TeleGeography

The State of the Network

2021 EDITION

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NEW YEAR, NEW DATA

More so than normal, our team is thrilled to usher in a new year.

Sure, that's in part because a new year signals the release of our fourth State of the Network Report—and with it a new batch of data and analysis on the way the world is connecting. But mostly because 2020 presented a unique set of challenges to the world, our industry, and our team.

Working remotely since March 2020, TeleGeography analysts continued to collect information on the way the world communicates, which was changing in real-time.

We kept tabs on operators racing to keep revenue margins ahead of eroding prices. We monitored COVID-induced spikes in global internet traffic.

We queried data center operators about shifts in their day-to-day operations. And we watched a small rally in international calling during the early days of the pandemic, only to see the voice industry return to its formerly scheduled slump.

Our team feels lucky that we were able to continue our research safely. Our 2021 State of the Network Report—a product that we think of as an annual snapshot—makes a point to underscore

Meet Our Experts

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COVID-19's impact across each chapter. Some of these effects are already proving to be one-off events, while others seem poised to make a more lasting impact on the market.

Per usual, this analysis was informed by TeleGeography data. It was collected throughout 2020 and you can find even more of it within our full suite of research apps.

Thank you for your continued readership and interest in our work. We can't wait to take on 2021 and get back to work, together.

— The TeleGeography Team

GLOBAL BANDWIDTH

MORE BANDWIDTH!

The global outbreak of COVID-19—and its associated economic impact—has amplified the role played by the international telecommunications industry and the bandwidth market that underpins it. The global bandwidth market has always been marked by change and uncertainty; the current crisis is just an extreme example of this.

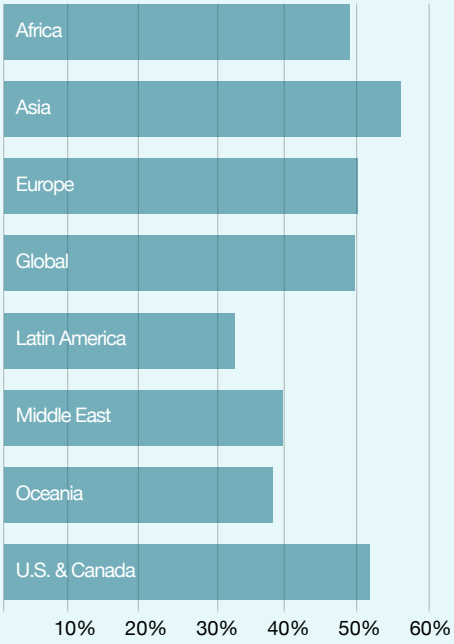
Working and learning from home have dramatically altered traffic patterns, yet the internet has proven remarkably resilient in the face of these sudden changes. Many network operators are accelerating plans to add capacity to stay ahead of demand. Local ISPs are increasing caching capabilities to reduce reliance on international links. Content providers are reducing bit rates for streaming video applications in some regions to help alleviate network congestion.

Meanwhile, life—and business—goes on. On the commercial side, operators race to keep revenue margins ahead of eroding prices, while bandwidth demand and supply continue to grow across global routes.

Our Global Bandwidth Research Service assesses the state of the global telecom transport network industry, evaluates the factors that shape long-term demand growth and price erosion, and provides some preliminary thoughts on the impact of COVID-19 on the industry. We assess market conditions on both a global level and on a regional level, focusing on critical submarine cable route markets.

Used International Bandwidth Growth

CAGR by Region, 2015-2019



Notes: Data represents used bandwidth connected across international borders and excludes domestic bandwidth. The global total removes double counting of bandwidth between regions, such that the sum of all regions will not equal the global total.

Demand Trends

If demand is the key factor in assessing the health of the global bandwidth market, then the market is thriving. Between 2017 and 2019 alone, international bandwidth used by global networks more than doubled to reach 1,492 Tbps.

Let's break this demand growth down to a more granular level. There are two big takeaways here.

The first is that demand growth has been strongest on links connected to Asia, which experienced a compound annual growth rate of 56% between 2015 and 2019.

The second is that growth in the most developed markets in the world—Europe and North America—wasn't far behind. While mature markets typically grow more slowly than developing markets, that's not the case when it comes to global bandwidth demand.

The Role of Content

Who's driving all this demand growth for international capacity?

Historically, it's been carrier networks, provisioning public internet services. More recently a handful of major content and cloud service providers—namely Google, Facebook, Amazon, and Microsoft—have become the primary sources of demand. As of 2019, these companies are now the dominant users of international bandwidth, accounting for 64% of all used international capacity.

But their capacity requirements vary extensively by route. Content providers' top priority in their international network planning is to link their data centers and major interconnection points. As such, they often take tremendous capacity on core routes, while focusing much less than traditional carriers do on secondary long-haul routes. To get a sense of this contrast, note that in 2019, content providers accounted for 90% of used capacity on the trans-Atlantic route but just 5% on the Europe-East Asia route.

While the share of content provider capacity on some routes may be much lower than on others, the growth in their demand across all routes has been relentless. A comparison of content providers'

international capacity demand growth compared to that of all other networks in the following figure reveals a stark contrast. Across six of the world's seven regions, content providers added capacity at a compound annual rate of at least 70% between 2015 and 2019, compared to a rate no higher than 45% for others.

Meeting Demand Requirements

Demand for international bandwidth is more than doubling every two years. To meet this demand, companies are investing in existing networks and in new infrastructure.

The lit capacity on major submarine cable routes continues to soar, keeping pace with demand. Between 2015 and 2019 lit capacity more than tripled on many routes. The pace of growth was the most rapid on the Trans-Atlantic route, where lit capacity increased over 5-fold between 2015 and 2019.

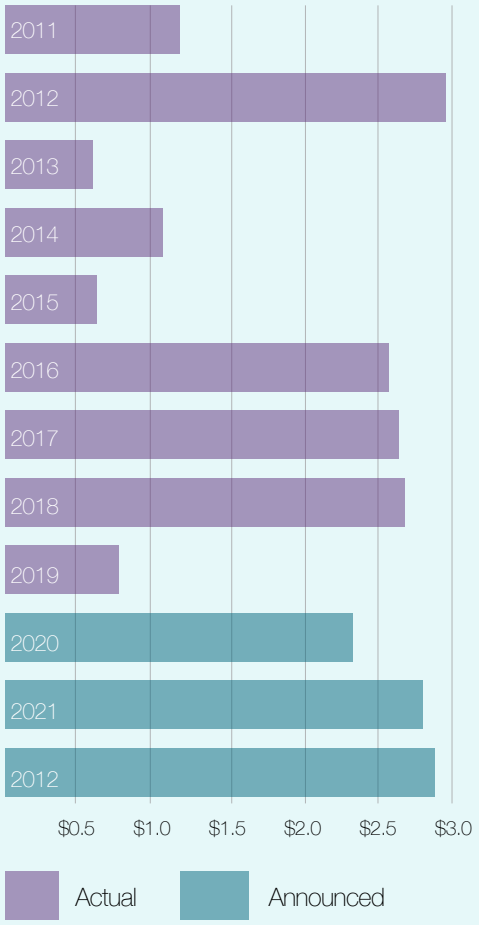
Aside from lighting new capacity, new systems are coming online across all routes. The year 2016 ushered in a period of significant global investment in the sector.

Cables with a combined construction cost of $8.7 billion entered service between 2016 and 2019, and every major subsea route saw new cables deployed during this timeframe. Investment is expected to continue across all global routes. Based on publicly announced planned cables, an additional $8.1 billion worth of new cables will be launched between 2020 and 2022. The trans-Pacific route will lead the way with $2.3 billion of new cable investment expected between 2020 and 2022.

A word of caution, however. The subsea cable business is impacted by the pandemic, and this could delay the expected launch of up-coming projects. In many cases, ship's crews have found it difficult to travel to and from work due to travel restrictions and quarantines. Travel restrictions also impact site visits for new cable landings. Supply chain disruptions are also possible, further delaying cable upgrades and the deployment of new cables.

Construction Cost of Submarine Cables

Construction Costs in USD billions



ɪtes: Total construction costs of all international and domestic ɔmarine cables entering service in designated years. ɔnstruction costs exclude the cost of subsequent capacity ɔgrades and annual operational costs. 2020-2022 construction sts based on announced contract values and TeleGeography ɛtimates. Not all planned cables may be constructed.

Pricing

Abundant supply and increasing competition have led to robust price erosion throughout the global bandwidth market. New 100 Gbps-equipped submarine cable systems and upgrades to existing networks have further lowered unit costs. And this has driven down both 10 Gbps and 100 Gbps wavelength prices. Across critical global routes, weighted median 10 Gbps and 100 Gbps prices fell an average of 14% and 23% compounded annually since 2016.

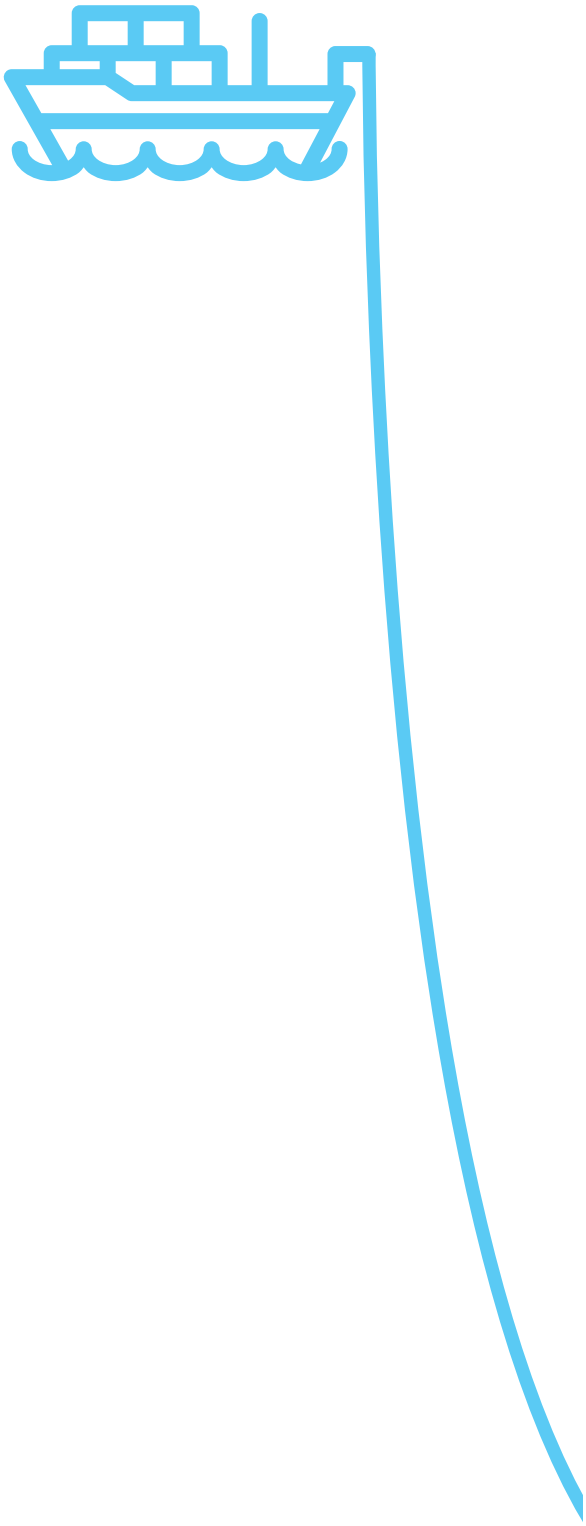
Yes, bandwidth prices decline reliably. But prices are not the same throughout the world. Our weighted median 10 Gbps lease price on the Frankfurt-London route comes in at just $724. Compare that to $18,000 for 10 Gbps between Los Angeles and Sydney. The cheaper intra-European route is shorter and benefits from more competition than the Australia-U.S. route. The comparison still clearly illustrates the range of prices between global hubs.

While differences persist, prices have converged somewhat over the past few years. Routes with historically high bandwidth prices are transforming into key inter-regional connectivity points with high demand growth, new supply, and competition. Price declines in these locations outpace the market, bringing them more in line with other core global routes.

With falling prices, the incentive to buy larger versus smaller circuits increases. In Q4 2019, carriers priced 100 Gbps wavelengths an average of 4.3 times higher than 10 Gbps for 10 times the capacity. That's down from 6.4 times more in 2015. Multiples vary by route, often corresponding with regional price differences. Shorter, intra-regional terrestrial links exhibit lower price multiples than longer, transoceanic subsea connections. For example, operators on Frankfurt-London and Los Angeles-New York report the lowest price multiples of the group.

We also tend to see low multiples where 100 Gbps adoption is strong or in markets where 10 Gbps prices stabilize at higher rates. On the subsea routes of Los Angeles-Tokyo and London–New York, the low multiples of 4.3 and 4.5 are driven by two factors. First, increasing demand continues to drive down 100 Gbps prices. Second, as demand shifts to higher capacities, sales of 10 Gbps circuits have moderated, resulting in more stable 10 Gbps prices.

Outlook



What does the future hold for the global bandwidth market? The two most predictable trends are persistent demand growth and price erosion. Beyond that, operators will have to navigate the major uncertainties of an evolving sector and a global pandemic. Here are a few of the key trends, among many, that will affect the long-haul capacity market in the coming years.

Expanding Frontiers by a Limited Group

Content providers' cable investments have largely focused on trans-Atlantic, trans-Pacific, U.S.-Latin American, and intra-Asian routes thus far. As their demand for capacity continues to grow across all routes, other paths are likely to draw content provider-backed cable construction in the near future.

Google's Equiano cable is the first foray into Africa by a content provider. Content providers already have new investments in the pipeline focused on India-Singapore and India-Europe.

Will new content providers join the existing few that are investing in submarine cable systems?

Our assessment is that a very limited group of players will continue to dominate content and cloud network demand. It seems unlikely that many more such networks, even the Chinese content providers, will reach sufficient demand volumes in the near-term to warrant their emergence as full-fledged owners of subsea cables.

Rising Utilization

Even with the introduction of many new cables and the ability of older cables to accommodate more capacity, the growth of potential capacity has failed to outpace that of lit capacity. We can already see that the percentage of capacity that is lit on major routes has begun to rise.

The U.S.-Latin America and Europe-Sub-Saharan Africa routes are exceptions to this trend. On the U.S.-Latin America route, three high-capacity cables were recently launched, decreasing the proportion of lit capacity relative to total potential capacity. On the

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Europe-Sub-Saharan Africa route, several cables have had major upgrades, and no additional lit capacity has been required in recent years. But this situation is only temporary, as operators are now planning additional upgrades and new cables.

Looming Cable Retirements

Cables are engineered to have a minimum design life of 25 years, but what really matters is the economic life. The economic life depends on a cable's revenue exceeding the costs. If the costs of operating a cable continually exceed the revenues, an operator may consider retiring the cable. This could happen well before a cable runs of out capacity. Many older cables laid in the late 1990s and early 2000s may soon become candidates for retirement. In fact, TAT-14, a trans-Atlantic cable laid in 2001, was retired in December 2020.

Addressing the Shannon Limit

In moving beyond 100 Gbps wavelengths, the industry faces a major challenge in that it will reach the very edge of the Shannon Limit—the theoretical channel capacity limit given a specified channel bandwidth and signal-to-noise ratio (SNR).

So how is the industry tackling this problem? By taking a multi-pronged approach. A few of the major strategies include increasing the number of fiber pairs, introducing multi-core fiber, and continuing to introduce more powerful processors. The concept of Spatial Division Multiplexing (SDM) has emerged at the forefront of strategies for increasing subsea cable system throughput moving forward. SDM simply refers to the use of an increased number of paths in a cable (either more fiber pairs or more cores per fiber pair).

Current transoceanic systems generally deploy 6 to 8 fiber pairs, but Dunant, which is slated to launch in 2020, will have 12, and future systems such at Amitie and Grace Hopper will have 16. As a long-term growth strategy, adding fiber pairs has limitations, and so the use of Multi-Core Fiber (MCF) is being explored as a way forward in the quest for more bandwidth. MCF technology will provide multiple spatial paths within a single fiber using advanced multiplexing techniques.

Wholesale Market Challenges

The rapid expansion of major content providers' networks has caused a shift in the global wholesale market. Google, Microsoft, Facebook, and Amazon are investing in new submarine cable systems and purchasing fiber pairs. This removes huge sources of demand from the addressable wholesale market. On the other hand, it drives scale to establish new submarine cable systems and lower overall unit costs.

Many submarine cable business models actually rely on this capital injection, allocating fiber and network shares to the largest consumers to cover initial investment costs, then selling remaining shares of system capacity as managed wholesale bandwidth.

Unit cost savings of large investments are a great incentive to investment for operators, but they don't want to be left with too much excess bandwidth. It's often a race to offload wholesale capacity before a new generation of lower-cost supply emerges. Carriers most likely to succeed are those with massive internal demand and less dependence on wholesale market revenues.

Both content and telco network operators are reckoning with massive bandwidth demand growth, driven by new applications and greater penetration into emerging markets. The sheer growth in supply will drive lower unit costs for bandwidth. In the face of unrelenting price erosion, the challenge for wholesale operators is to carve out profitable niches where demand trumps competition.

COVID-19's Impact

With all that said, we have to acknowledge the impact that the COVID-19 pandemic could have on the future supply of international capacity.

Temporary cable factory closures combined with delays in permitting and marine installation could hamper the deployment of many planned cables. In the interim, the existing cables will play a pivotal role in ensuring resilient global connectivity until more cables can be added.

While facing likely delays in new cable deployments, operators are also addressing a surge in network demand in the midst of the outbreak. Operators have felt this increase most acutely in the access networks, but all parts of global networks are experiencing accelerated growth due to the pandemic.

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Operators are taking steps to respond to this traffic growth by managing traffic throughput, boosting cache deployments, accelerating capacity upgrades, and addressing network maintenance needs.

The full impact of COVID-19 on networks is evolving rapidly. We will continue to monitor the developments and provide updates. We are collating our analysis and news about the pandemic's impact on networks on a rolling basis on a dedicated State of the Network: Updates on COVID-19 site.

GLOBAL INTERNET

INTERNET BENDS, DOESN'T BREAK

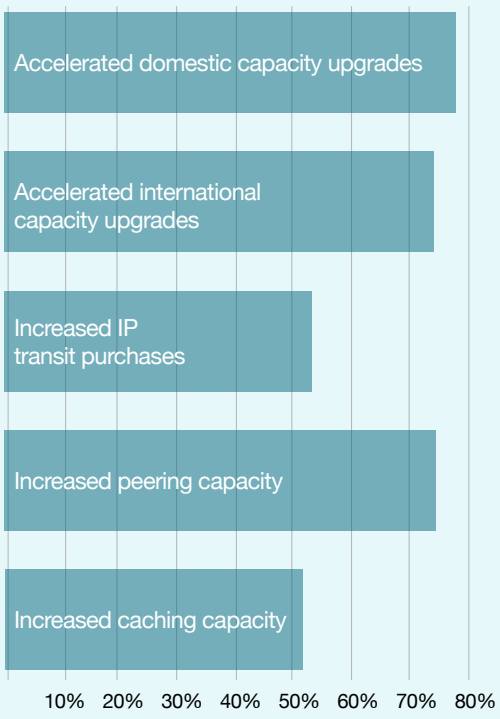
The global outbreak of COVID-19—and its associated economic and social impact—has laid bare the crucial, irreplaceable role that the internet plays in our daily lives.

Starting in March 2020, internet traffic patterns shifted and volumes surged as students around the world learned from home, adults worked from home, and everybody did at least something from home. To its enormous credit, the internet bent but—for the most part—did not break as network operators scrambled to deal with the swell in traffic.

In our Global Internet Geography Research Service, we discuss the impact of COVID-19 within the larger framework of our analysis and statistics on internet capacity and traffic. We also discuss factors impacting IP transit pricing, and the role individual backbone operators play. Based on discussions and surveys with dozens of network operators around the globe, we tentatively conclude that COVID-related expansion in internet traffic and bandwidth is largely a one-off phenomenon, and that the trends we've observed in recent years will largely continue. International internet bandwidth and traffic growth had been gradually slowing in recent years, but they remain brisk. IP transit price declines continue globally, but significant regional differences in prices remain.

Measures Taken by Operators Due to COVID-19

Percent of Respondents Indicating "Yes"



Internet Traffic and Capacity

Global internet bandwidth rose last year by 35%, a substantial increase over the previous year's "modest" 26%. Driven largely by the response to the COVID-19 pandemic, this represents the largest one year increase since 2013, and has driven up the most recent 4-year CAGR to 29%. Total international bandwidth now stands at 618 Tbps. The pace of growth had been slowing, but we still see a near tripling of bandwidth since 2016.

Strong capacity growth is visible across regions. Africa experienced the most rapid growth of international internet bandwidth, growing at a compound annual rate of 47% between 2016 and 2020. Asia sits just behind Africa, rising at a 40% compound annual rate during the same period.

International internet traffic growth largely mirrors that of internet capacity. However, traffic and capacity growth seldom move in perfect tandem. (Network operators will often add capacity in anticipation of traffic growth.) Average and peak international internet traffic increased at a compound annual rate of 30% between 2016 and 2020, comparable to the 29% compound annual growth rate in bandwidth.

Let's take a look at the recent impact that COVID-19 has had on traffic growth. As you might imagine, all that stay-at-home activity has had a pronounced impact on traffic. In 2020, average international internet traffic increased 48%, while peak traffic rose 47%.

COVID-19 is a global phenomenon, so it's no surprise that all the major regions of the world show traffic growth outpacing capacity growth in 2020. Latin America featured the largest disparity, with average traffic rising 59% and peak traffic rising 51%, compared to 32% for capacity.

Prices

As network requirements balloon, global IP transit prices continue to decline. Even in the face of a global pandemic. But the pace of price erosion over the past three years and the factors driving it vary throughout the world. Declines have been greatest in emerging markets, where prices are highest. Increases in volume, local

traffic exchange, and number of suppliers can improve economy of scale, underlying transport cost, and competition, respectively. In established global hubs, prices continue to fall at a significant pace, largely a result of escalating volume and declining unit cost.

Price erosion in global hubs such as London and Miami continues at a steady clip—25% and 32%, respectively, since 2017. Both cities house some of the most robust markets and lowest prices for IP transit. Not only due to regional traffic exchange. They also draw intercontinental traffic from Africa, the Middle East, and Latin America, where remote traffic exchange is more cost-effective than buying transit locally. This further fuels the high-volume market dynamics in the global hubs.

Similarly, Singapore has cemented itself as a hub for intra-regional traffic exchange in Asia. Accordingly, it hosts the most competitive prices in the region. But even with a 25% rate of price erosion since 2017, IP transit in Singapore remains more expensive than western Europe and the United States.

Since 2017, the price of a 10 GigE port in Singapore has hovered at about three times the price in London, a reflection of differences in market participants, underlying costs, as well as continued robust price declines in the British capital.

The price for a 10 GigE port in Johannesburg dropped 44% over the past three years. This largely reflects falling transport prices linking South Africa to Europe. But also, Johannesburg's position as a regional market leader in terms of carrier neutral data centers, localized content, the presence of cloud service providers, and carrier competition.

Similarly, a majority of international traffic connecting Latin America and Oceania is intercontinental, transiting undersea cables to the U.S. to exchange traffic and access content (often more cost effectively than locally). But both regions have seen upgrades to existing systems and the launch of new regional submarine cables linking them to global internet hubs in the U.S. This has greatly bolstered supply and competition, lowering underlying transport costs. As a result, prices for 10 GigE ports in São Paulo and Sydney fell 38% and 22% compounded annually over the past three years. Weighted median prices in the two cities are $1.04 and $3.50 per Mbps.

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Initial evidence suggests that the spike in the rate of bandwidth and traffic growth from the pandemic may be a one-time event and a return to typical rates of growth could be in sight.

In the transit market, 100 GigE ports are starting to gain traction where 100 Gbps transport is already well entrenched. Some carriers are considering 400 GigE ports, while others are already looking forward to another 10x upgrade to 1 Tbps ports. While price multiples between 10 GigE and 100 GigE ports have declined, for many customers the motivation to upgrade to a larger port is not purely financial. Ease of management and future proofing the network have become particularly important in light of recent events. With the shift to higher capacity ports and increasing localization of traffic exchange and content hosting, continued price erosion is a safe bet for the foreseeable future.

Provider Connectivity

Our rankings of provider connectivity includes analysis based on BGP routing tables, which govern how packets are delivered to their destinations across myriad networks as defined by autonomous system numbers (ASNs). Every network must rely on other networks to reach parts of the internet that it does not itself serve; there is no such thing as a ubiquitous internet backbone provider.

If you want a single, simple number to identify the best-connected provider in the world, you may come away disappointed. There are several ways to measure connectivity, and each highlights different strengths and weaknesses of a provider's presence. One basic metric is to count the number of unique Autonomous Systems (AS) to which a backbone provider connects, while filtering out internal company connections. The results are presented in the table below.

We've seen little change amongst the top providers based on this ranking system. Hurricane Electric and CenturyLink have swapped the top spot for several years. Hurricane edged out then-Level 3 in 2017 as the best-ranked ISP in terms of overall connections, but the CenturyLink merger with Level 3 moved the combined entity back to the top in 2018. Hurricane Electric maintains a small lead in 2020.

In addition to examining overall number of connections, we also used our analysis of BGP routing tables to look at the "reach" (a measure of the number of IP addresses an upstream ASN has been given access to from downstream ASNs) and "share" (which compares an upstream provider's reach to all other upstream providers of a downstream ASN.) The results of this analysis paint a different picture. In some cases, an ISP might end up high-ranked in terms of number of connections but low-ranked in terms of share or reach when the number of IP addresses passed from its customers is relatively small.

Finally, to focus on which backbone providers best serve the end-user ISP market and corporations, we compare upstream provider connections to downstream broadband ISPs, calculated the top providers to Fortune 500 companies, and examined connectivity to specific industry sectors such as hosting, medical, and finance.

Outlook

The combined effects of new internet-enabled devices, growing broadband penetration in developing markets, higher broadband access rates, and bandwidth-intensive applications will continue to fuel strong internet traffic growth.

While end-user traffic requirements will continue to rise, not all of this demand will translate directly into the need for new long-haul capacity. A variety of factors shape how the global internet will develop in coming years:

Post-COVID-19 growth trajectory. Initial evidence suggests that the spike in the rate of bandwidth and traffic growth from the pandemic may be a one-time event and a return to typical rates of growth could be in sight. Operators we spoke to indicated they were not making major upward adjustments to their demand forecasts due to COVID-19.

IP Transit Price Erosion. It is not a bold prediction that IP transit prices will continue to fall globally, as they always have. The rate of decline will be greatest in emerging markets. In these markets, high prices have greater potential to fall due to increases in volume and local traffic exchange that improve economy of scale. In established global hubs, prices will also fall, largely a result of escalating volume and declining unit cost.

CDNs and Caching. While the increase in broadband users and access rates will continue to drive traffic growth in access networks, much of this growth may be managed locally within a network and may not lead to proportional increases in traffic on international links. Thus CDNs and caching will continue to have a localizing effect on traffic patterns and dampen international internet traffic growth.

Content Providers. Beyond the impacts of CDNs and caching, the largest content providers' private networks are having a major impact on the growth of internet capacity requirements. As the content providers extend their networks into new locations, the traditional backbone operators are adjusting the networks in response. In some cases, backbone operators may reduce capacity on some routes or shift capacity to new locations.

DATA CENTERS

THE CONNECT EFFECT

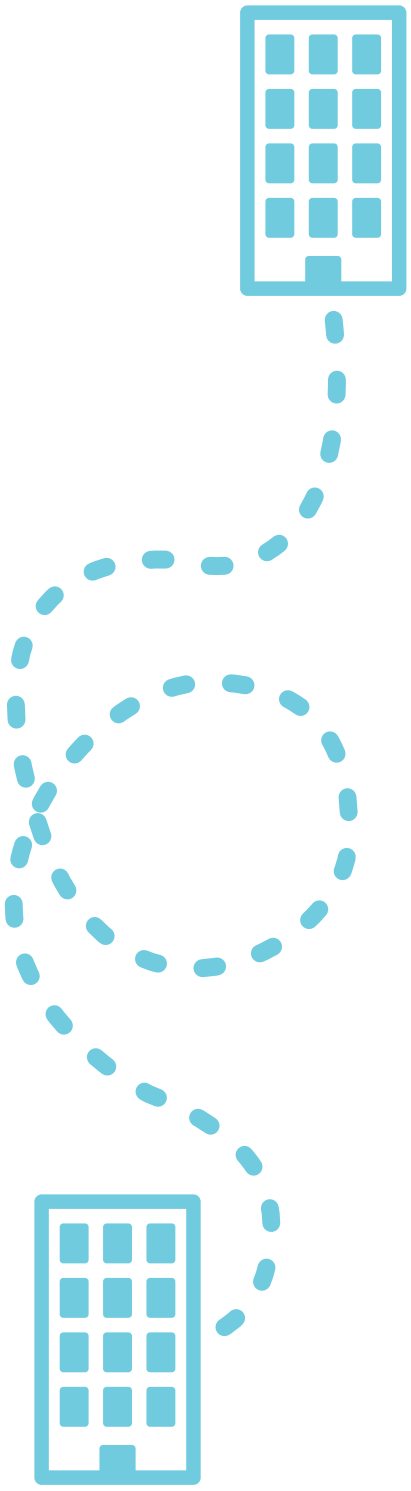
The COVID Impact

As we published our 2020 Data Center Research Service update, the pandemic was truly making its mark in the global marketplace.

Network and data center services have never been more critical to connect a world in relative isolation. So we supplemented our 2020 data center site survey by asking global data center operators for their assessment of the pandemic's effect on their operations as of September. Here's what they told us.

Construction projects are moving forward: 65% of respondents indicated that they have not experienced delays in site construction or expansion because of the pandemic. While that may come as a surprise, a significant minority indicated that there were delays or that the situation varied by market. Project timelines have varied extensively, continuing apace in some locations, while grinding to a complete halt in others.

Data center demand is generally strong: About half of respondents (48%) indicated that customer demand was increasing as a result of the pandemic. A quarter said that demand varied by market, while 20% indicated that they had seen no particular change in demand thus far. Only 7% of respondents reported a decrease in data center demand as a result of the pandemic.



Cloud providers driving demand increase: When asked which market verticals were driving demand the most, cloud and hyper-scale were the most ubiquitous responses, although numerous sectors were noted. Government, carriers, and gaming services were cited as growth drivers as well.

Enterprise demand is falling: While the data center sector is fairing better than most in the pandemic, it isn't immune to the problems facing the wider market. As enterprises and retail service providers face tremendous exposure to decreased demand for their own services, some data center customers from these verticals are throttling their demand for colocation services as well.

Colocation pricing holds steady: A vast majority of respondents (83%) stated that they were not altering colocation rates as a result of the pandemic.

Our September COVID-19 survey largely corroborated outlooks that operators have shared with us over the course of the last nine months. Here are a few other observations that have been shared with us this year.

Demand for colocation and cross-connects are particularly strong in industries involving video streaming, gaming, and cloud provisioning, as work, education, and entertainment shift heavily online. Traffic levels within data centers have stretched out to sustained peak levels that last throughout the day.

Daily operations continue with stringent safety procedures in place. On-site staff at many data centers are taking on more remote hands responsibilities as customer representatives forego travel to maintain equipment. In some cases, this increased demand on data center staff is causing slight operational delays.

The effect of the pandemic on operator supply chains is decidedly mixed. Some equipment suppliers and data center customers have sufficient stock to keep ahead of demand for the time being, but others have already experienced shortages.

Pricing expectations have held steady throughout the year. Operators have consistently reported little or no change in baseline colocation rates, most recently affirming this trend in our November pricing update.

Pricing

Individual Pricing Components

As of H2 2020, the European average price per kilowatt for a 4-kilowatt colocation cabinet remains about 25% higher than the North American rate. Over the course of 2020, we saw no discernible COVID effect in the moving averages, with only slight fluctuations in Asian and European average rates and no change in U.S. rates.

Among mature global markets, Singapore and Hong Kong are always among the priciest in our survey, but major network convergence points in Europe and North America are also costly places to rent server space. Frankfurt and Singapore top the list of most expensive global hubs in our current survey with median rates around $500 per kilowatt.

Reported per-kilowatt rates for high-density cabinets (cabinets with 10-kilowatt density) are on average just 3% lower than those for standard 4-kilowatt cabinets, though premiums or discounts can vary extensively. Among 22 markets reporting high-density prices, operators in all of the Asian markets indicated the same or higher prices for high-density colocation, while all North American operators indicated the same or lower rates per kilowatt for high-density cabinets. European operator responses were highly mixed.

When observing large-scale retail leases (100 kilowatts), we also see consistent regional distinctions. The median rates for large-scale retail leases in each of our APAC markets is the same or higher than for standard stand-alone cabinet rates. But in Europe and North America, per-kilowatt rates are almost universally discounted—averaging 10% at the higher scale.

The average price multiple for a North American fiber cross-connect is just 2.0 times the average European rate—the lowest we've seen. European rates have risen at a steady clip, and now average nearly $140 per cross-connect. In Asia, cross-connect rates fall between the European and North American averages.

Historically, operators in North America have charged more for fiber cross-connects than for Ethernet, whereas European operators typically charged more for Ethernet cross-connects. Now, most Eu-

ropean operators have largely swung in the direction of discounting Ethernet cross-connect fees relative to the cost of fiber cross-connects, with the exceptions of those in Frankfurt and Amsterdam.

Total Cost Model

Regional differences in base prices per kilowatt and the costs of cross-connects contribute directly to differences in average TCO. Among the markets covered in our H2 2020 pricing update, the average TCO in European markets when one cross-connect is assumed ($1,923) is about 17% higher than that in North American markets ($1,648). The average Asian TCO exceeds $2,100, although this would be lower if we had sufficient data to include one of our lower-cost Asian markets in the full TCO sample. Hong Kong, Singapore, and Frankfurt are among the more expensive markets in the survey, with average total costs in excess of $2,000 per month.

When five cross-connects are assumed, the North American average TCO is about 14% higher than the European average. The average North American TCO reaches $2,800. The Asian average TCO is even higher, at nearly $3,000 per month. On the metro level, Hong Kong remains unchanged as one of the most expensive markets in the survey–unsurprising considering the fact that both its base and cross-connect prices are among the highest of all metros surveyed. Singapore and New York join several other (mostly U.S.) markets from the survey in an expensive cluster averaging at least $3,000 per month.

Price Trends

We continue to see stable baseline and cross-connect pricing across global markets both historically and in forecasted expectations. Both in response to our current pricing update and in our recent COVID-19 questionnaire over the summer, operators overwhelmingly indicated that base colocation prices would remain unchanged in the near term.

Asian hubs remain among the most expensive globally. Given regulatory and political challenges in Singapore and Hong Kong, the data center and network industries are searching for alternative locations to distribute deployments. Few viable options have come to light, and so continued high demand in Hong Kong and Singapore fuels consistently high prices.

Capacity and Providers

Metro Capacity

Tokyo remains the largest retail colocation market in the world, with 10.3 million square feet of gross retail capacity reported in 2020—but nearly 40% of that is accounted for by the various entities of the NTT Group.

Washington (really, Northern Virginia) is the second-largest retail market and arguably the most dynamic. By our measure, Hong Kong now edges out London as the third-largest global market, while the New York metropolitan region falls below London and Dallas in the ranking of largest retail market by gross data center footprint.

A number of sizable regional markets have cropped up around the globe in recent years. Madrid, Moscow, and Stockholm in Europe; Atlanta, Denver, and Montreal in North America; and Osaka and Mumbai in Asia have become critical secondary markets with around 1 to 3 million square feet of retail space.

Market Growth

Long-term growth across markets tends to be modest in both large and smaller markets. Between 2015 and 2020, the median compound annual growth rate in gross retail colocation capacity among the 49 markets highlighted in the study was just 5%. That's not to say there isn't growth but that the gross capacity added to the market on an annual basis doesn't add tremendously to the already-substantial established base in many of these locations.

Major hubs outpacing the median growth rate include Amsterdam and Washington, each with at least 15% compound annual growth in retail capacity.

On the other end of the spectrum, retail capacity growth has been essentially flat in Hong Kong, Silicon Valley, and Paris.

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Growth in Gross Retail Colocation Floor Space for Select Metro Areas

Million Square Feet 2016-2020

1. Tokyo
10. 3 million sq ft
CAGR: 4%

2. Washington
8.1 million sq ft
CAGR: 16%

3. Hong Kong
6.7 million sq ft
CAGR: 2%

4. London
6.4 million sq ft
CAGR: 7%

5. Seoul
6.1 million sq ft
CAGR: 3%

6. Dallas
5.6 million sq ft
CAGR: 5%

7. New York
5.5 million sq ft
CAGR: 3%

8. Frankfurt
5.5 million sq ft
CAGR: 9%

9. Singapore
5.1 million sq ft
CAGR: 3%

10. Chicago
5.1 million sq ft
CAGR: 7%

Vacancy

Seattle, Singapore, and Dallas had relatively high space availability between 40% and 55% as of 2020. In Singapore, the high vacancy level was heavily affected by very low reported occupancy at a few large sites, while in Dallas, a mix of both large and small sites reported high vacancy levels.

On the opposite end of the spectrum, respondents indicated that fitted colocation capacity in Miami, London, and Salt Lake City was at least 80% filled.

Providers

With a footprint that's 50% larger than its next biggest competitor NTT, Equinix has doubled its gross data center footprint in just four years to reach 24.2 million square feet of capacity.

When considering the number of operational sites, NTT edges out Equinix with 219 sites. In comparing both gross capacity and number of sites, Equinix and NTT dwarf all other retail colocation providers in scale.

On the wholesale side, Digital Realty's capacity is nearly 2.5 times as large as that of its next-largest competitor, the STT Group, at nearly 25 million gross square feet. This excludes Interxion capacity (which we still count as retail capacity) and triple-net lease capacity.

The STT Group of companies (consisting of ST Telemedia Singapore, STT GDC India, GDS Services, STT GDC Thailand, and Virtus) now exceeds 10 million gross square feet of capacity. GDS Services has been developing new sites across China at a blistering rate, adding or imminently launching 14 sites since September 2019 alone and developing at least 10 more in the near-term pipeline.

Among the operators tracked in our database, at least 80 data center sites are known to be in the pipeline right now. This construction will be quite evenly spread across global regions, with North America edging out Asia for the biggest percentage of new deployments.

Data center operators are investing both in edge and core markets for future development. Retail colocation providers are doubling down in large markets like San Francisco, Paris, and Sydney, but smaller markets like Oslo and Mumbai are well-represented too.

Planned wholesale construction spans the gamut from the very largest markets like Washington, Singapore, and London, to secondary Chinese markets and other edge locations like Bangkok and Berlin.

Proprietary Data Centers

Among the proprietary data center operators tracked in the Data Center Research Service, all are rapidly expanding into new markets. Collectively, Facebook, Microsoft, Google, and Amazon have deployed 15 new data centers globally (many of which come in the form of cloud service availability zones) in the last year alone.

Their growth is expected to accelerate over the near term with at least 34 more proprietary sites and cloud region deployments in the immediate pipeline.

Facebook alone currently operates eleven proprietary data center campuses with 13.3 million square feet of operational capacity and room for further growth. That's up more than 45% from their reported operational capacity just one year ago. The company has six more campuses in the pipeline, with more than 6 million square feet of capacity in the initial phases alone.

Power

Despite increased interest in high-density service provisioning, reported density levels haven't shifted much. At the highest levels we track, only about 20% of sites currently provision site density levels exceeding 200 W/sq ft, and that proportion hasn't dramatically shifted in at least the last six years.

Operators at most sites (65% of those reporting) support only density levels of up to 10 kilowatts per rack (kW/rack). The share of sites offering the highest density levels exceeding 20 kW/rack is just 12%.

The average site density levels in Dallas and Chicago exceed 200 W/sq ft. This puts their average density levels into the very highest range that we track. Dallas also has an above-average rack density level of 13 kW/rack. On the other end of the spectrum, Frankfurt has below average site density levels, and Hong Kong has low rack density provisioning.

10 Highest Capacity International Internet Hub Cities

Domestic routes omitted, 2020

Frankfurt, Germany
Bandwidth: 110.6 Tbps

London, U.K.
Bandwidth: 74.8 Tbps

Amsterdam, Netherlands
Bandwidth: 71.2 Tbps

Paris, France
Bandwidth: 67.9 Tbps

Singapore, Singapore
Bandwidth: 56.3 Tbps

Hong Kong, China
Bandwidth: 33.8 Tbps

Stockholm, Sweden
Bandwidth: 32.0 Tbps

Miami, U.S.
Bandwidth: 30.9 Tbps

Marseille, France
Bandwidth: 28.8 Tbps

Los Angeles, U.S.
Bandwidth: 25.2 Tbps

As of 2020, our survey indicates that most sites don't operate at a very low PUE level. A significant minority of sites (38%) operate below 1.5, but that percentage hasn't shifted over the past three years.

Connectivity

As in the previous few years, 2020 respondents indicated that Lumen (formerly CenturyLink), Verizon, and Zayo are the most prominent carriers in their facilities. These three operators are especially widespread in North America. AT&T and Cogent are also common in North American facilities, while Colt, GTT, and BT are heavily represented in European data centers. Telstra, China Telecom, China Unicom, Tata, and NTT are among the most ubiquitous carriers across Asian sites.

By our estimates, Equinix FR5—the former Ancotel site at Kleyerstraße 90 in Frankfurt—is the most carrier-dense colocation site in the world. Critical facilities run by TELEHOUSE in London and SUNeVision in Hong Kong are also among the most connected sites globally.

VOICE

A CONTINUED DECLINE IN CALLING

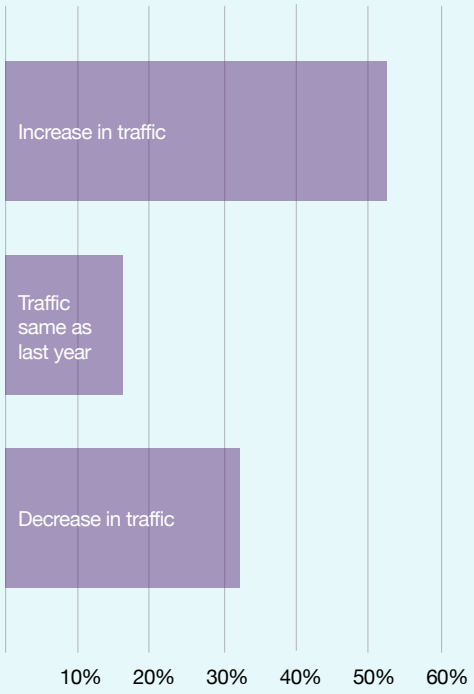
As our TeleGeography Report and Database illustrates, international voice market doesn't bring a lot of joy these days. 2015 marked a turning point in the international voice market—the first time since the Great Depression that international call traffic declined, even if only by one half percent. It's been downhill ever since, as the slump in voice traffic has turned into a fact of life. Carriers' traffic fell a further 9% in 2017 and 4% in 2018. The misery continued in 2019, as traffic dropped another 6%, to 435 billion minutes. The COVID-19 pandemic spurred a short-term rally in international call volumes in early 2020, but things pretty much returned to normal after that.

The COVID Impact

The global outbreak of COVID-19—and its associated economic and social impact—has upended the way billions of people live their lives. Has it had an impact on international calling? We queried a number of international operators to find out. Only a bare majority of operators responding to the survey we sent out in late 2020 reported that they had, in fact, seen a jump in international call volumes as the pandemic tightened its grip in March. (Nearly a third saw a dip in traffic compared to the year before.) The bump in traffic was short-lived, however. Only 4% of carrier reported that traffic levels remained elevated by the second and third quarters of the year.

Carriers Reporting Year-on-Year Traffic Increase

March 2020



Notes: Original question: "Did you see an increase in international traffic in March 2020 compared to the same period in 2019?"

The OTT Effect

A new market dynamic—social calling that replaced business communications as the primary driver of ILD usage—fueled a long era of international call traffic growth that began in the 1990s. In 1990, U.S. international call prices averaged over one dollar per minute(!) and business users accounted for 67% of ILD revenue.

A wave of market liberalization in the subsequent decade brought new market entrants, causing prices to tumble, and making international calling ever more affordable to consumers. In the early 2000s, the introduction of low-cost prepaid phones made it possible for billions of people in developing countries to obtain their own telephones, and to keep in touch with friends and family abroad easily. Call volumes soared, and by 2015, calls to mobile phones in developing countries accounted for 65% of global ILD traffic.

The transition to mobile and social calling drove a 20-year boom in voice traffic, but has also left the industry uniquely vulnerable to the rise of mobile social media.

While Skype was the dominant communications application for computers, a veritable menagerie of smartphone-based communications applications, such as WhatsApp, Facebook Messenger, WeChat (Weixin), Viber, Line, KakaoTalk, and Apple's FaceTime, now pose a greater threat. WhatsApp had about 2 billion monthly active users in 2020, with Facebook Messenger topping 1.3 billion. WeChat reported about 1.2 billion active users at the same time.

TeleGeography estimates that seven OTT communications applications—WhatsApp, Facebook Messenger, WeChat, QQ, Viber, Line, and KakaoTalk—combined had nearly 6 billion monthly users in September 2020. These estimates exclude apps for which directly comparable data is unavailable, including Apple's FaceTime, Google Hangouts, and Skype (the latter two of which have over 1 billion downloads from Google's App Store).

It's hard to pin precise numbers on the volume of international OTT communications. However, a simple thought experiment helps to illuminate its likely scale. Between 1983 and 2007, international

phone traffic grew at a compounded annual growth rate (CAGR) of 15%, and traffic grew an even faster 21% CAGR between 1927 and 1983.

It's hard to believe then that the recent decline in traffic means that people have lost interest in communicating with friends and family abroad. Rather, it suggests that they are turning to other means of keeping in touch.

TeleGeography has fairly reliable estimates of Skype's traffic through 2013, when the company carried 214 billion minutes of on-net (Skype-to-Skype) international traffic. Telcos terminated 547 billion minutes of international traffic in 2013, and OTT plus carrier traffic totaled 761 billion minutes.

If we assume that total international (carrier plus OTT) traffic has continued to grow at a relatively modest 13% annually since 2013 (with a drop to 9% in 2018 due to texting, video, and email), the combined volume of carrier and OTT international traffic would have expanded to 1.47 trillion minutes in 2019, and to 1.61 trillion minutes in 2020. This calculation suggests that cross-border OTT traffic overtook international carrier traffic in 2016, and would near 1.2 trillion minutes in 2020, far exceeding the 409 billion minutes of carrier traffic projected by TeleGeography.

International Wholesale Services

Many retail service providers, such as mobile operators, MVNOs, and cable broadband providers, rely heavily on wholesale carriers to transport and terminate their customers' international calls. Wholesale carriers terminated approximately 307 billion minutes of traffic in 2019, down 6% from 2018.

Even though wholesale traffic declined in 2019, over the last ten years wholesale traffic grew at a compounded annual rate of 3% while overall traffic only grew 1% per annum. By 2019, wholesale carriers terminated more than two-thirds (71%) of international traffic—up from 59% in 2008. Traffic to mobile phones in emerging markets has historically spurred expansion of the wholesale market,

Wholesale carriers terminated approximately 307 billion minutes of traffic in 2019, down 6% from 2018.

and that demand continues to drive wholesale's growth: In 2019 wholesale carriers terminated 86% of traffic to Sub-Saharan Africa and South America, and 83% to Central Asia. In contrast, only 54% of traffic to western Europe was terminated by wholesale operators. Revenues on calls to sub-Saharan Africa grew 20% between 2012 and 2019, $3.1 billion to $3.7 billion.

Declining wholesale prices stabilized in 2015 and have managed to inch up since. This, combined with recent dips in wholesale volumes, has resulted in uneven wholesale revenues in recent years. Revenues were actually up last year to $16 billion.

Wholesale operators make the bulk of their revenues in only a handful of regional markets. Sub-Saharan Africa, for example, received 6% of the world's wholesale traffic, but accounted for 23% of wholesale revenues ($3.7 billion.) Countries in the Middle East accounted for 6% of world wholesale traffic, but 11% of wholesale revenues ($1.8 billion).

Wholesale revenues are bolstered by a select set of low-traffic routes with stubbornly high prices. For example, the France to Tunisia accounts for just 0.3% of international traffic, but, at $0.54 per minute, it provides 3% of all revenues. Thanks to low termination prices in Mexico, the U.S.-Mexico route serves as a converse example: that massive route represents 9% of all international traffic in the world, but only 0.5% of wholesale carrier revenues.

Who's carrying all this traffic? In 2019, seven carriers in TeleGeography's ranking transported more than 20 billion minutes of traffic, down from 11 in 2015. Among the nine largest carriers in the world, only one terminated more traffic in 2019 than in 2018.

Prices & Revenues

Until 2015, international carrier voice traffic had increased in each of the previous 60 years. In each of the past four years, paid call volumes have slumped, with no end in sight. International carriers had already suffered from revenue stagnation due to slow traffic growth and falling prices.

The unprecedented occasion of outright traffic decline, however, marked a new and depressing turning point. In reviewing developments from the past year, three major trends stand out:

1. Retail international call revenues peaked in 2012, and have been on the decline ever since. Retail revenues have decreased from $99 billion in 2012 to $64 billion in 2019.

2. Retail prices were essentially unchanged in 2019, at about $0.15 per minute. Unfortunately, we anticipate that traffic loss will overwhelm this recent price stabilization, and that revenues will decline by a forecasted 8% in 2020.

3. At current run rates, international service revenues will fall to $50 billion by 2023. If that trend holds true, revenues will have declined by nearly half of the $99 billion total in the 10 years after 2012.

Research Catalog

Business Broadband Pricing Data
An extensive database of broadband service providers, plans, and prices.

Cloud and WAN Infrastructure
This tool profiles international WAN services offered by 180 providers and analyzes trends in VPN, Ethernet, DIA, and IPL availability and pricing, as well as cloud connectivity services.

Data Center Research Service
A comprehensive online guide for understanding data centers, network storage, and the nature of interconnection.

Dedicated Internet Access Pricing Data
TeleGeography's database of dedicated internet access price benchmarks for corporate and retail customers

Ethernet Over MPLS Pricing Data
This database presents information on prices connected to Layer 2, point-to-point Ethernet private line transport service delivered over an MPLS mesh.

Ethernet Over SDH or SONET Pricing Data
In this module, we track long-haul city-to-city routes between major global business centers.

Ethernet VPN Pricing Data
TeleGeography's database of layer 2 Ethernet VPN or VPLS services targeted at mid-market/enterprise customers.

Global Bandwidth Forecast Service
Detailed forecasts of international bandwidth supply, demand, prices, and revenues, updated quarterly.

Global Bandwidth Research Service
The most complete source of data and analysis for long-haul networks and the undersea cable market.

Global Internet Geography
The most complete source of data and analysis about international internet capacity, traffic, service providers, ASN connectivity, and pricing.

GlobalComms Database Service
The most complete source of data about the wireless, broadband, and fixed-line telecom markets, covering over 225 countries and 2,900+ service providers.

GlobalComms Forecast Service
Wireless, broadband, and wireline market metrics and forecasts by country and region.

i3forum Insights
A user-driven voice benchmarking tool for i3forum consortium members; powered by TeleGeography.

IP Transit Forecast Service
Detailed historical data and forecasts of IP transit service volumes, prices, and revenues by country and region.

IP Transit Pricing Data
A database of wholesale internet access price quotes by port speed and committed data rate from more than 60 carriers in over 100 cities around the world.

Local Access Pricing Data
A database of global local access prices, reflecting actual transaction prices paid by carriers for leased private lines and Ethernet circuits.

MPLS VPN Pricing Data

TeleGeography's price benchmark tracks VPN port and capacity charges at capacity increments between 128 Kbps and 10 GigE.

SD-WAN Research Service

The only product that catalogs and analyzes the SD-WAN market so you can find the right fit.

TDM Pricing Data

TeleGeography experts routinely survey facilities-based service providers that offer point-to-point private line TDM. Both domestic and international routes are covered in our list of tracked and surveyed routes.

TeleGeography Report and Database

The most comprehensive source of data on international long-distance carriers, traffic, prices, and revenues.

WAN Cost Benchmark

Provides tailored end-to-end price benchmarks for enterprise wide area networks, based on the client's specified site locations and service requirements.

WAN Geography Benchmark

A WAN Geography benchmark is your personalized cloud and WAN compass. This bespoke tool helps users optimize their network architecture for the cloud.

WAN Manager Survey

This special survey report is a treasure trove of analysis based on the experiences of WAN managers whose day-to-day role covers designing, sourcing, and managing U.S. national, regional, and global corporate wide area computer networks.

WAN Market Size Report

This vital report presents individual market sizes for key elements of the corporate network broken out by geography.

Wavelengths Pricing Data

In this module, we focus on long-haul city-to-city routes between major global business centers.