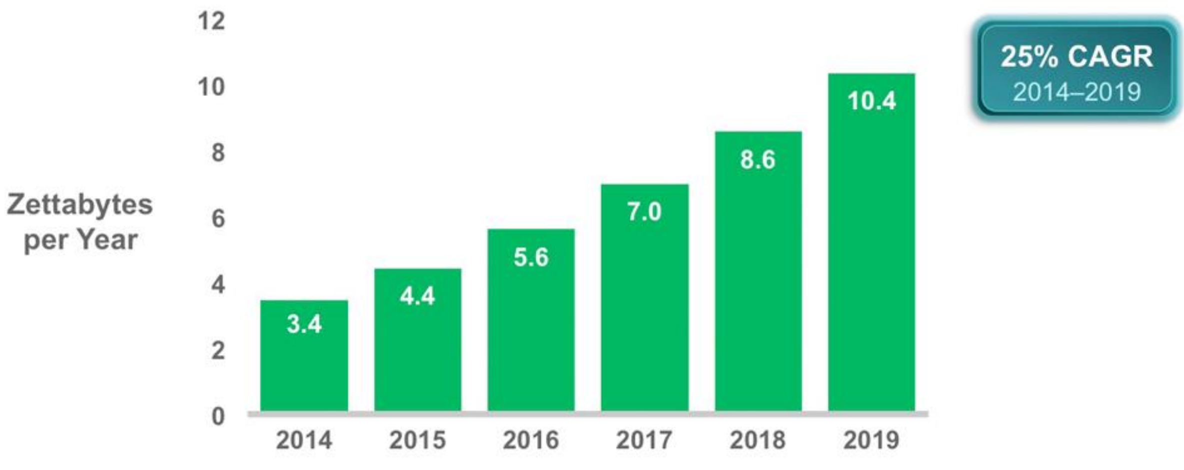
Quantitatively, the impact of cloud computing on data center traffic is clear. Most Internet traffic has originated or terminated in a data center since 2008, when peer-to-peer traffic (which does not originate from a data center but instead is transmitted directly from device to device) ceased to dominate the Internet application mix. Data center traffic will continue to dominate Internet traffic for the foreseeable future, but the nature of data center traffic is undergoing a fundamental transformation brought about by cloud applications, services, and infrastructure. The importance and relevance of the global cloud evolution is highlighted by one of the top-line projections from this updated forecast—by 2019 eighty-three percent, or more than four-fifths of data center traffic, will be cloud traffic.

The following sections summarize not only the volume and growth of traffic entering and exiting the data center, but also the traffic carried between different functional units within the data center, cloud versus traditional data center segments, and business versus consumer cloud segments.

Global Data Center IP Traffic: Three-Fold Increase by 2019

Figure 1 summarizes the forecast for data center IP traffic growth from 2014 to 2019.

Figure 1. Global Data Center IP Traffic Growth



Source: Cisco Global Cloud Index, 2014–2019

Although the amount of global traffic crossing the Internet and IP WAN networks is projected to reach 2.0 ZB per year by 2019[1], the amount of annual global data center traffic in 2014 is already estimated to be 3.5 ZB—and by 2019, will triple to reach 10.4 ZB per year. This increase represents a 25-percent CAGR. The higher volume of data center traffic is due to the inclusion of traffic inside the data center (typically, definitions of Internet and WAN stop at the boundary of the data center).

The global data center traffic forecast, a major component of the Cisco GCI report, covers network data centers worldwide operated by service providers as well as private enterprises. Please refer to Appendix A for more details about the methodology of the data center and cloud traffic forecasts, and Appendix B for the positioning of the GCI Forecast relative to the Cisco VNI Global IP Traffic Forecast.

Table 1 provides details for global data center traffic growth rates.

Table 1. Global Data Center Traffic, 2014–2019

Data Center IP Traffic, 2014–2019							
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**CAGR 2014–2019**
By Type (EB per Year)							
Data center to user	613	760	946	1,185	1,495	1,886	25%
Data center to data center	234	321	432	564	723	905	31%
Within data center	2,602	3,342	4,233	5,235	6,358	7,566	24%
By Segment (EB per Year)							
Consumer	2,103	2,758	3,550	4,444	5,599	6,885	27%
Business	1,346	1,665	2,061	2,540	2,977	3,472	21%
By Type (EB per Year)							
Cloud data center	2,110	2,956	4,017	5,328	6,854	8,622	33%
Traditional data center	1,339	1,467	1,594	1,656	1,722	1,735	5%
Total (EB per Year)							
Total data center traffic	3,449	4,423	5,611	6,984	8,576	10,357	25%

Source: Cisco Global Cloud Index, 2015

Definitions:

- **Data center to user**: Traffic that flows from the data center to end users through the Internet or IP WAN
- **Data center to data center**: Traffic that flows from data center to data center
- **Within data center**: Traffic that remains within the data center
- **Consumer**: Traffic originating with or destined for consumer end users
- **Business**: Traffic originating with or destined for business end users
- **Cloud data center**: Traffic associated with cloud consumer and business applications
- **Traditional data center**: Traffic associated with non-cloud consumer and business applications

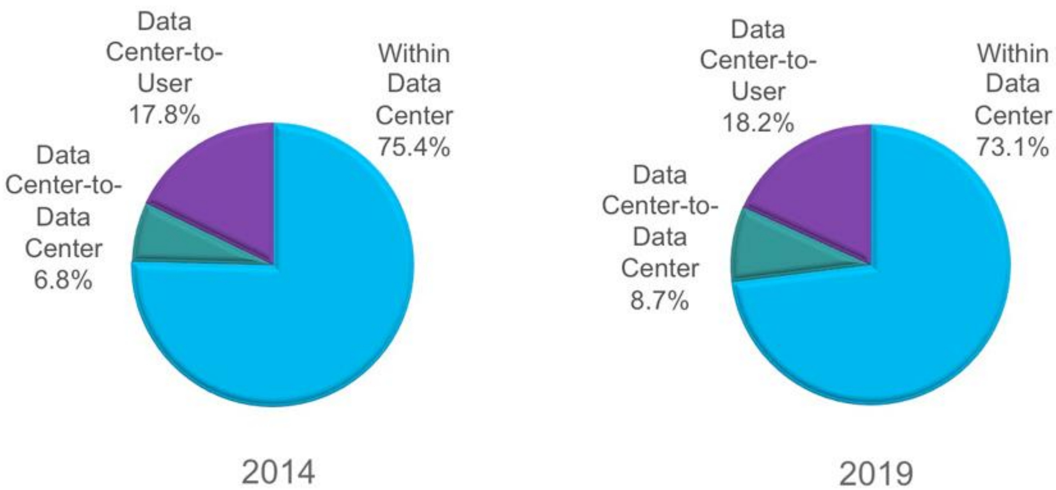
[1] Refer to: Cisco Visual Networking Index: Forecast and Methodology, 2014–2019.

Data Center Traffic Destinations: Most Traffic Remains Within the Data Center

Consumer and business traffic flowing through data centers can be broadly categorized into three main areas (Figure 2):

- **Traffic that remains within the data center**: For example, moving data from a development environment to a production environment within a data center, or writing data to a storage array
- **Traffic that flows from data center to data center**: For example, moving data between clouds, or copying content to multiple data centers as part of a content distribution network
- **Traffic that flows from the data center to end users through the Internet or IP WAN**: For example, streaming video to a mobile device or PC

Figure 2. Global Data Center Traffic by Destination



Source: Cisco Global Cloud Index, 2014–2019

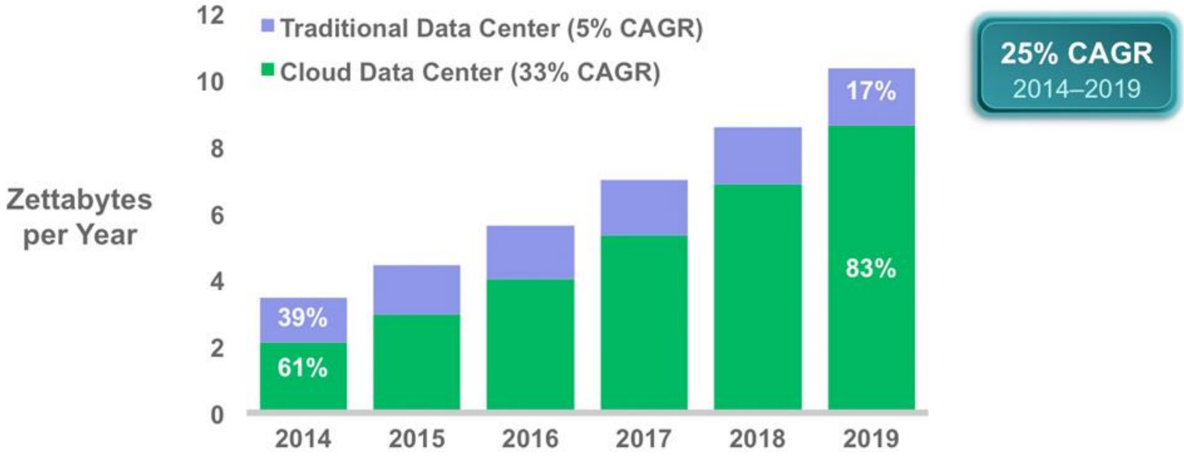
The portion of traffic residing within the data center will decline slightly over the forecast period, accounting for 75.5 percent of data center traffic in 2014 and about 73 percent by 2019. Despite the decline, the majority of traffic remains within the data center because of factors such as the functional separation of application servers, storage, and databases, which generates replication, backup, and read and write traffic traversing the data center. Furthermore, parallel processing divides tasks and sends them to multiple servers, contributing to internal data center traffic.

Traffic between data centers is growing faster than either traffic to end users or traffic within the data center, and by 2019, traffic between data centers will account for almost 9 percent of total data center traffic, up from nearly 7 percent at the end of 2014. The high growth of this segment is due to the increasing prevalence of content distribution networks, the proliferation of cloud services and the need to shuttle data between clouds, and the growing volume of data that needs to be replicated across data centers.

Global Data Center and Cloud IP Traffic Growth

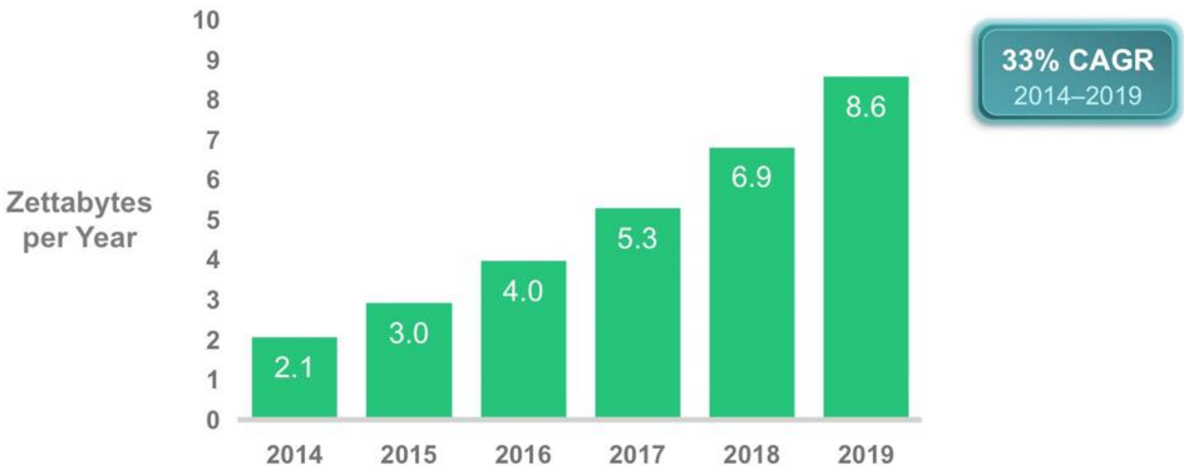
Data center traffic on a global scale will grow at a 25-percent CAGR (Figure 3), but cloud data center traffic will grow at a faster rate (33 percent CAGR) or 4.1-fold growth from 2014 to 2019 (Figure 4).

Figure 3. Total Data Center Traffic Growth



Source: Cisco Global Cloud Index, 2014–2019

Figure 4. Cloud Data Center Traffic Growth



Source: Cisco Global Cloud Index, 2014–2019

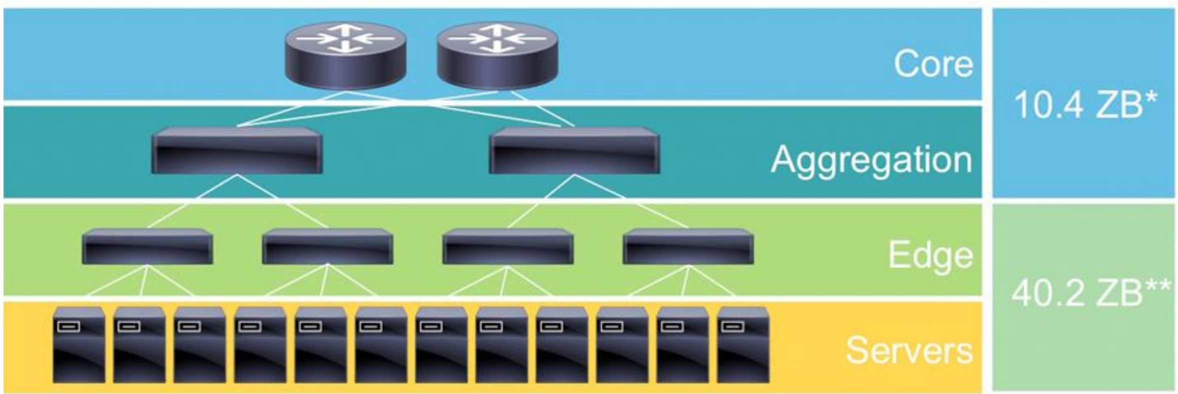
Global cloud traffic crossed the zettabyte threshold in 2014, and by 2019, more than four-fifths of all data center traffic will be based in the cloud (for regional cloud traffic trends, please refer to Appendix C. Cloud traffic will represent 83 percent of total data center traffic by 2019.

Significant promoters of cloud traffic growth include the rapid adoption of and migration to cloud architectures and the ability of cloud data centers to handle significantly higher traffic loads. Cloud data centers support increased virtualization, standardization, and automation. These factors lead to better performance as well as higher capacity and throughput.

SDN/NFV Architecture Impact—Wild Card

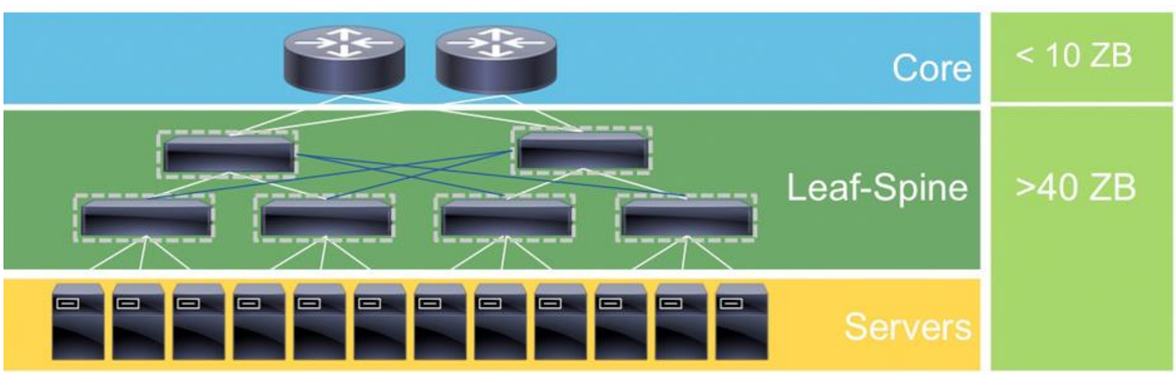
Three technology trends are transforming the data center: leaf-spine architectures (which flatten the tiered architecture of the data center), software-defined networks (SDNs, which separate the control and forwarding of data center traffic), and network function virtualization (NFV, which virtualizes a variety of network elements). Currently, GCI measures data center traffic at the aggregation/core tier (Figure 5). The new architectures will streamline the traffic flows of the data center such that the traffic reaching the highest tiers of the data center may fall below 10.4 zettabytes per year, and the newly merged aggregation and access layers of the data center will carry more than 40 zettabytes of traffic per year (Figure 6).

Figure 5. Traditional Data Center Architecture



*Currently forecasted as 2019 total data center traffic.
** Currently not captured in the forecast.
Source: Cisco Global Cloud Index, 2014–2019

Figure 6. Evolving Data Center Architecture

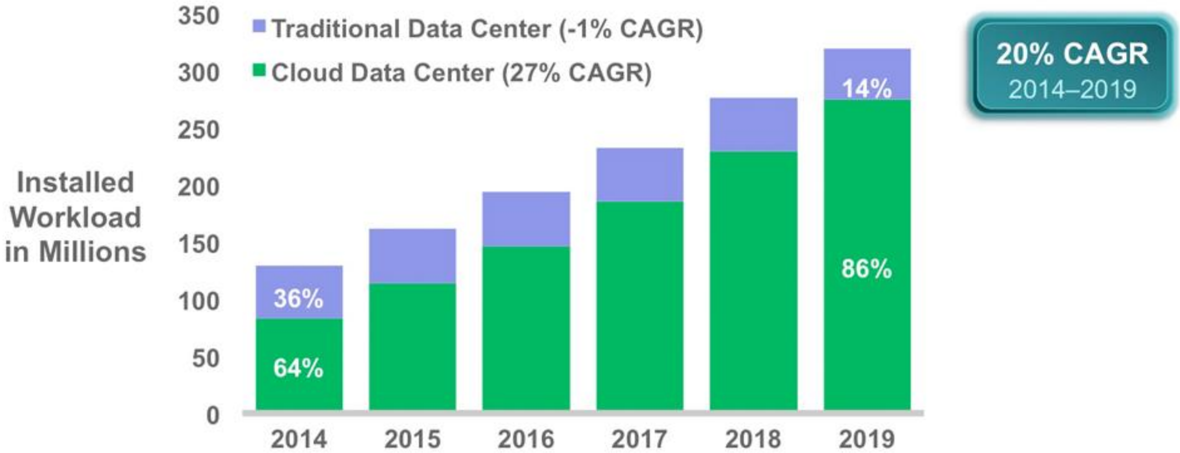


Note: According to Current Analysis 2015 Global SDN Buyer Study, within two years, more than 80 percent of companies expect to implement SDN, and 69 percent of those plan to implement SDN in the data center, compared to 47 percent and 31 percent for WAN and LAN, respectively.
Source: Cisco Global Cloud Index, 2014–2019

Trend 2: Continued Global Data Center Virtualization

A server workload is defined as a virtual or physical set of computer resources, including storage, that are assigned to run a specific application or provide computing services for one to many users. A workload is a general measurement used to describe many different applications, from a small lightweight SaaS application to a large computational private cloud database application. For the purposes of quantification, we consider each workload being equal to a virtual machine or a container. The Cisco Global Cloud Index forecasts the continued transition of workloads from traditional data centers to cloud data centers. By 2019, more than four-fifths (86 percent) of all workloads will be processed in cloud data centers (Figure 7). For regional distributions of workloads, refer to Appendix D.

Figure 7. Workload Distribution: 2014–2019



Source: Cisco Global Cloud Index, 2014–2019

Cloud workloads are expected to more than triple (grow 3.3-fold) from 2014 to 2019, whereas traditional data center workloads are expected to see a global decline, for the first time, at a negative 1-percent CAGR from 2014 to 2019. Traditionally, one server carried one workload. However, with increasing server computing capacity and virtualization, multiple workloads per physical server are common in cloud architectures. Cloud economics, including server cost, resiliency, scalability, and product lifespan, along with enhancements in cloud security, are promoting migration of workloads across servers, both inside the data center and across data centers (even data centers in different geographic areas). Often an end-user application can be supported by several workloads distributed across servers. This approach can generate multiple streams of traffic within and between data centers, in addition to traffic to and from the end user. Table 2 provides details about the shift of workloads from traditional data centers to cloud data centers.

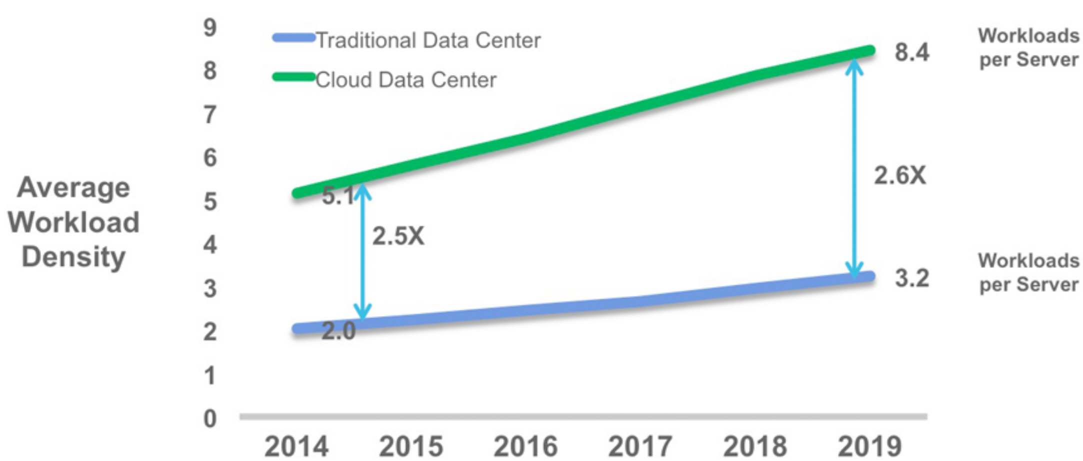
Table 2. Workload Shift from Traditional Data Centers to Cloud Data Centers

Global Data Center Workloads in Millions							
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**CAGR 2014–2019**
Traditional data center workloads	46.0	48.2	48.3	47.4	47.1	44.5	-1%
Cloud data center workloads	83.5	113.6	145.9	185.3	229.5	275.1	27%
Total data center workloads	129.5	161.8	194.2	232.7	276.6	319.7	20%
Cloud workloads as a percentage of total data center workloads	64%	70%	75%	80%	83%	86%	NA
Traditional workloads as a percentage of total data center workloads	36%	30%	25%	20%	17%	14%	NA

Source: Cisco Global Cloud Index, 2015

One of the main factors prompting the migration of workloads from traditional data centers to cloud data centers is the greater degree of virtualization (Figure 8) in the cloud space, which allows dynamic deployment of workloads in the cloud to meet the dynamic demand of cloud services. This greater degree of virtualization in cloud data centers can be expressed as workload density. Workload density measures average number of workloads per physical server. The workload density for cloud servers will grow from 5.1 in 2014 to 8.4 by 2019. In comparison, the workload density in traditional data center servers will grow from 2.0 in 2014 to 3.2 by 2019.

Figure 8. Increasing Cloud Virtualization



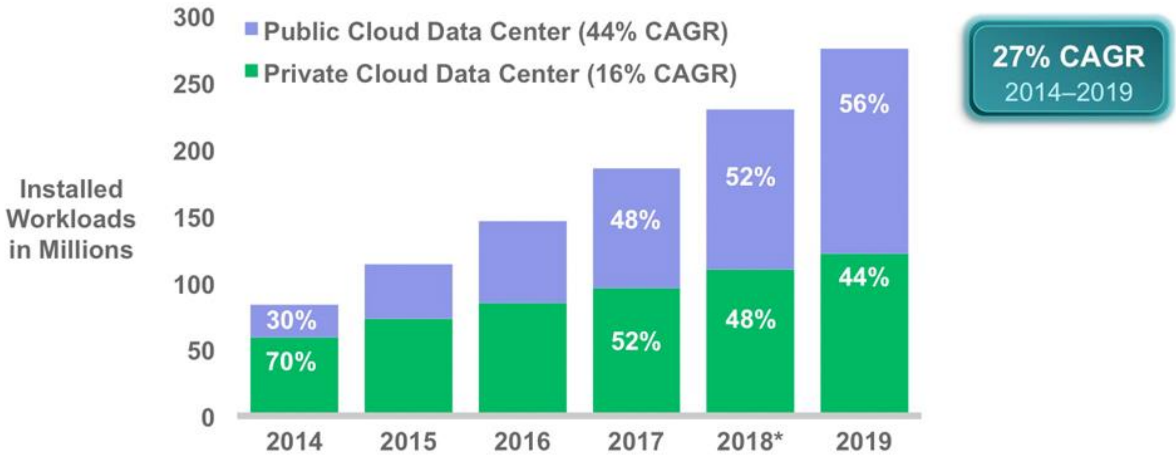
Source: Cisco Global Cloud Index, 2014–2019

Public vs. Private Cloud[2]

We look into the growth of public cloud vs. private cloud through workload analysis. Public cloud, as indicated by the workloads growth, is growing faster than the private cloud. As the business sensitivity to costs associated with dedicated IT resources grows along with demand for agility, we can see a greater adoption of public cloud by the businesses, especially with strengthening of public cloud security. Although many mission-critical workloads might continue to be retained in the traditional data centers or private cloud, the public cloud adoption is increasing along with the gain in trust in public cloud. Some enterprises might adopt a hybrid approach to cloud. In a hybrid cloud environment, some of the cloud computing resources are managed in-house by an enterprise and some are provided by an external provider. Cloud bursting is an example of hybrid cloud where daily computing requirements are handled by a private cloud, but for sudden spurts of demand the additional traffic demand (bursting) is handled by a public cloud.

While the overall cloud workloads are growing at a CAGR of 27 percent from 2014 to 2019 (Figure 9), the public cloud workloads are going to grow at 44-percent CAGR from 2014 to 2019, and private cloud workloads will grow at a slower pace of 16-percent CAGR from 2014 to 2019. By 2018 there will be more workloads (56 percent) in the public cloud as compared to private cloud (44 percent).

Figure 9. Public vs. Private Cloud Growth

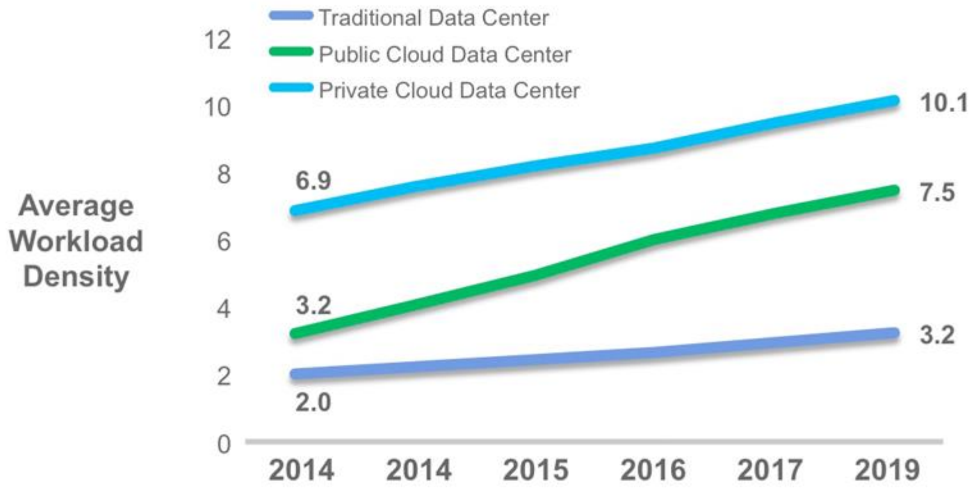


Source: Cisco Global Cloud Index, 2014–2019

This growth of workloads in the public cloud space is also reflected in the growth of virtualization, as shown in Figure 10. While the workload density in private cloud data centers will continue to outpace that in public cloud data centers, the gap continues to narrow over the forecast period. In 2014, the average workloads per physical server in private data centers were more than double of those in public cloud, but by 2019 this difference will decrease to 1.4 times.

[2] For definition of public and private cloud, please refer to Appendix E.

Figure 10. Public Cloud Virtualization Gaining Momentum



Source: Cisco Global Cloud Index, 2014–2019

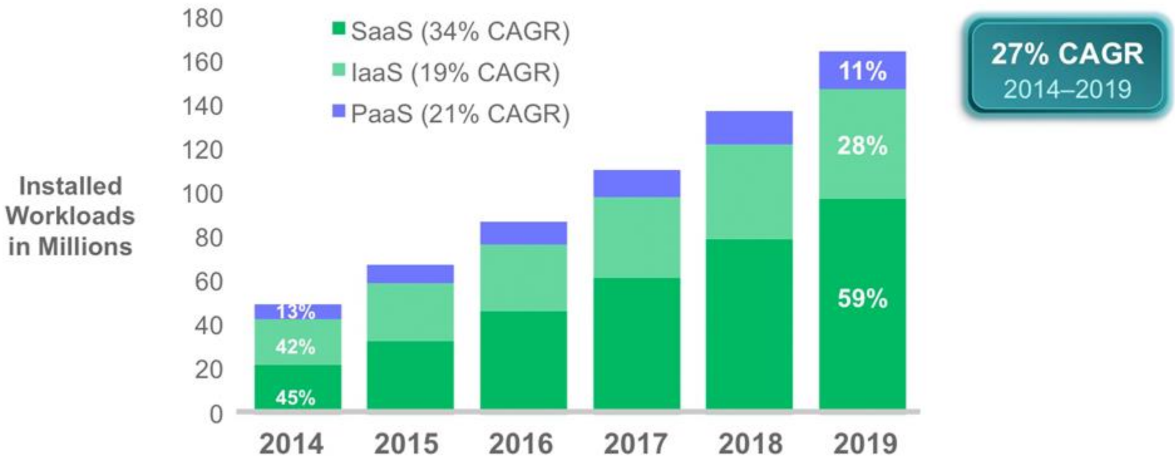
Trend 3: Cloud Service Trends

This section reviews the growth of the three different cloud service categories: IaaS, PaaS, and SaaS[3]. Although numerous other service categories have emerged over time, they can be aligned within the IaaS, PaaS, and SaaS categorization. For example, business process-as-a-service (BPaaS) is considered part of SaaS. For simplicity we can think of these three service models as different layers of cloud with infrastructure at the bottom, the platform next, and finally software at the top.

GCI categorizes a cloud workload as IaaS, PaaS, or SaaS based upon how the user ultimately uses the service, regardless of other cloud services types that may be involved in the final delivery of the service. As an example, if a cloud service is a SaaS type but it also depends on some aspects of other cloud services such as PaaS or IaaS, such a workload is counted as SaaS only. As another example, if a PaaS workload operates on top of an IaaS service, such a workload is counted as PaaS only.

At the aggregate cloud level, we find that SaaS workloads maintain majority share throughout the forecast years, and by 2019 will have 59-percent share of all cloud workloads, growing at 34-percent CAGR from 2014 to 2019 (Figure 11). PaaS will have the second-fastest growth, although it will lose the share of total cloud workloads from 13 percent in 2014 to 11 percent by 2019.

Figure 11. SaaS Most Highly Deployed Global Cloud Service from 2014 to 2019

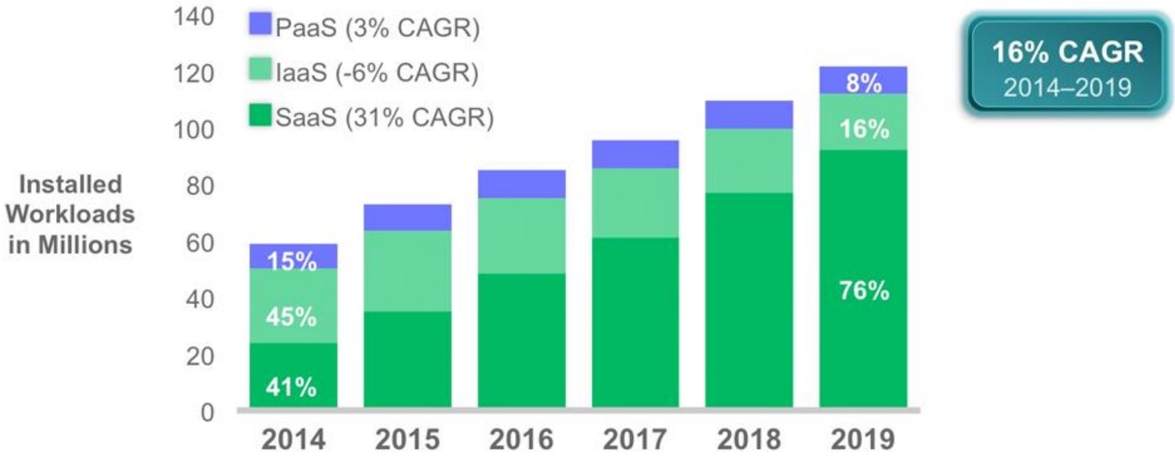


Source: Cisco Global Cloud Index, 2014–2019

In order to understand the reasons behind this trend, we have to analyze the public and private cloud segments a bit more deeply. In the private cloud, initial deployments were predominantly IaaS. Test and development types of cloud services were the first to be used in the enterprise; cloud was a radical change in deploying IT services, and this use was a safe and practical initial use of private cloud for enterprises. It was limited, and it did not pose a risk of disrupting the workings of IT resources in the enterprise. As trust in adoption of SaaS or mission-critical applications builds over time with technology enablement in processing power, storage advancements, memory advancements, and networking advancements, we foresee the adoption of SaaS type applications to accelerate over the forecast period (Figure 12), while shares of IaaS and PaaS workloads decline.

[3] For definition of IaaS, PaaS, and SaaS, please refer to Appendix E.

Figure 12. SaaS Gains Momentum in Private Cloud

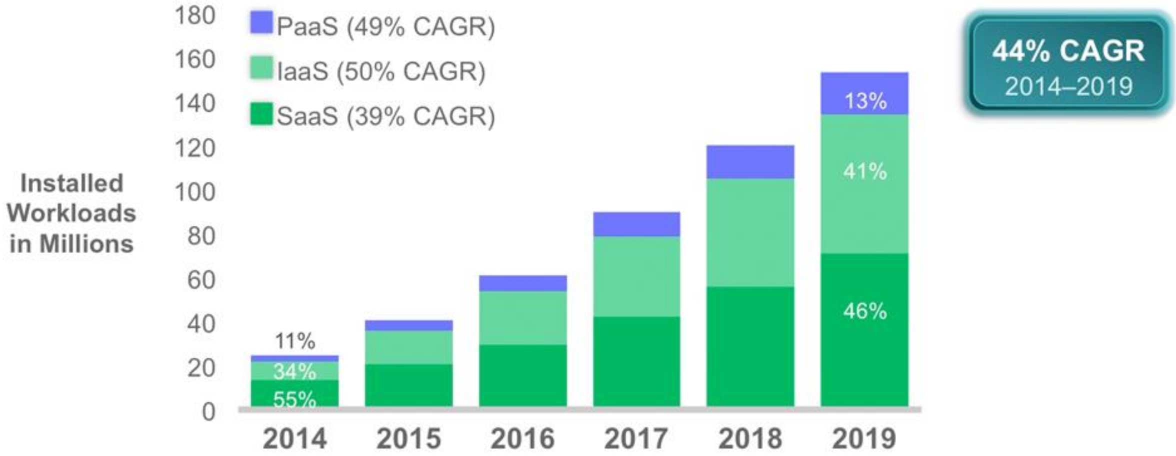


Source: Cisco Global Cloud Index, 2014–2019

In the public cloud segment the first cloud services to be deployed were SaaS. SaaS services offered in the public cloud were often a low-risk and easy-to-adopt proposition, with some clear financial and flexibility benefits to users. The first users of SaaS were the consumer segment, followed by some small and medium-sized businesses. As public SaaS solutions become more sophisticated and robust, larger enterprises are adopting these services as well, beginning with less-critical services. Enterprises, especially large ones, will be carefully weighing the benefits (scalability, consistency, cost optimization, etc.) of adopting public cloud services against the risks (security, data integrity, business continuity, etc.) of adopting such services.

As shown in Figure 13, IaaS and PaaS have gone beyond the initial stages of deployment in the public cloud. Spend on public IaaS and PaaS is still small compared with spend on enterprise data center equipment, data center facilities, and associated operating expenses. These cloud services will gain momentum over the forecast period as more competitive offers come to the market and continue to build enterprise trust for outsourcing these more technical and fundamental services.

Figure 13. IaaS and PaaS Gain Public Cloud Share of Workloads



Source: Cisco Global Cloud Index, 2014–2019

Trend 4: Global Digitization—IoE and Big Data

Potential Impact of "Big Data" on Global Data Centers

Cloud services are accelerated in part by the unprecedented amounts of data being generated by not only people but also machines and things. Cisco GCI estimates that more than 500 zettabytes will be generated by all people, machines, and things by 2019, up from 135 zettabytes generated in 2014.

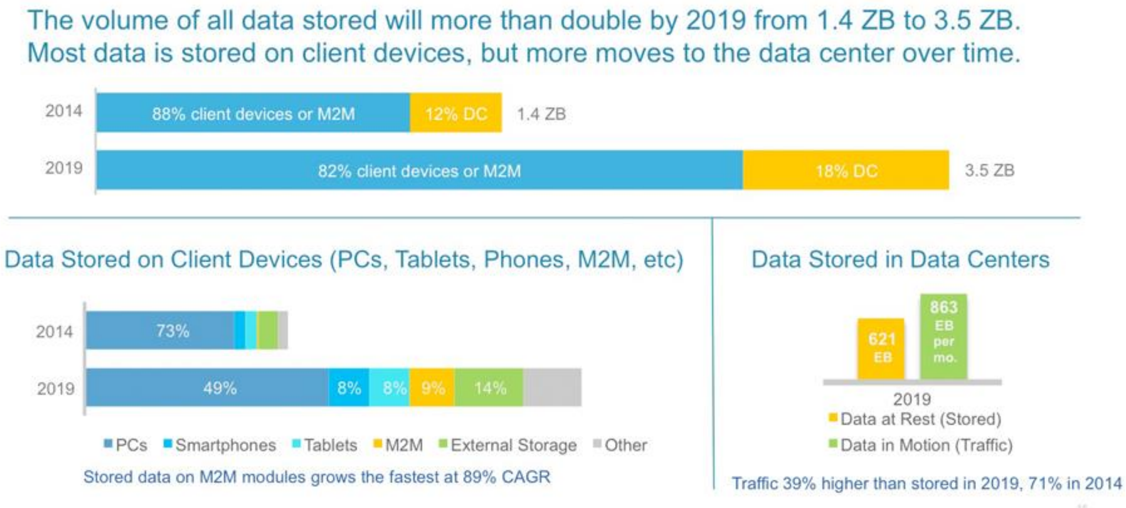
Figure 14 shows examples of the amounts of data that will be generated by planes, automobiles, and buildings, among other things and systems.

Figure 14. Smart City—Multiple Applications Create Big Data

Source: Cisco Global Cloud Index, 2014–2019

Most of the more than 500 zettabytes that will be generated by 2019 will be ephemeral in nature and will neither be saved nor stored. Cisco GCI now estimates that the total volume of stored data on client devices and in data centers will reach 3.5 zettabytes by 2019. Most stored data resides in client devices today and throughout the forecast period, but more data will move to the data center over time (Figure 15). In addition to larger volumes of stored data, the stored data will be coming from a wider range of devices by 2019. Currently, 73 percent of data stored on client devices resides on PCs. By 2019, stored data on PCs will reduce to 49 percent, with a greater portion of data on smartphones, tablets, and machine-to-machine (M2M) modules. Stored data associated with M2M grows at a faster rate than any other device category at a CAGR of 89 percent.

Figure 15. Data Center Storage Analysis



Source: Cisco Global Cloud Index, 2014–2019

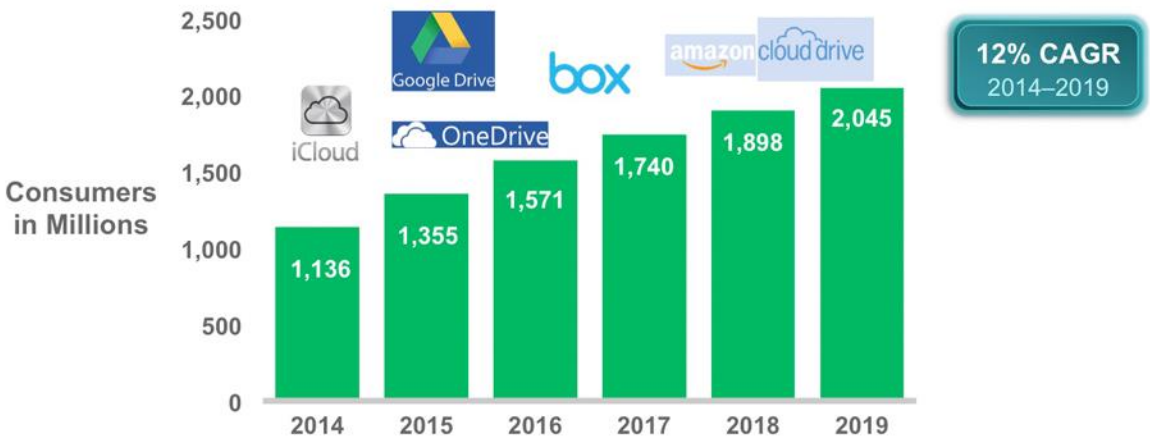
Over time, cloud-based services will enable consumers and businesses alike to move more of their stored data to a central repository that can provide ubiquitous access to content and applications through any device at any location. The following section covers the growth in consumer cloud storage.

Consumer Cloud Storage Growth

Along with the growth in consumer Internet population and multidevice ownership devices, we are seeing a significant growth in the use of cloud services such as consumer cloud storage, also called personal content lockers. In personal content lockers, users can store and share music, photos, and videos through an easy-to-use interface at relatively low or no cost. Furthermore, the proliferation of tablets, smartphones, and other mobile devices allows access to personal content lockers in a manner convenient to the user.

Cisco GCI estimates that by 2019, 55 percent (2 billion) of the consumer Internet population will use personal cloud storage, up from 42 percent (1.1 billion users) in 2014 (Figure 16).

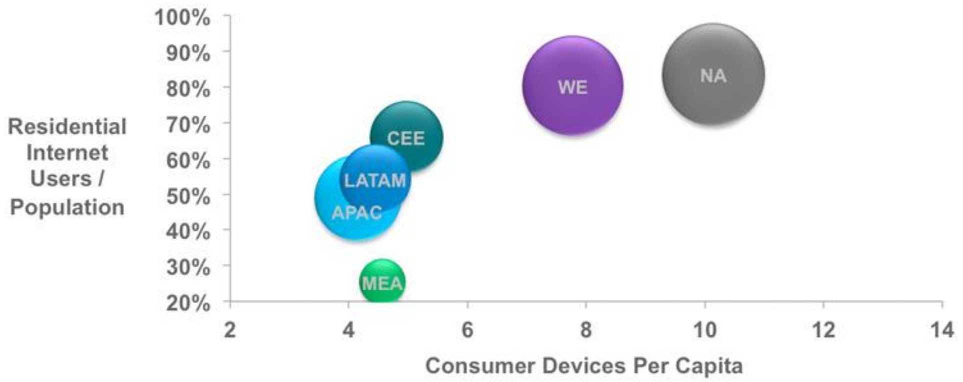
Figure 16. Personal Cloud Storage—Growth in Users



Source: Cisco Global Cloud Index, 2014–2019; Juniper Research

Figure 17 demonstrates the projected expansion of consumer cloud storage in relation to multiple device usage and growing Internet access at a regional level in 2019. The high adoption of consumer cloud storage services in North America and Western Europe as depicted by the size of the bubble for those regions clearly shows a high correlation with the regional consumer Internet penetration as well as average of devices per consumer. For details for other regions, please refer to Appendix F.

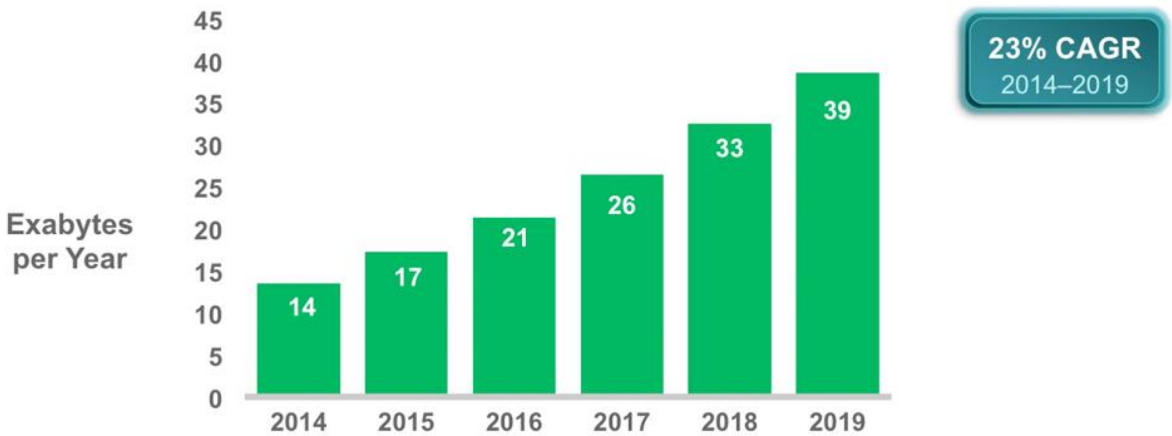
Figure 17. Personal Cloud Storage Accelerated by Growth in Internet Access and Multidevice Ownership



The size of the bubbles represents the adoption of consumer cloud storage as a percentage of residential Internet population.
Source: Cisco Global Cloud Index, 2014–2019

Cisco GCI forecasts that global consumer cloud storage traffic will grow from 14 EB annually in 2014 to 39 EB by 2019 at a CAGR of 23 percent (Figure 18). This growth translates to per-user traffic of 1.6 Gigabytes (GB) per month by 2019, compared to 992 MB per month in 2014.

Figure 18. Consumer Cloud Storage Traffic* Growth

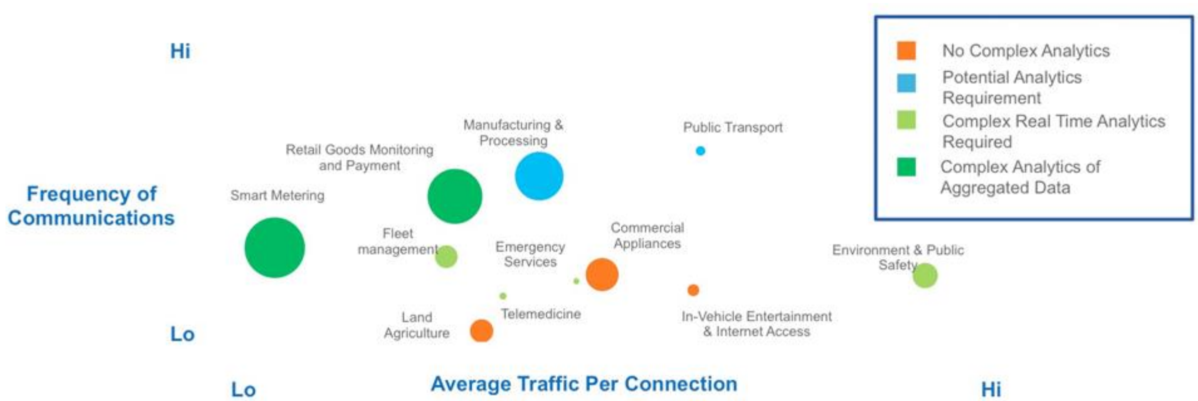


*Consumer cloud storage traffic includes personal content lockers, cloud backup, etc., and does not include cloud DVR.
Source: Cisco Global Cloud Index, 2014–2019

M2M and Real-Time Analytics

Growth in machine-to-machine connections and applications is also driving new data analytics needs. Although not all M2M applications promote a lot of traffic, the sheer number of these connections is capable of delivering intelligent, actionable information if the data from them can be analyzed. Figure 19 maps several of such M2M applications for their frequency of network communications, average traffic per connection, and data analytic needs. Applications such as smart metering can benefit from real-time analytics of aggregated data that can optimize the usage of resources such as electricity, gas, and water. On the other hand, applications such as emergency services and environment and public safety can be much enhanced through distributed real-time analytics that can help make real-time decisions that affect entire communities. Although some other applications such as manufacturing and processing can have potential efficiencies from real-time analytics, their need is not very imminent.

Figure 19. Growth in M2M Connections Drive New Data Analytics Needs



The size of the bubble represents total M2M connections for each application.
Source: Cisco Global Cloud Index, 2014–2019; Machina Research

IPv6 Adoption Fosters Cloud Growth

Another important component of the Internet of Everything and adoption of cloud services is the growth of IPv6 capability among users, devices, network connectivity, and content enablement. With the American Registry for Internet Numbers (ARIN) out of IPv4 addresses this year, the move to IPv6 becomes even more significant.

According to Google, the percentage of IPv6 global users who access Google through IPv6 has doubled and is nearly 9 percent as of October 2015, up from 4.54 percent last year.

In several countries, the proportion of Internet users enjoying IPv6 connectivity has grown exponentially, with Belgium and Germany showing a 7-percent increase, Switzerland ~12-percent increase, and the United States nearly 11-percent increase since last year (Source: Cisco Labs). Based on Cisco Lab projections, globally 32 percent of users will be IPv6-capable by October 2019 (Figure 20).

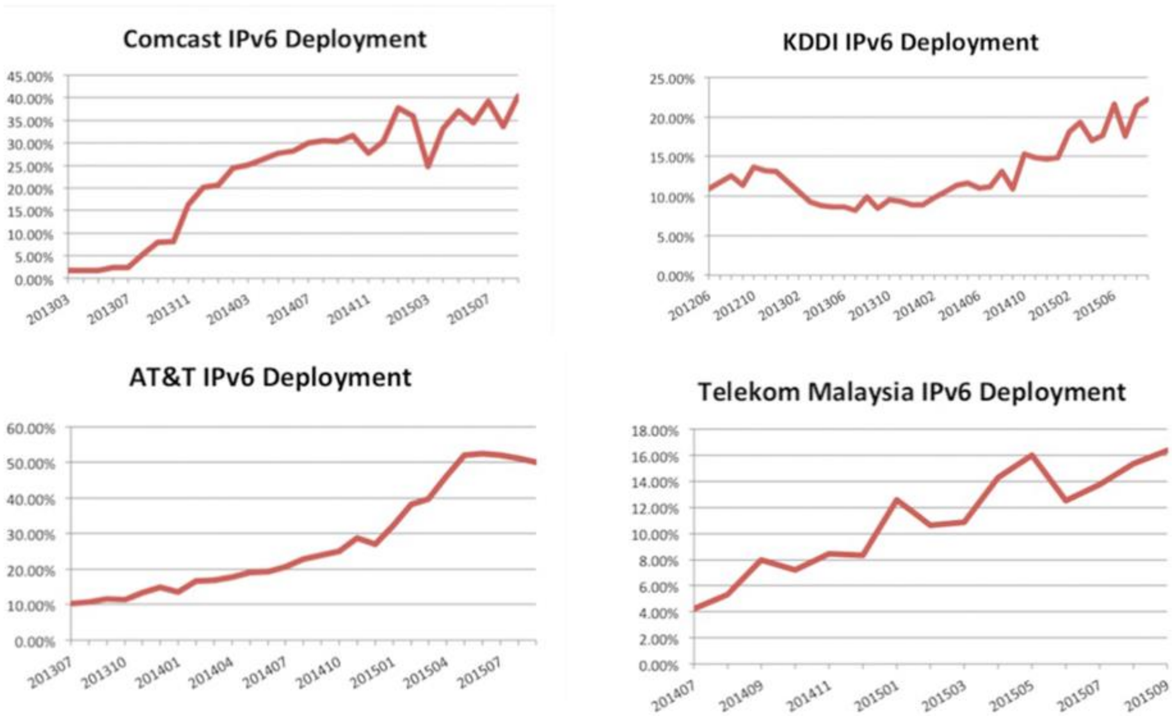
Figure 20. IPv6 User Projections

Source: Forecast simulation tool at 6lab.cisco.com

From a device perspective, there will be 10 billion IPv6-capable fixed and mobile devices in 2019, up from 3 billion in 2014, a CAGR of 26 percent, and in terms of percentages, 41 percent of all fixed and mobile networked devices will be IPv6-capable in 2019, up from 22 percent in 2014. (Source: Cisco VNI white paper, "The Zettabyte Era")

There have been specific country initiatives and cloud provider deployments that have positively affected local IPv6 content reachability. In addition, recent advancements in IPv6 network deployment signify service providers' focus on IPv6 connectivity on both mobile and fixed networks. According to the World IPv6 Launch Organization, in September 2015 IPv6 deployment within Verizon Wireless was 72 percent, AT&T ~50 percent, T-Mobile 48 percent, Comcast ~40 percent, Deutsche Telecom 23 percent, Japan's KDDI ~22 percent, and Telekom Malaysia 16 percent (Figure 21).

Figure 21. IPv6 Deployments



Source: World IPv6 Launch Organization

Content providers are also moving to increase the IPv6 enablement of their sites and services. Cisco's IPv6 Lab reports that nearly 7,000 websites (as of Oct. 1, 2015) of the 27,736 websites tracked are IPv6-capable, up from 5,880 websites (as of Oct. 1, 2014). Cisco's IPv6 Lab tests 27,736 websites every day, from the top 500 websites for each of the 120 countries listed by Alexa (redundancy is not tested by Cisco IPv6 Lab).

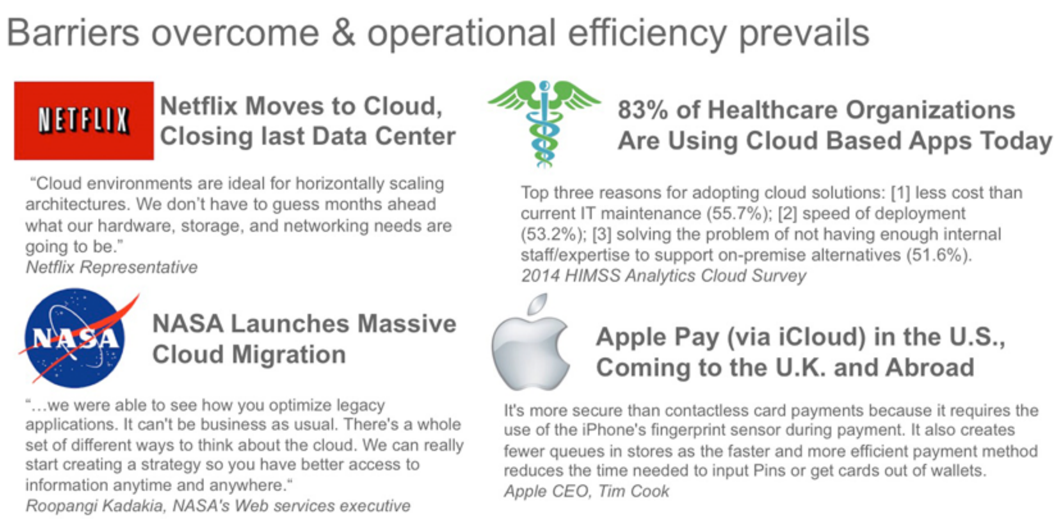
In addition, content providers are continuing to make strides in IPv6, enabling video and other rich-media content. Based on industry feedback, the IPv6 cloud looks similar to the IPv4 cloud, with video making up a significant percentage of the downstream traffic profile.

Trend 5: Global Cloud Readiness

Security—Imperative for Cloud Growth

The move to the cloud is imminent. In just the past year, a variety of businesses and organizations have reported their plans for cloud migration or adoption. For example, Netflix Inc. announced plans to shut down the last of its traditional data centers during 2015, a step that will make it one of the first big companies to run all of its IT in the public cloud. “For our streaming business, we have been 100% cloud-based for customer facing systems for some time now, and are planning to completely retire our data centers later this summer.”[4] Several additional cloud examples are provided in Figure 22.

Figure 22. Examples of Broad Cloud Adoption



Scalability and allocation of resources are the major advantages of virtualization (refer to the section “Trend 2: Continued Global Data Center Virtualization”) and cloud computing. Administrators can bring up virtual machines (VMs) and servers quickly without having the overhead of ordering or provisioning new hardware. Hardware resources can be reassigned quickly and extra processing power can be consumed by other services for maximum efficiency. By taking advantage of all the available processing power and untethering the hardware from a single server model, cost efficiencies are being realized in both private and public clouds.

According to the National Institute of Technology (NIST), cloud computing can be divided into three main service types (refer to the section “Trend 3: Cloud Service Trends”): Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS), and each affects data control and governance a little differently. With IaaS, the customer may have full control of the actual server configuration, granting them more risk management control over the environment and data. In PaaS, the provider manages the hardware and underlying operating system, limiting enterprise risk management capabilities on those components. With SaaS, both the platform and the infrastructure are fully managed by the cloud provider, meaning if the underlying operating system or service isn’t configured appropriately the data in the higher layer application may be at risk.

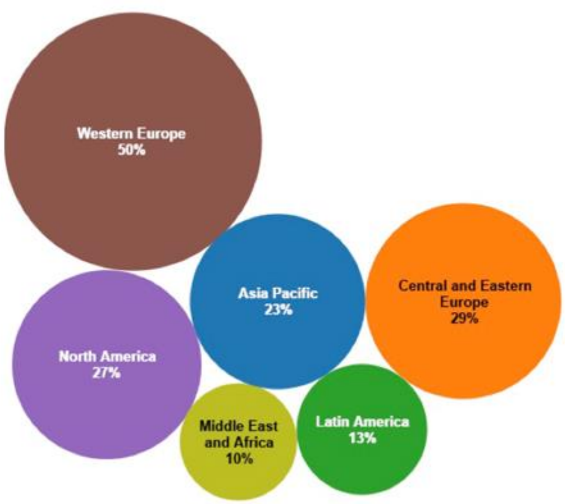
[4] http://blogs.wsj.com/cio/2015/08/14/the-morning-download-netflix-leads-way-into-cloud-closing-final-data-center/

Globally, data breaches are estimated to cost companies $2.1 trillion by 2019, while cybercrimes and espionage cost companies nearly $500B today.[5] The last several years have undoubtedly been the most eventful period from a cloud security threat perspective, with various instances of massive breaches and escalating distributed denial-of-service (DDoS) amplification attacks. Many network security vendors and other networking device manufacturers raced to patch their appliances against Heartbleed, a serious vulnerability in the popular OpenSSL cryptographic software library, and Shellshock, an open-source vulnerability, which set off a series of patch releases, among many others. The response showcased the effectiveness of security vendors to provide support and assistance to customers in need. It also shed light on the broad adoption and very quickly evolving landscape of cloud security and management. Across cloud services, 16.2 percent of files contain one or more of the previously mentioned sensitive data types, and an alarming 27.8 percent of users have uploaded sensitive data to the cloud. The most common type of sensitive data found in the cloud is confidential data comprising 47.0 percent of cloud data loss incidents.[6]

Users expect their online experiences to be always available and always secure—and their personal and business assets to be safe. As more data, business processes, and services move to the cloud, organizations are challenged to protect websites and infrastructure without sacrificing performance for security.

To help meet user expectations, more secure Internet servers are being deployed worldwide. This situation creates a growing infrastructure footprint that provides more stringent authorization and authentication processes and better serves end users with secure transactions and communication. The percentage of secure Internet servers that conduct encrypted transactions over the Internet using a Secure Sockets Layer (SSL) to the total number of web facing servers is shown in Figure 23. In the past year, North America and Western Europe led with the percentage of secure Internet servers compared to web-facing Internet servers.

Figure 23. Percentage of Secure Internet Servers to Total Web-Facing Internet Servers by Region



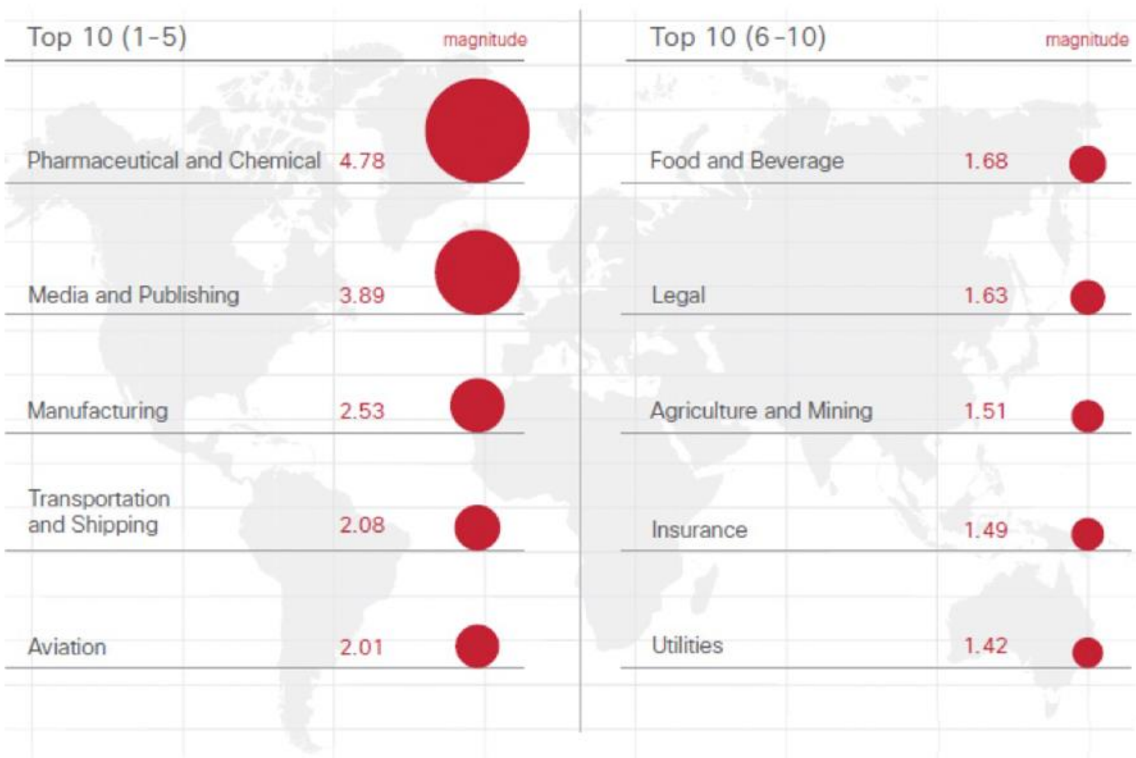
Source: Cisco GCI 2015, UN, NetCraft, Synergy Research

[5] https://lemon.fish/2015/09/cover-your-assets-data-protection-and-breach-detection/
[6] https://www.skyhighnetworks.com/cloud-report/

Although end-user security concerns exist, the time of amateur hackers is long over, and hacking is now an organized crime or state-sponsored event. DDoS attacks against customers remain a major operational threat to service providers. Attacks against infrastructure continue to grow in prominence. Phishing and malware threats occur on a daily basis.

According to the Cisco 2015 Annual Security report, the pharmaceutical and chemical industry has emerged as the number one high risk industry for web malware encounters in 2014. For the first half of the year, media and publishing held the top spot, but had edged down to second place by November. Rounding out the top five are manufacturing, transportation and shipping, and aviation, respectively. All of these industries placed in the top five for the first half of 2014, per Figure 24.

Figure 24. Industry Risk of Web Malware Encounters, All Regions, January 1–November 15, 2014



Source: Cisco Security Research

IoE and big data requirements are starting a new wave of security discussions and technology convergence. As enterprises and service providers move to public and private clouds and modernize data centers with SDN or consume IT-as-a-Service (ITaaS), security becomes an even more complex concern. Besides hardware appliances, virtual machines, and server software, innovative services that use SDN and NFV will help to improve the data integrity and security of cloud infrastructures.

Network Speeds and Latency Analysis

The cloud-readiness study offers a regional view of the requirements for broadband and mobile networks to deliver next-generation cloud services. The enhancements and reliability of these networks will support the increased adoption of cloud computing solutions that deliver basic as well as advanced application services. For example, consumers expect to be able to communicate with friends as well as stream music and videos at any time, any place. Business users require reliable access to business communications along with mobile solutions for video conferencing and mission-critical customer and operational management systems.

The study also explores the ability of each global region (Asia Pacific, Central and Eastern Europe, Latin America, Middle East and Africa, North America, and Western Europe) to support a sample set of basic, intermediate, and advanced business and consumer cloud applications. Each region's cloud readiness is assessed with relation to the sample services based on download and upload fixed and mobile network speeds as well as associated network latencies (segmented by business and consumer connections). Download and upload speeds as well as latencies are essential measures to assess network capabilities for cloud readiness. Figure 25 provides the business and consumer cloud service categories and the corresponding network requirements used for this study. Tables 3 through 5 describe the requirements and define a sample set of applications from each of the readiness categories. Note that the concurrent use of applications can further influence the user experience and cloud accessibility.

Figure 25. Sample Business and Consumer Cloud Service Categories

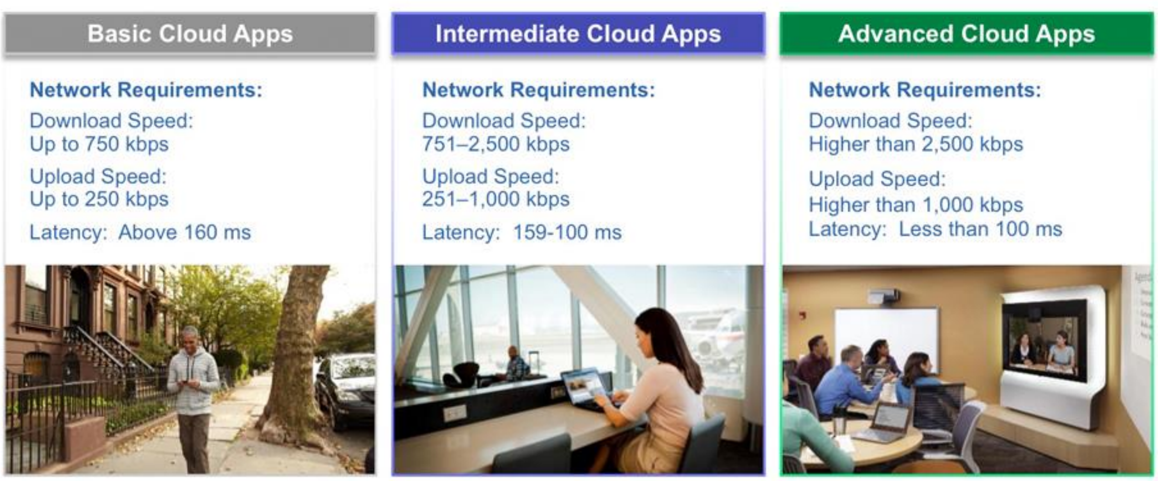


Table 3. Sample Basic Applications

Apps	Definitions	Download	Upload	Latency
Stream basic video and music	Deliver sound and video without the need to download files of different audio or video formats using computer servers connected to the Internet to access information.	High	Low	Medium
Text communications (email and instant messaging)	A cross-platform messaging application that allows the exchange of messages without having to pay for Short Message Service (SMS), using an Internet data plan	Low	Low	Medium
Voice over IP (VoIP) (Internet telephony)	A broad range of services transmitting voice over the Internet.	Low	Low	Medium
Web browsing	Accelerate web experiences and searching through cloud computing using technology to shift the workload to the cloud servers.	Low	Low	Medium
Web conferencing	A cloud application used to interact with other participants and have that "live and in-person" feeling for attendees; it offers services such as collaborative web browsing and application sharing.	Medium	Medium	Medium
Cloud-based learning management system	This app provides the user with the flexibility of being able to access and collaborate with others in a centralized environment. With information housed in a virtual storage environment, it allows work to be completed outside the boundaries of the formal learning or work institutions	High	Medium	Medium

Table 4. Sample Intermediate Applications

Apps	Definitions	Download	Upload	Latency
Enterprise resource planning (ERP) and customer relationship management (CRM)	ERP and CRM systems allow businesses to manage their business and business relationships and the data and information associated with them.	Medium	Low	Medium
High-definition (HD) video streaming	Deliver HD video without the need to download files of HD video formats using computer servers connected to the Internet to access information.	High	Low	Low
Standard-definition (SD) video conferencing	Two-way interactive SD video communication delivered using Internet technologies that allow people at different locations to come together for a meeting.	Medium	Medium	Medium
Web electronic health records (EHRs)	EHRs are designed to contain and share information from all providers involved in a patient's care in a structured format allowing patient information to be easily retrieved and transferred in ways that can aid patient care.	Medium	High	Low
Voice over LTE (VoLTE)	This standardized system allows for transferring traffic for VoLTE.	Low	Low	Low
Personal content locker	Asynchronous storage enables applications that use compound files to efficiently render their content when accessed by means of existing Internet protocols, with a single request to a server triggering the download of nested objects contained within a webpage, eliminating the need to separately request each object.	High	High	Low

Table 5. Sample Advanced Applications

Apps	Definitions	Download	Upload	Latency
Telemedicine	Telemedicine is the use of medical information exchanged from one site to another through electronic communications to improve a patient's clinical health status and includes using two-way video, email, smartphones, wireless tools, and other forms of telecommunications technology.	Medium	Medium	Low
HD video conferencing	Two-way interactive HD video communication is delivered using Internet technologies that allow people at different locations to come together for a meeting.	High	High	Low
Ultra HD video streaming	This app delivers Ultra HD video without the need to download files of different video formats using computer servers connected to the Internet to access information.	High	High	Low
Virtual office	A virtual office is a mobile or remote work environment equipped with telecommunication links but without a fixed office space In the virtual office combination of offsite live communication and address services allows businesses to reduce traditional office costs while still maintaining business professionalism.	Medium	Medium	Low
High-frequency stock trading	These apps support the rapid turnover of positions through the use of sophisticated trading algorithms, which process hundreds of trades in fractions of a second on the basis of changing market conditions.	Low	Low	Low
Connected vehicles safety applications	These apps involve the development and deployment of a fully connected transportation system that makes the most of multimodal, transformational applications requiring a combination of well-defined technologies, interfaces, and processes that, combined, help ensure safe, stable, interoperable, reliable system operations that minimize risk and maximize opportunities.	Low	Low	Low

Regional network performance statistics were ranked by their ability to support these three cloud service categories. More than 250 million records from Ookla's Speedtest[7] along with data from Ovum-Informa, Synergy Research, Point Topic, United Nations (UN), World Bank, NetCraft, International Telecommunication Union (ITU), International Labor Organization (ILO), and other sources were analyzed from more than 150 countries to understand cloud readiness. The regional averages of these measures are included as follows and in Appendix G.

The cloud readiness characteristics follow.

Network Access

- **Internet ubiquity**: This indicator measures fixed and mobile Internet penetration while considering population demographics to understand the pervasiveness and expected connectivity in various regions.

Network Performance

- **Download speed**: With increased adoption of mobile and fixed bandwidth-intensive applications, end-user download speed is an important characteristic. This indicator will continue to be critical for the quality of service delivered to virtual machines, CRM, and ERP cloud platforms for businesses, video download, and content-retrieval cloud services for consumers.

[7] Measured by Speedtest.net, small binary files are downloaded and uploaded between the web server and the client to estimate the connection speed in kilobits per second (kbps).

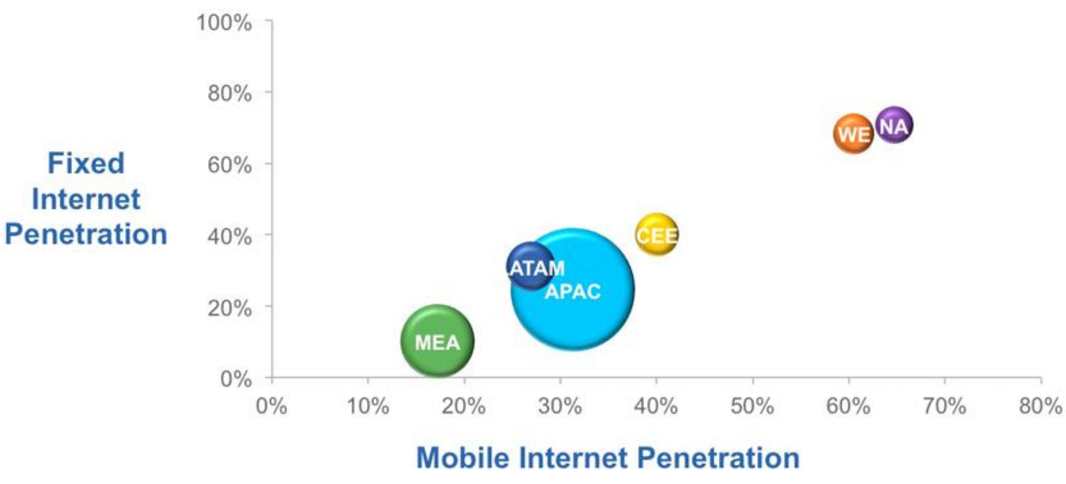
- **Upload speed**: With the increased adoption of virtual machines, tablets, and video conferencing in enterprises as well as by consumers on both fixed and mobile networks, upload speeds are especially critical for delivery of content to the cloud. The importance of upload speeds will continue to increase over time, promoted by the dominance of cloud computing and data center virtualization, the need to transmit many millions of software updates and patches, the distribution of large files in virtual file systems, and the demand for consumer cloud game services and backup storage.
- **Network latency**: Delays experienced with VoIP, viewing and uploading videos, online banking on mobile broadband, or viewing hospital records in a healthcare setting are due to high latencies (usually reported in milliseconds). Reducing delay in delivering packets to and from the cloud is crucial to delivering today's advanced services (and ensuring a high-quality end-user experience).

Internet Ubiquity

Figures 26 and 27 summarize Internet penetration as a percentage of regional population in 2014 and 2019, respectively. North America and Western Europe led in Internet access (fixed and mobile) in 2014 and will continue to lead by 2019. However, all regions will show measurable improvement in broadband access to their respective populations throughout the forecast period. Asia Pacific leads in the number of subscribers throughout the forecast period because of the region's large population.

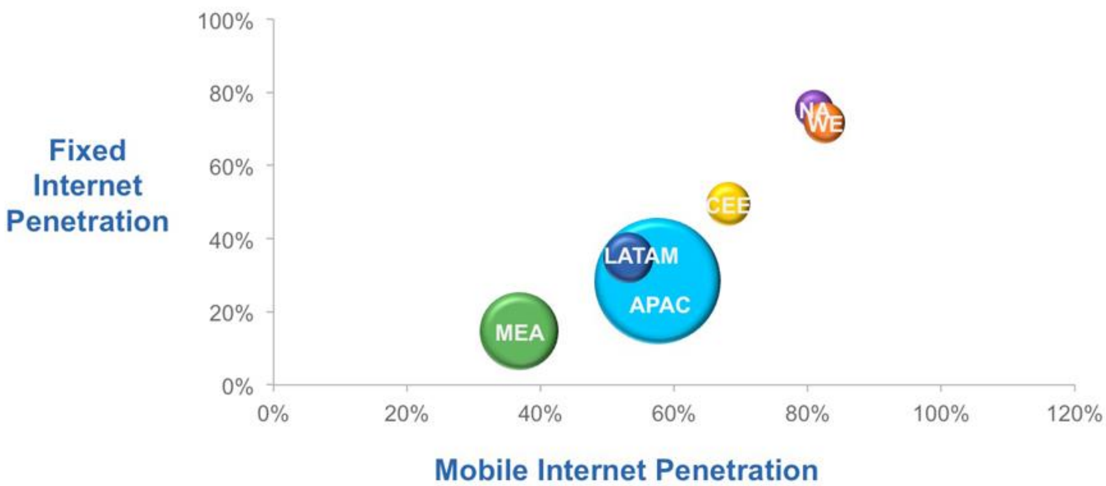
To understand Internet access ubiquity, we use internal projections and a bottom-up approach that includes estimating broadband lines and average users per household, and then validating the country estimates against country-specific telecom-reported data. From the mobile perspective, the approach focuses on mobile Internet users instead of subscriptions, preventing duplicative calculations (because some users may have multiple subscriptions). Please refer to Appendix H for further details.

Figure 26. Regional Broadband Ubiquity, 2014



The size of the bubbles represents the total population of the region.
Source: Cisco Global Cloud Index, 2014–2019

Figure 27. Regional Internet Ubiquity, 2019



The size of the bubbles represents the total population of the region.
Source: Cisco Global Cloud Index, 2014–2019

Global Average Download and Upload Speed Overview (2015)

Download and upload speeds as well as latencies are important measures to assess network capabilities for cloud readiness. The Cisco GCI Supplement provides additional country-level details for download speeds, upload speeds, and latencies. To support cloud services and applications, the quality of the broadband connection is critical. Although theoretical speeds offered by fixed and mobile operators can seem adequate, many extraneous factors are involved in the actual network measurements. Speeds and latencies vary within each country and region, based on urban and rural deployment of fixed and mobile broadband technology, proximity to traditional and cloud data centers, and the quality of customer premises equipment (CPE).

Lesser variability in download speeds, upload speeds, and latency will allow consumers to access advanced cloud applications consistently throughout the country. To measure this variability, we have also included the median download speeds and median upload speeds, along with the update to the mean or average download speeds and upload speeds, all measured and typically represented in kilobits per second (kbps) or megabits per second (Mbps).

Key Results

- The global average fixed download speed is 24.7 Mbps, and the global median fixed download speed is 16.2 Mbps.
- The global average fixed upload speed is 12.3 Mbps, and the global median upload speed is 6.9 Mbps.
- The global average mobile download speed is 11.1 Mbps, and the global median mobile download speed is 7.7 Mbps.
- The global average mobile upload speed is 5.3 Mbps, and the global median mobile upload speed is 2.8 Mbps.

Regional Fixed Download and Upload Speeds

- **Average fixed download speeds**: Central and Eastern Europe leads with 28.3 Mbps, and Asia Pacific follows with 28.1 Mbps.
- **Average fixed upload speeds**: Central and Eastern Europe leads with 20.9 Mbps, and Asia Pacific follows with 16.0 Mbps (Figure 28). Please refer to Appendix G and the Cisco GCI Supplement for further details.
- **Median fixed download and upload speeds**: Median speeds are lower than the average/mean speeds, as shown in Figure 28, because of a higher distribution of speeds in the region that are lower than the mean. Besides the required network characteristics for advanced cloud application, for an optimal end-user experience in larger user bases with cloud services, the majority of speeds must also be closer to the mean. This factor is a critical factor. To understand speed distribution patterns in detail for a select list of countries, please refer to the Cisco GCI Supplement.

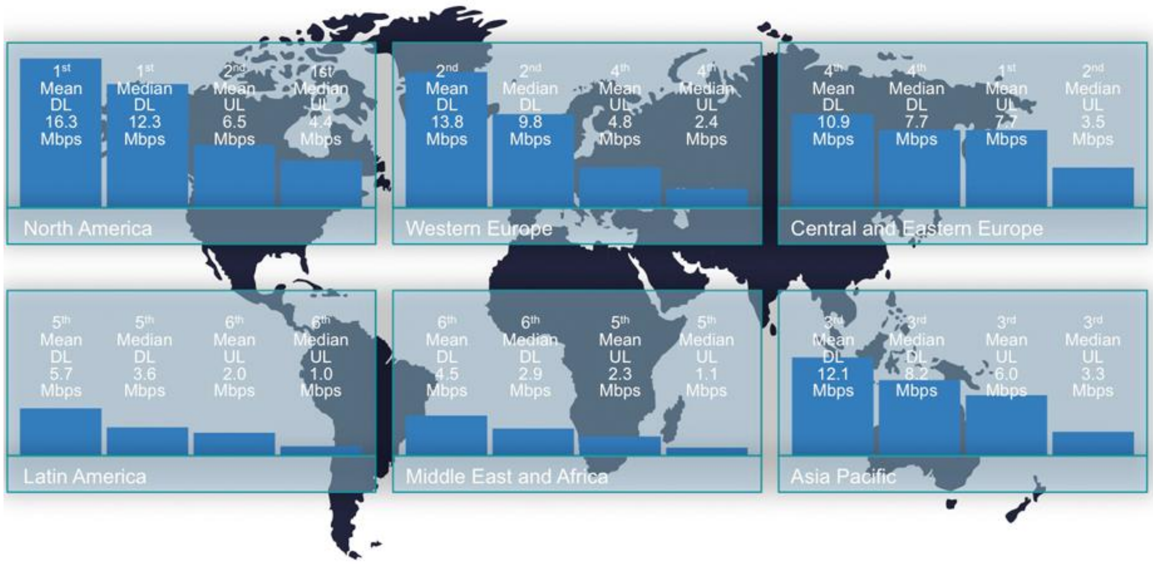
Figure 28. Regional Average Fixed Speeds, 2015

Source: Cisco Global Cloud Index, 2014–2019

Regional Average Mobile Download and Upload Speeds

- **Average mobile download speeds**: North America leads with 16.3 Mbps, and Western Europe follows with 13.8 Mbps.
- **Average mobile upload speeds**: Central and Eastern Europe leads with 7.7 Mbps, and North America follows with 6.5 Mbps (Figure 29). Please refer to Appendix G and the Cisco GCI Supplement for further details.
- **Median mobile download and upload speeds**: Median speeds are lower than mean mobile speeds within all regions, with the distribution of speeds in the regional population tending to be lower than the average.

Figure 29. Regional Average Mobile Speeds, 2015



Source: Cisco Global Cloud Index, 2014–2019

Network Latency

- Global average fixed latency is 41 ms.
- Central and Eastern Europe leads in average fixed latency with 33 ms, and Asia Pacific closely follows with 35 ms.
- Global average mobile latency is 90 ms.
- North America leads in average mobile latency with 63 ms, and Western Europe follows with 70 ms.

Please refer to Appendix G and the Cisco GCI Supplement for further details.

Conclusion

In summary, we can draw several main conclusions from the updated Cisco GCI 2014–2019 report.

Global data center traffic is firmly in the zettabyte era and will triple from 2014 to reach 10.4 ZB annually by 2019. Not only is the data center traffic growing, but it is also getting streamlined with architectural innovations such as SDN and NFV, which offer new levels of optimization data centers. A rapidly growing segment of data center traffic is cloud traffic, which will more than quadruple over the forecast period and represent more than 80 percent of all data center traffic by 2019. An important traffic enabler in the rapid expansion of cloud computing is increasing data center virtualization, which provides services that are flexible, fast-to-deploy, and efficient. By 2019, more than four-fifths of all workloads will be processed in the cloud.

Within the cloud segment private cloud will have significantly more workloads than the public cloud initially, but public cloud will grow faster than the private cloud over the forecast period, and by 2018 the majority share of workloads will transition to public cloud. However, throughout the forecast period private cloud will continue to outpace public cloud in its degree of virtualization. As the business sensitivity to costs associated with dedicated IT resources grows along with demand for agility, we can see a greater adoption of public cloud by the businesses, especially with strengthening of public cloud security. Many enterprises will adopt a hybrid approach to cloud as they transition some workloads from internally managed private clouds to externally managed public clouds. All three types of cloud service delivery models—IaaS, PaaS, and SaaS—will continue to grow as more and more businesses realize the benefits of moving to a cloud environment.

Additional trends influencing the growth of data center and cloud computing include increasing digitization, the widespread adoption of multiple devices and connections or the IoE phenomenon, and the growth of mobility. An extraordinary amount of data is being generated by IoE applications—to the tune of 500 ZB by 2019. However, only a relatively very small portion of that content (about 3.5 ZB), will be stored. Over time, more and more of the data resident on client devices will move to the data center. To address these rising user demands, cloud-based services such as consumer cloud storage are gaining momentum. By 2019, more than 50 percent (55%) of the consumer Internet population will be using personal cloud storage. Growth in M2M connections and applications is also driving new data analytics needs. Another important component of the IoE is the growth of IPv6 capability among users, devices, network connectivity, and content enablement. Given the fact that the American Registry for Internet Numbers (ARIN) ran out of IPv4 addresses this year, the move to IPv6 becomes even more significant.

This study also considers the importance of Internet ubiquity and its relationship to cloud readiness. Based on the analysis of regional average download and upload speeds and latencies for business and consumer mobile and fixed networks, all regions have made significant strides to reach a capable level of supporting basic and intermediate cloud services. There have been significant fourth-generation (4G) investments over the last couple of years, now reflected in an almost 4-fold growth in the number of countries that meet the single advanced application readiness criteria for mobile networks compared to last year. The focus now turns to continuing to improve network capabilities to support the advanced cloud applications that organizations and end users expect and rely upon.

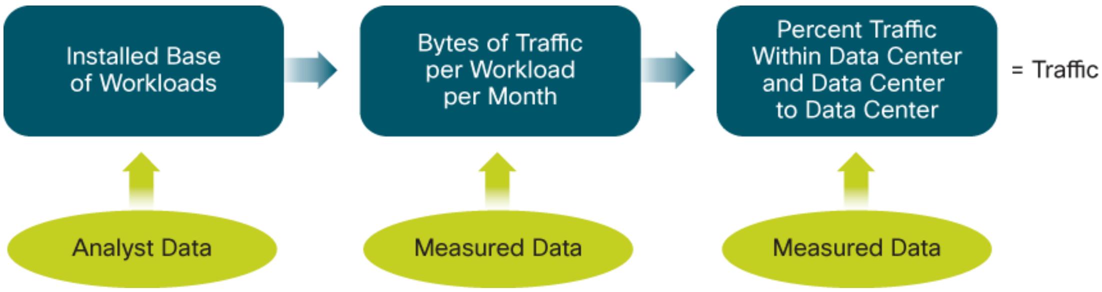
For More Information

For more information, please visit www.cisco.com/go/cloudindex.

Appendix A: Data Center Traffic Forecast Methodology

Figure 30 outlines the methodology used to forecast data center and cloud traffic. The methodology begins with the installed base of workloads categorized by workload type and implementation and then applies the volume of bytes per workload per month to obtain the traffic for current and future years.

Figure 30. Data Center Traffic Forecast Methodology



Analyst Data

Data from several analyst firms and international agencies (including Gartner, IDC, Juniper Research, Ovum, Synergy, ITU, and the United Nations) was used as inputs to the Global Cloud Index analysis. For example, analyst data was considered to calculate an installed base of workloads by workload type and implementation (cloud or noncloud). The analyst input consisted of server shipments with specified workload types and implementations. Cisco then estimated the installed base of servers and the number of workloads per server to obtain an installed base of workloads.

Measured Data

Network data was collected from a variety of enterprise and Internet centers. The architectures of the data centers analyzed vary, with some having a three-tiered and others a two-tiered architecture. For three-tiered data centers, data was collected from four points: the link from the access routers to the aggregation routers, the link from the aggregation switches or routers to the site or regional backbone router, the WAN gateway, and the Internet gateway. For two-tiered data centers, data was collected from three points: the link from the access routers to the aggregation routers, the WAN gateway, and the Internet gateway.

For enterprise data centers, any traffic measured northbound of the aggregation also carries non–data center traffic to and from the local business campus. For this reason, to obtain ratios of the volume of traffic carried at each tier, it was necessary to measure the traffic by conversations between hosts rather than traffic between interfaces, so that the non–data center conversations could be eliminated. The hosts at either end of the conversation were identified and categorized by location and type. To be considered data center traffic, at least one of the conversation pairs had to be identified as appearing in the link between the data center aggregation switch or router and the access switch or router.

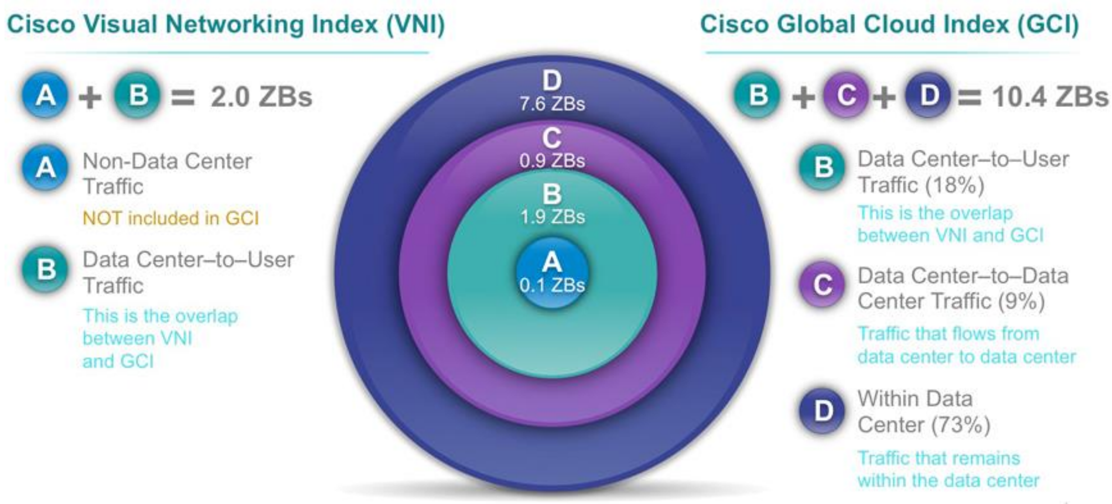
In addition, as noted in this paper, the methodology for the estimation of cloud data center traffic has changed since the last release of the Cisco Global Cloud Index. The previous methodology included all storage traffic in the noncloud traffic category. The updated methodology includes storage traffic associated with cloud workloads in the cloud traffic category. For example, storage traffic associated with cloud application development would be counted as cloud traffic in the updated methodology, but would have been excluded in the previous methodology.

Appendix B: Global Cloud Index and Visual Networking Index

The Cisco Global Cloud Index (GCI) and Cisco Visual Networking Index (VNI) are distinct forecasts that have an area of overlap. The Cisco VNI forecasts the amount of traffic crossing the Internet and IP WAN networks, whereas the Cisco GCI forecasts traffic within the data center, from data center to data center, and from data center to user. The Cisco VNI forecast consists of data center-to-user traffic, along with non–data center traffic not included in the Cisco GCI (various types of peer-to-peer traffic).

The Cisco GCI includes data-center–to-user traffic (this area is the overlap with the Cisco VNI) data-center–to–data center traffic, and traffic within the data center. The Cisco VNI forecasts the amount of traffic crossing the Internet and IP WAN networks (Figure 31).

Figure 31. Cisco VNI and Global Cloud Index



Source: Cisco Global Cloud Index, 2014–2019

Appendix C: Regional Cloud Traffic Trends

The Cisco Global Cloud Index includes regional forecast data for cloud traffic growth (Table 6).

- In 2014, North America generated the most cloud traffic (888 EB annually), followed by Asia Pacific (588 EB annually) and Western Europe (390 EB annually).
- By 2019, North America will generate the most cloud traffic (3.6 ZB annually), closely followed by Asia Pacific (2.3 ZB annually) and Western Europe (1.5 ZB annually).
- From 2014 to 2019, the Middle East and Africa is expected to have the highest cloud traffic growth rate (41-percent CAGR), followed by Central and Eastern Europe (38-percent CAGR) and North America (33-percent CAGR).

Table 6. Cloud Traffic Growth by Region, in Exabytes

Region	2014	2015	2016	2017	2018	2019	CAGR 2014–19
Asia Pacific	588	810	1,092	1,440	1,848	2,335	32%
Central and Eastern Europe	90	125	171	239	326	447	38%
Latin America	103	141	187	244	312	399	31%
Middle East and Africa	50	73	105	149	208	280	41%
North America	888	1,273	1,749	2,321	2,960	3,648	33%
Western Europe	390	533	713	936	1,200	1,512	31%

Source: Cisco Global Cloud Index, 2014–2019

Appendix D: Workload Distribution by Region

Tables 7, 8, and 9 summarize data center workloads by type and region.

Table 7. Regional Distribution of Total Data Center Workloads, in Millions

Total Data Center Workloads in Millions							
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**CAGR 2014–2019**
Asia Pacific	30.7	41.8	54.3	69.5	87.2	106.2	28.2%
Central and Eastern Europe	3.7	4.5	5.3	6.4	7.7	9.0	19.6%
Latin America	4.4	5.6	6.7	8.1	9.8	11.5	21.0%
Middle East and Africa	3.2	4.0	4.8	5.9	7.0	8.3	20.6%
North America	59.2	71.8	83.5	97.1	112.4	126.3	16.4%
Western Europe	28.2	34.1	39.6	45.8	52.5	58.4	15.7%

Source: Cisco Global Cloud Index, 2014–2019

Table 8. Regional Distribution of Cloud Workloads, in Millions

Cloud Data Center Workloads in Million							
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**CAGR 2014–2019**
Asia Pacific	20.9	30.9	42.7	57.6	74.9	94.0	35.1%
Central and Eastern Europe	2.4	3.2	4.1	5.2	6.5	7.9	27.5%
Latin America	3.0	4.1	5.3	6.9	8.6	10.3	28.3%
Middle East and Africa	2.1	2.9	3.7	4.8	6.0	7.3	28.2%
North America	37.2	48.9	60.9	75.1	90.9	106.2	23.3%
Western Europe	18.0	23.5	29.1	35.7	42.7	49.4	22.4%

Source: Cisco Global Cloud Index, 2014–2019

Table 9. Regional Distribution of Traditional Data Center Workloads, in Millions

Traditional Data Center Workloads in Millions							
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**CAGR 2014–2019**
Asia Pacific	9.9	10.9	11.5	11.9	12.3	12.2	4.3%
Central and Eastern Europe	1.3	1.3	1.3	1.2	1.1	1.1	-4.3%
Latin America	1.5	1.5	1.4	1.3	1.3	1.2	-4.1%
Middle East and Africa	1.1	1.1	1.1	1.1	1.0	1.0	-3.1%
North America	22.0	22.8	22.6	21.9	21.5	20.1	-1.8%
Western Europe	10.3	10.6	10.4	10.1	9.8	9.0	-2.5%

Source: Cisco Global Cloud Index, 2014–2019

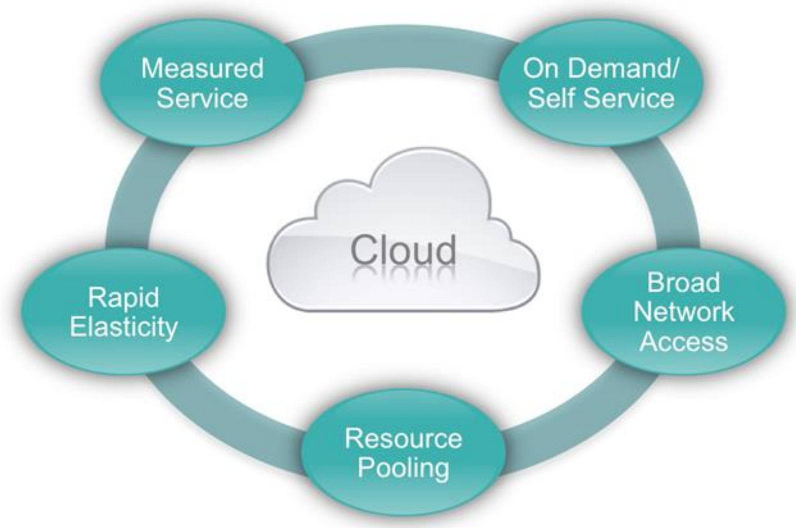
Appendix E: Cloud Definitions

Cloud Definition

The Cisco GCI aligns with the industry-standard cloud computing definition from the National Institute of Technology (NIST). The NIST definition lists five essential characteristics of cloud computing (Figure 32):

- On-demand self-service
- Broad network access
- Resource pooling
- Rapid elasticity or expansion
- Measured service

Figure 32. Essential Characteristics of Cloud

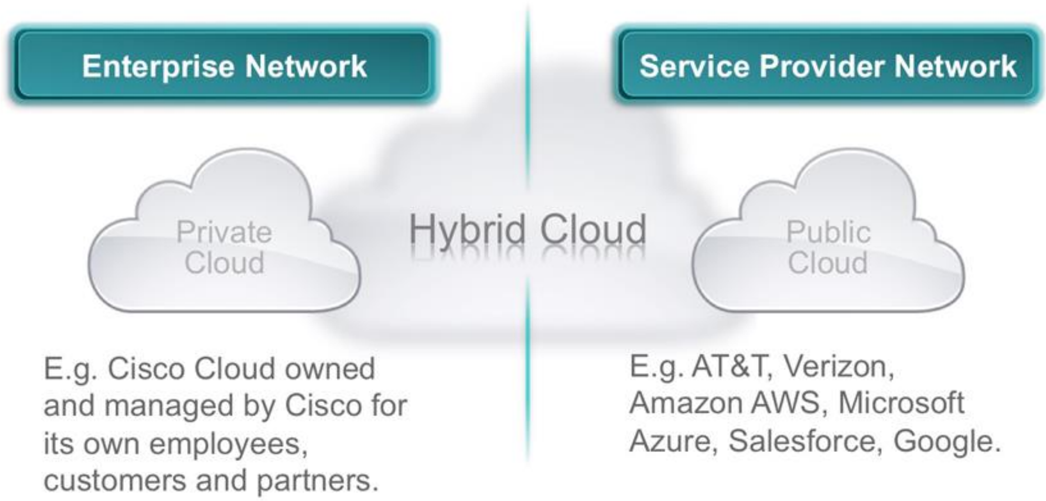


Cloud Deployment Models

Cloud deployment models include private, public, and hybrid clouds (or a combination of them). These distinct forms of cloud computing enable a variety of software, platform, and infrastructure services. Cloud data centers can be operated by service providers as well as private enterprises.

However, there is a slight variation from the NIST definition on how we classify private and public clouds. A cloud service could be public or private, depending on the demarcation line—the physical or virtual demarcation—between the public telecommunications network (WAN) and the private network of an organization (LAN) (Figure 33).

Figure 33. Cloud Deployment Models



If the cloud assets lie on the service provider side of the demarcation line, then it would be considered a public cloud service. Virtual private cloud (VPC) falls in this category. Also the multitenant consumer cloud services would fall in this category.

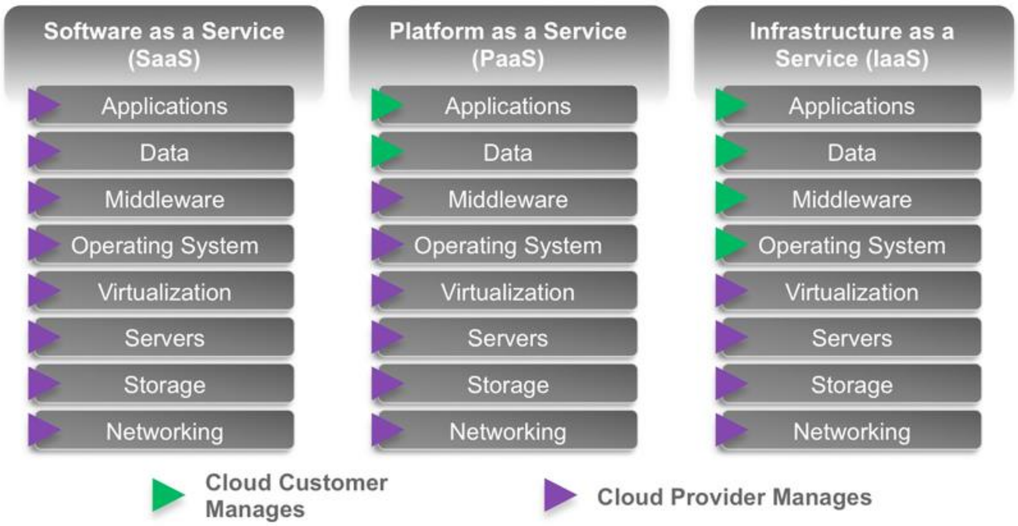
If the cloud assets lie on the organization side of the demarcation line, then the service would be considered a private cloud service. In general, a dedicated cloud owned and managed by an organization's IT would be considered a private cloud.

Hybrid cloud, as the name suggests, is a combination of public and private clouds. In a hybrid cloud environment, some of the cloud computing resources are managed in-house by an enterprise and some are managed by an external provider. We define private and public as distinct categories; we do not separately break out the hybrid cloud because it is simply a superset of the private and public clouds in varying degrees.

Cloud Service Models (IaaS, PaaS, and SaaS)

The Cisco GCI forecast for cloud workload splits across the three main cloud services models—SaaS, PaaS, and IaaS (Figure 34). They are defined in line with NIST's definitions.

Figure 34. Cloud Service Models—IaaS, PaaS, and SaaS



SaaS

The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through either a thin-client interface, such as a web browser (for example, web-based email) or a program interface. The consumer neither manages nor controls the underlying cloud infrastructure, including networks, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user-specific application configuration settings.

PaaS

The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or -acquired applications created using programming languages, libraries, services, and tools supported by the provider. The consumer neither manages nor controls the underlying cloud infrastructure, including network, servers, operating systems, or storage, but has control over the deployed applications and possibly configuration settings for the application-hosting environment.

IaaS

The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. The consumer neither manages nor controls the underlying cloud infrastructure but has control over operating systems, storage, and deployed applications; and possibly limited control of select networking components (for example, host firewalls).

Appendix F: Regional Consumer Cloud Storage

Table 10 provides regional details for 2019 regarding consumer Internet users (adoption percent), average number of consumer devices per Internet user, and the number of consumer cloud storage users (percent of consumer Internet users).

Table 10. Regional Consumer Cloud Storage Users by 2019

Region	Consumer Internet Users in Millions (% of Population)	Average Number of Devices per Consumer Internet User	Consumer Cloud Storage Users in Millions (% of Internet Users)
Asia Pacific	2,022 (49%)	4.1	1,176 (58%)
Central and Eastern Europe	321 (66%)	5.0	134 (42%)
Latin America	355 (54%)	4.4	141 (40%)
Middle East and Africa	401 (25%)	4.6	65 (16%)
North America	311 (83%)	10.1	257 (83%)
Western Europe	341 (80%)	7.8	272 (80%)

Source: Cisco Global Cloud Index, 2014–2019

Appendix G: Regional Cloud Readiness Summary

Table 11 summarizes cloud readiness for businesses and consumers by region, considering download and upload speeds, and latency. Please refer to the Cisco GCI Supplement for more details.

Table 11. Regional Cloud Readiness

Network	Region	Average Download Speeds (Mbps)	Average Upload Speeds (Mbps)	Average Latency (ms)
Fixed	Asia Pacific	28.1	15.9	35
	Central and Eastern Europe	28.3	20.9	33
	Latin America	7.6	2.4	64
	Middle East and Africa	7.0	2.2	77
	North America	25.4	8.8	42
	Western Europe	22.8	7.4	44
Mobile	Asia Pacific	12.1	6.1	83
	Central and Eastern Europe	10.9	7.7	75
	Latin America	5.7	2.0	116
	Middle East and Africa	4.5	2.3	156
	North America	16.3	6.5	63
	Western Europe	13.7	4.8	70

Source: Cisco Global Cloud Index, 2014–2019

Appendix H: Internet Ubiquity

Tables 12 and 13 summarize regional Internet access penetration for 2014 and 2019. For fixed Internet access, internal projections were used based on a bottom-up approach that includes estimating broadband lines and average users per household, and then validating the country estimates against country-specific telecom-reported data. On the mobile side, the approach focuses on mobile Internet users instead of subscriptions, preventing duplicative calculations (because some users may have multiple subscriptions).

Table 12. Regional Internet Penetration (Percentages Indicate Users with Internet Access per Region) in 2014

Region	Fixed Internet Users in Millions (2014)	Mobile Internet Users in Millions (2014)	Population in Millions (2014)
Asia Pacific	970 (25%)	1,237 (31%)	3,955
Central and Eastern Europe	193 (40%)	193 (40%)	483
Latin America	193 (31%)	168 (27%)	623
Middle East and Africa	143 (10%)	241 (17%)	1,405
North America	253 (71%)	232 (65%)	358
Western Europe	286 (68%)	253 (60%)	418

Source: Cisco Global Cloud Index, 2014–2019

Table 13. Regional Internet Penetration (Percentages Indicate Users with Internet Access per Region) in 2019

Region	Fixed Internet Users in Millions (2019)	Mobile Internet Users in Millions(2019)	Population in Millions (2019)
Asia Pacific	1,170 (28%)	2,371 (57%)	4,126
Central and Eastern Europe	241 (50%)	331 (68%)	487
Latin America	228 (35%)	348 (53%)	655
Middle East and Africa	232 (15%)	579 (37%)	1,574
North America	281 (75%)	302 (81%)	373
Western Europe	304 (72%)	350 (83%)	424

Source: Cisco Global Cloud Index, 2014–2019

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