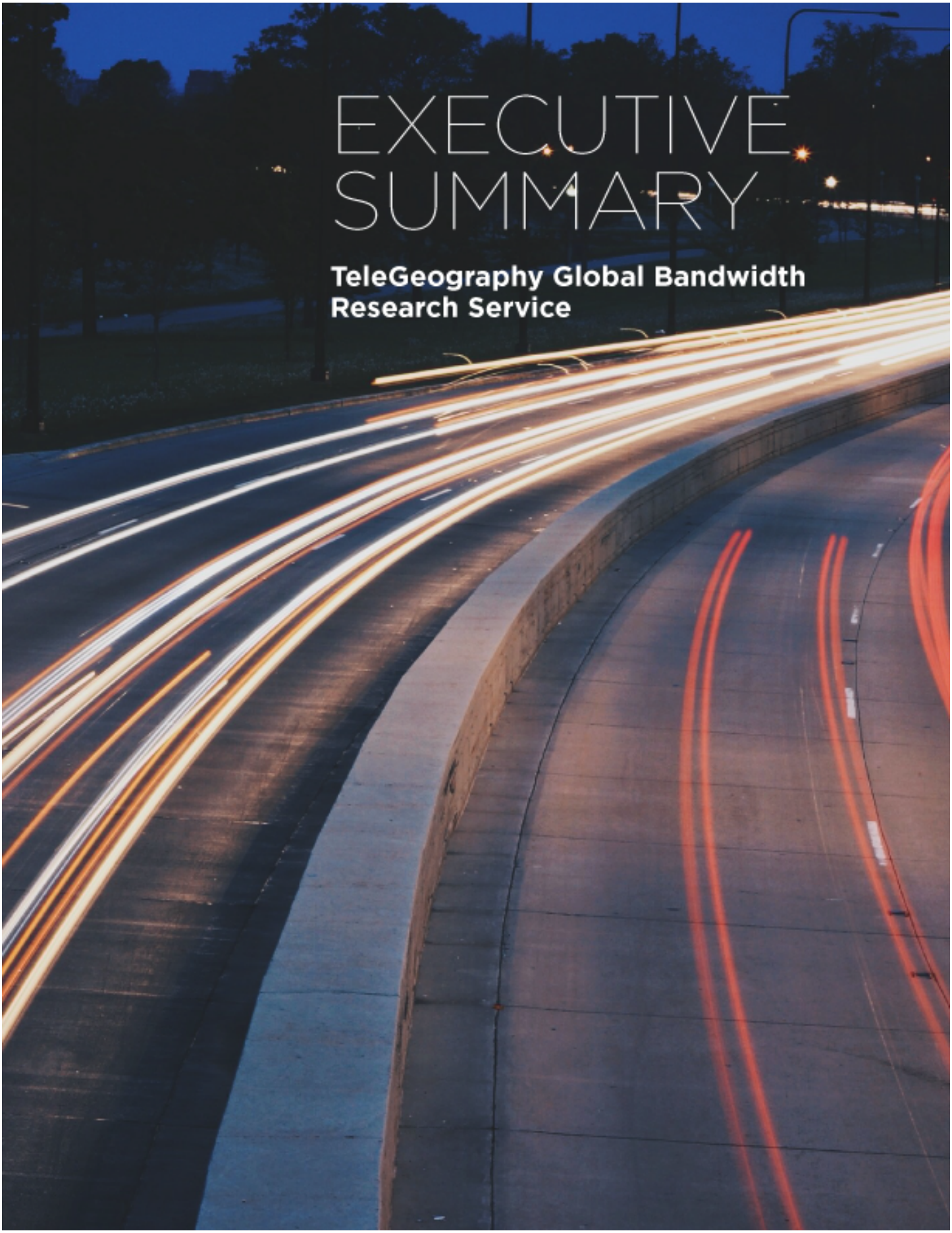


EXECUTIVE SUMMARY

TeleGeography Global Bandwidth Research Service

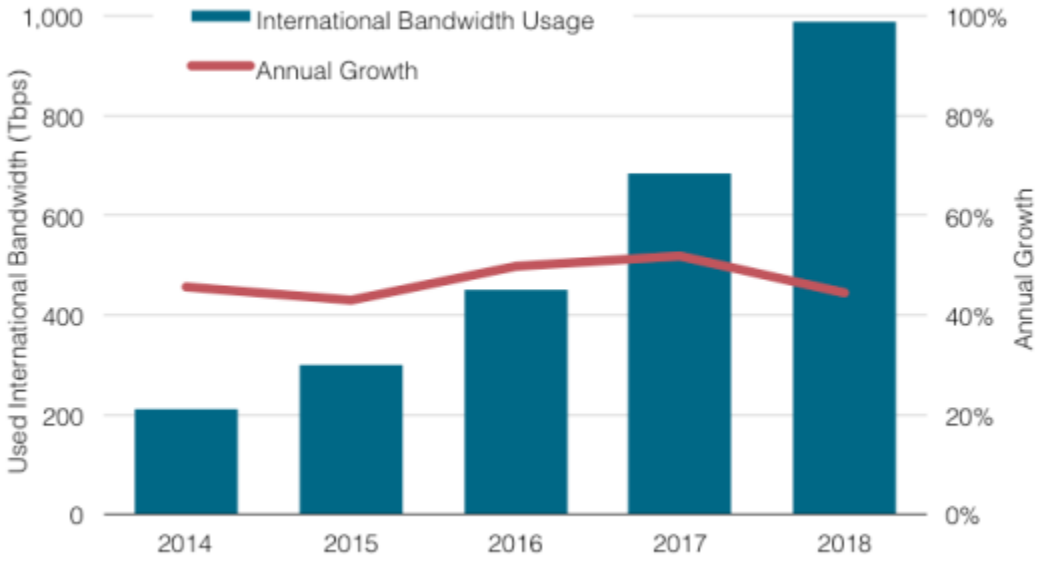
Executive Summary

The global bandwidth market is marked by change and uncertainty. New network builders shape changes in traffic flows, operators race to keep revenue margins ahead of constantly eroding prices, and the industry now faces the very limits of cable capacity as we know it. Our *Global Bandwidth Research Service* assesses the state of the global telecom transport network industry and evaluates the factors that shape long-term demand growth and price erosion.

Demand Trends

If demand is the key factor in assessing the health of the global bandwidth market, then the market is thriving. Between 2016 and 2018 alone, international bandwidth used by global networks more than doubled to reach 988 Tbps.

FIGURE 1
Worldwide International Bandwidth Growth, 2014-2018



Source: TeleGeography

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Let's break this demand growth down to a more granular level. If you look at the figure "Used International Bandwidth Growth by Region, 2014-2018", two observations jump out. The first is that demand growth has been strongest on links connected to Asia, which experienced a compound annual growth rate of 53% between 2014 and 2018. 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 slower than developing markets, that's not the case here.

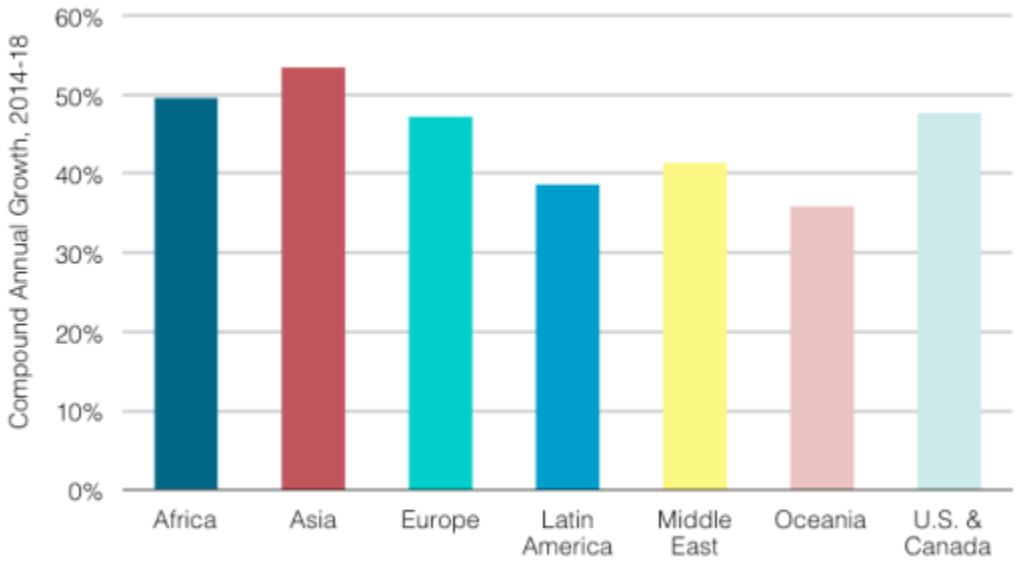
The Role of Content

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 2018, these companies are now the dominant users of international bandwidth, accounting for 54% of all used international capacity.

But their capacity requirements vary extensively by route. Content providers concentrate network planning on linking their data centers and major interconnection points. As such, they often take tremendous capacity on core routes, while focusing much less on secondary long-haul routes than traditional carriers. To get a sense of this contrast, note that in 2018, content providers accounted for 78% of used capacity on the trans-Atlantic route but just 3% on the Europe-Middle East & Egypt route.

FIGURE 2

Used International Bandwidth Growth by Region, 2014-2018



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.

Source: TeleGeography

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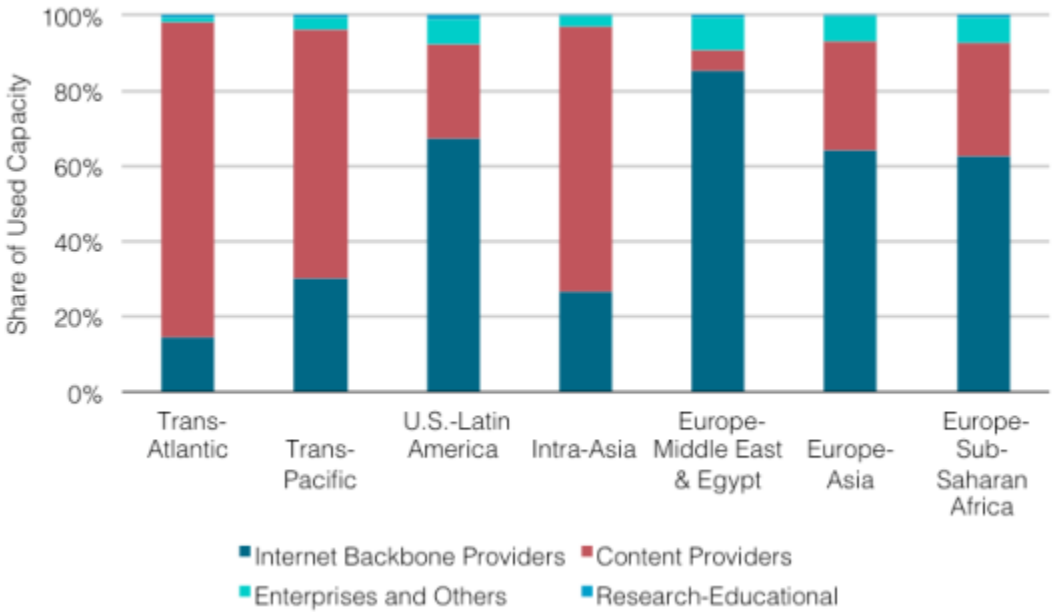
FIGURE 3

Share of Used Bandwidth by Category for Major Routes, 2018



Source: TeleGeography

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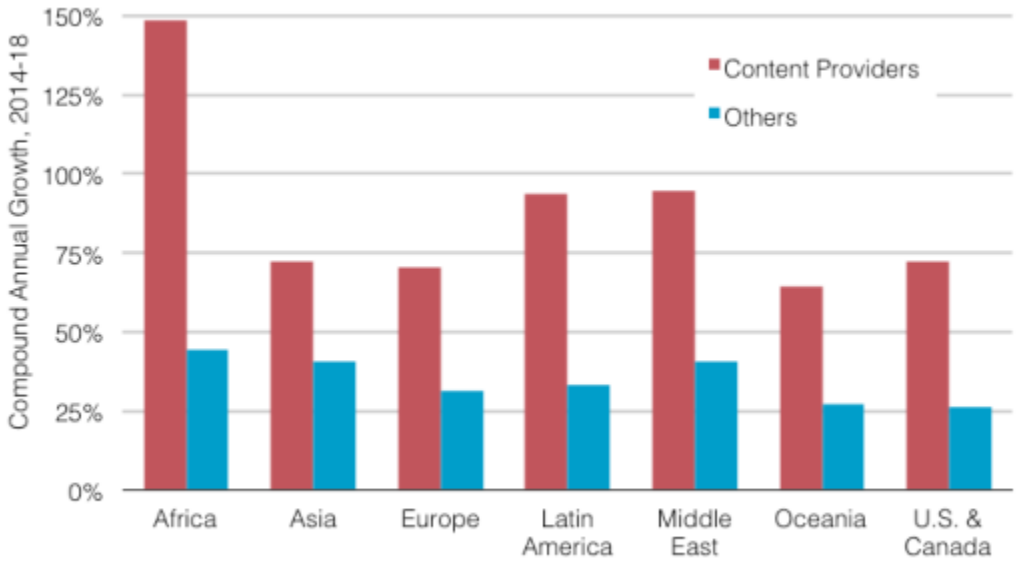
While the share of content provider capacity on some routes may be much lower than on others, the growth in their demand across all routes has been relentless. A comparison of the international capacity growth experienced by content providers versus all other sources in "Content Providers versus Others Bandwidth Growth by Region, 2014-2018" reveals a stark contrast. Across all world regions, content providers added capacity at a compound annual rate of at least 65% between 2014 and 2018, compared to a rate no higher than 43% for others.

FIGURE 4

Content Providers versus Others Bandwidth Growth by Region, 2014-2018



Source: TeleGeography

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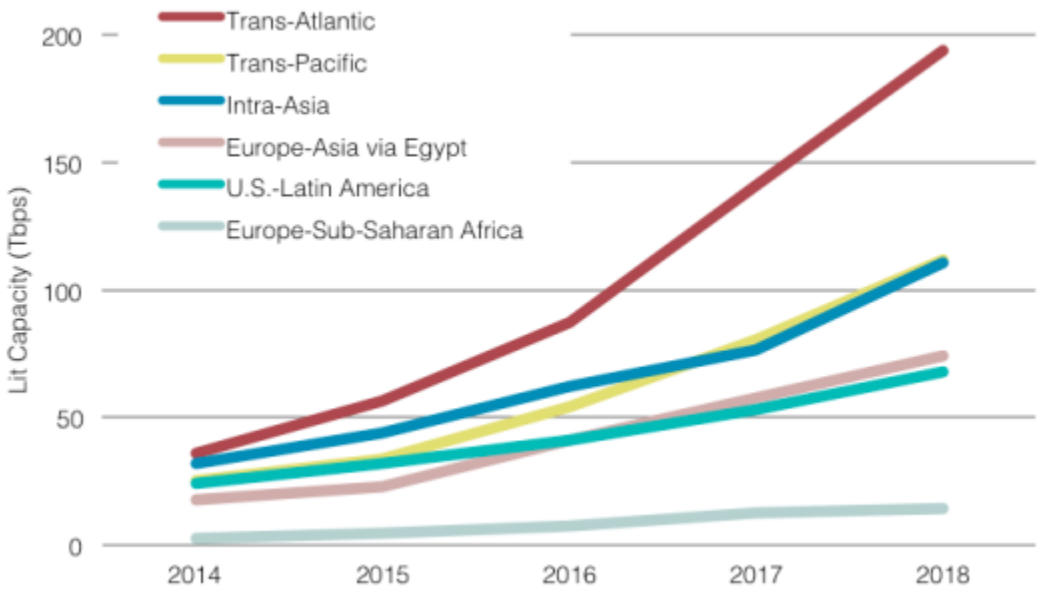
Meeting Demand Requirements

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 2014 and 2018 lit capacity more than tripled on many route. The pace of growth was the most rapid on Europe-Sub-Saharan African routes, where lit capacity increased over 5-fold between 2014 and 2018.

FIGURE 5

Lit Submarine Cable Supply by Route, 2014-2018



Notes: Data reflects lit capacity in unprotected terms at the end of the respective year. Intra-Asia capacity only includes cables with landings in both Hong Kong and Japan. Trans-Pacific capacity excludes Southern Cross and Telstra Endeavour. Trans-Atlantic capacity excludes Atlantis-2.

Source: TeleGeography

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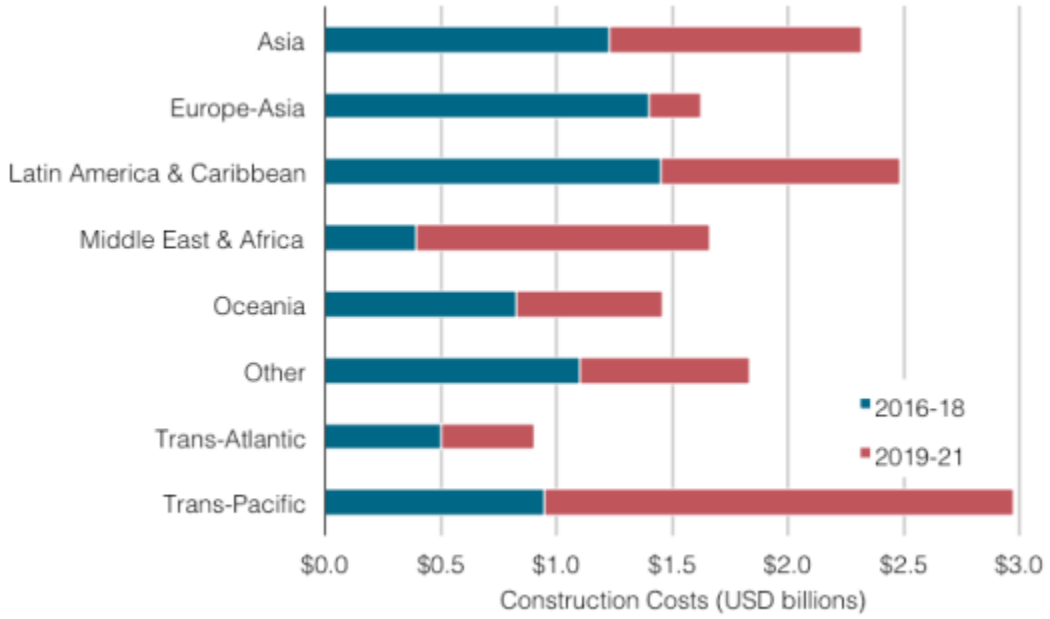
Aside from lighting new capacity, new systems are coming online across all routes. The year 2016 ushered in a period of significant global investment in the sector. Cables with a combined construction cost of $7.9 billion entered service between 2016 and 2018. Based on publicly announced planned cables, an additional $7.4 billion worth of new cables will be launched between 2019 and 2021. Notably, every major subsea route saw new cables deployed between 2016 and 2018, and investment is poised to continue across all routes. The trans-Pacific route leads the way with $2 billion of new cable investment expected from 2019 to 2021.

FIGURE 6

Construction Cost of New Submarine Cables Entering Service by Region, 2016-2021



Notes: Construction costs based on the year that the cable entered service. Construction costs exclude the cost of subsequent capacity upgrades and annual operating costs. 2019-2021 construction costs based on announced contract values and TeleGeography estimates. Not all planned cables may be constructed.

Source: TeleGeography

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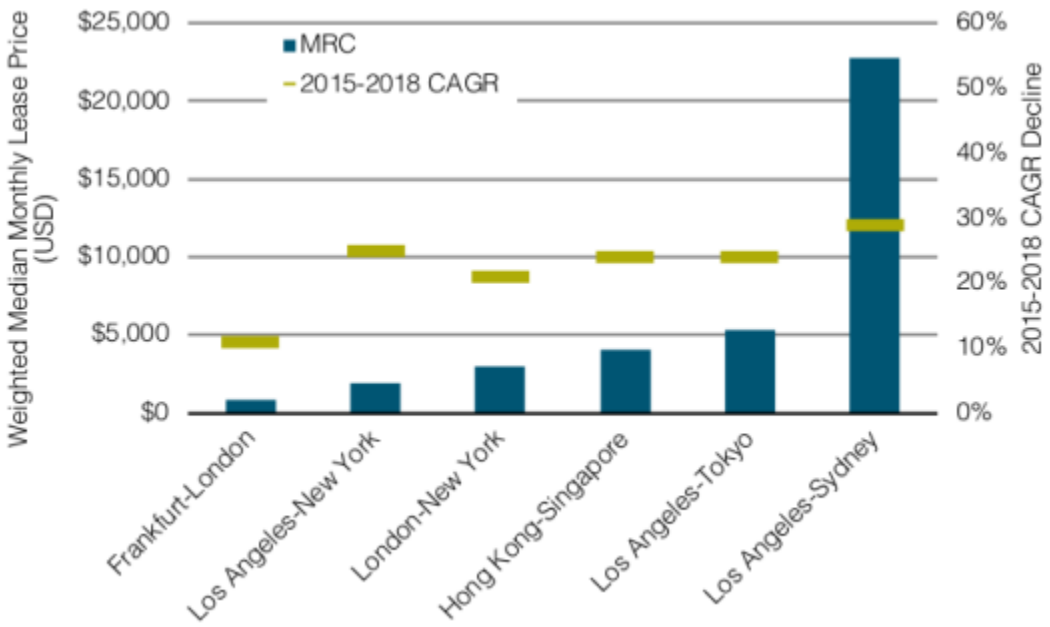
Pricing

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 27% and 24% compounded annually since 2015.

Yes, bandwidth price declines are widespread. But significant differences in price still exist depending on your destination. In Q4 2018, 10 Gbps monthly lease prices ranged from just $795 on the Frankfurt-London route to $22,766 between Los Angeles and Sydney. This is largely a reflection of differences in available supply and competition—on both international and domestic segments.

FIGURE 7

Weighted Median 10 Gbps Monthly Lease Prices on Select International Routes, Q4 2018



Notes: Each bar represents the weighted median monthly lease price for an unprotected 10 Gbps wavelength. The line represents the percentage decline of the weighted median price calculated as a three year compound annual growth rate. Prices are in USD and exclude local access and installation fees.

Source: TeleGeography

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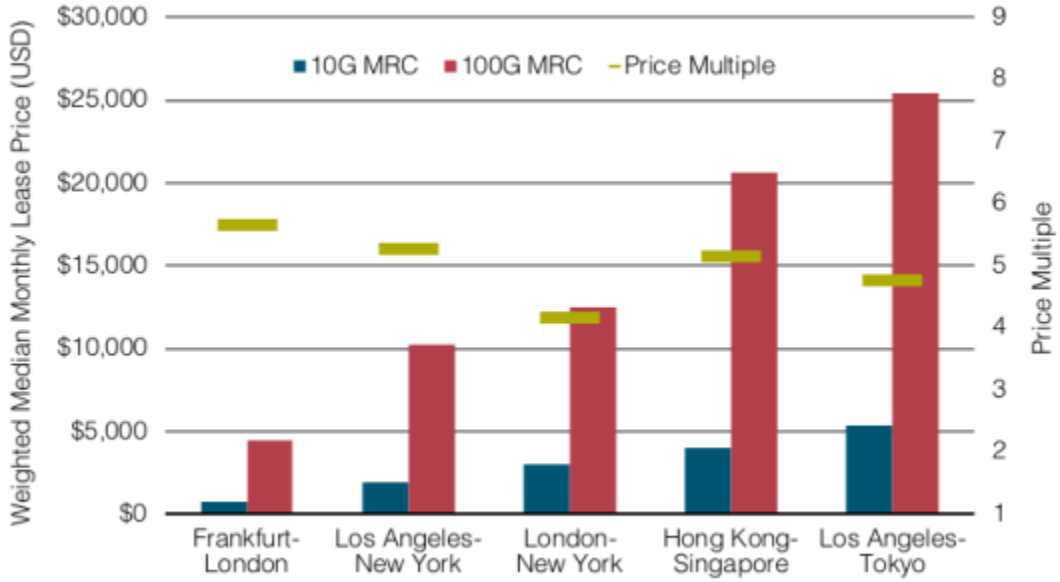
Although differences remain, prices in general are converging. Prices declines on high growth and underserved routes are outpacing those in established markets. And new cable systems and technological advancements have narrowed the unit cost of capacity.

With falling prices, the incentive to buy larger versus smaller circuits increases. In Q4 2018, the average multiple of 100 Gbps over 10 Gbps service among key routes was 5, down from 6.4 in 2015. Individual route multiples ranged from 4.2 on the shorter connection between London and New York to 5.8 on the route between Miami and São Paulo. Capacity multiples for 100 Gbps tend to be lower when sellers compete aggressively for 100 Gbps business but not for 10 Gbps. That is, a low 100 Gbps to 10 Gbps multiple can arise both from a relatively low 100 Gbps price or a high 10 Gbps price.

FIGURE 8

10 Gbps and 100 Gbps Wavelength Weighted Median Prices and Multiples on Select International Routes, Q4 2018



Notes: Each bar represents the weighted median price for an unprotected wavelength for the listed capacity and route. Prices are in USD and exclude local access and installation fees. MRC = Monthly recurring charge. Multiples are derived by dividing the price of the larger circuit by the price of the smaller circuit.

Source: TeleGeography

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Outlook

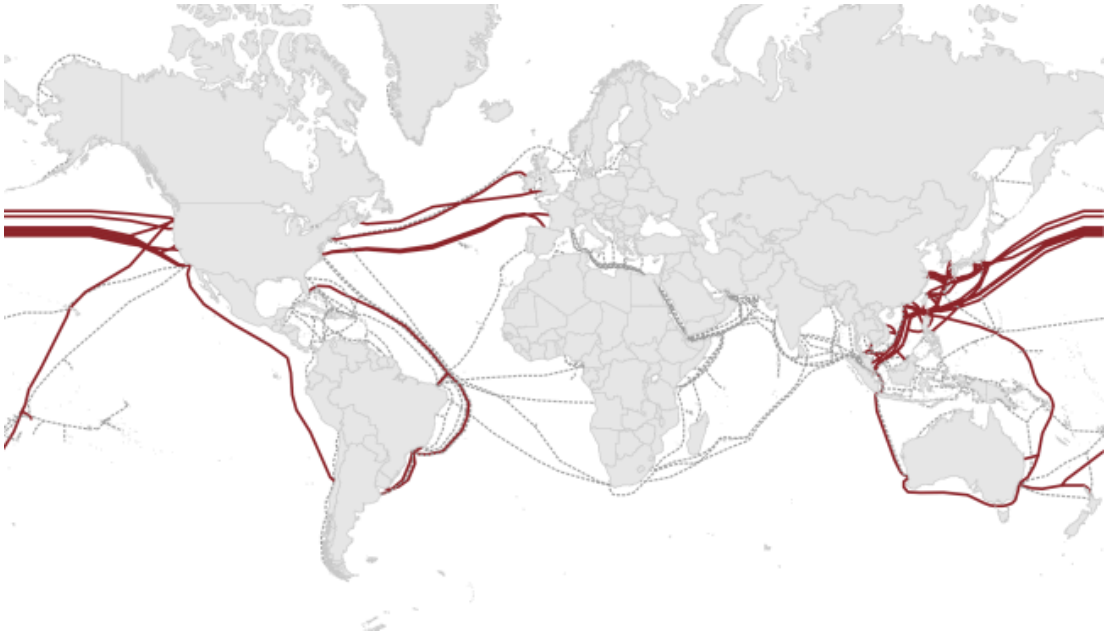
What does the future hold for the global bandwidth market? The two most predictable trends are persistent demand growth and price erosion. Beyond that, operators will have to navigate major uncertainties in continuing to move forward in an evolving sector. Here are a few of the key trends, among many, 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. In particular, India-Singapore, India-Europe, and Europe-Africa may attract content provider interest in new systems.

FIGURE 9

Map of Content Provider Submarine Cable Investments



Notes: Map shows in service and planned cables with a ready-for-service (RFS) data in 2012 or later. Submarine cables in red are those in which at least one content provider is publicly known to be an investor. Content providers also have capacity on other cables.

Source: TeleGeography

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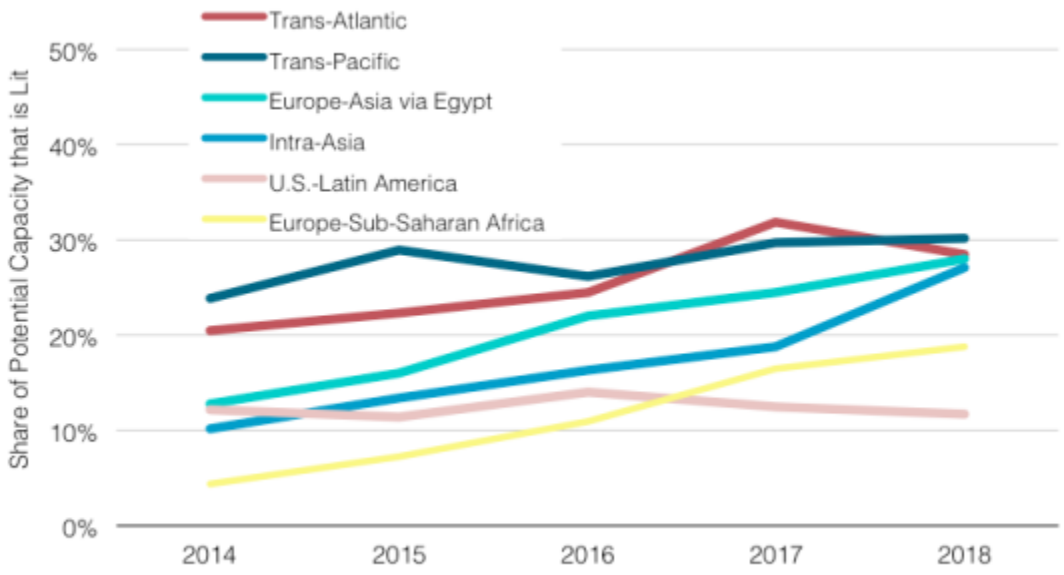
Content provider demand dominates the development of certain routes; will new content providers follow suit? Our assessment is that a very limited group of players will continue to dominate content and cloud network demand. It seems unlikely that many more such networks, even the Chinese content providers, 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. As you can see in the figure “Percentage of Potential Capacity that is Lit on Major Submarine Cable Routes, 2014-2018”, this means that the percentage of capacity that is lit on major routes has begun to rise. The one exception is the U.S.-Latin America route, where the recent launches of the three high-capacity cables has caused lit capacity to decline as a share of total potential capacity.

FIGURE 10

Percentage of Potential Capacity that is Lit on Major Submarine Cable Routes, 2014-2018



Notes: Data reflects the percentage of potential capacity that was lit at the end of the respective year. Potential capacity figures are based on operators' view of theoretical maximum capacity as of year-end. Intra-Asia capacity only includes cables with landings in both Hong Kong and Japan. Trans-Pacific capacity excludes Southern Cross and Telstra Endeavour. Trans-Atlantic capacity excludes Atlantis-2.

Source: TeleGeography

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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.

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. One interim technique to add more capacity on transoceanic systems in the short term will be to implement Spatial Division Multiplexing (SDM), which lowers the total output power per fiber pair and uses less power-intensive modulation to enable the addition of extra fiber pairs. 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 could have even more. As a long-term growth strategy, adding fiber pairs has limitations. The general consensus in the industry is that once systems reach somewhere between 24 and 32 fiber pairs, mechanical complications will increase to

the point where the trend is unsustainable.

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. Although this removes large swaths of bandwidth from the managed wholesale bandwidth market, it also 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.

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