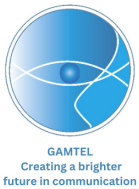
# BROADBAND INVESTMENT DEMANDS AND TRENDS 2023

WORLD BROADBAND ASSOCIATION

This report analyzes the demand for broadband investment as well as current investment trends. It provides some best practice and recommendations for different stakeholders around broadband investment.

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# SUMMARY

This white paper is targeted at a number of different stakeholders including governments and regulators, telecom operators, broadband infrastructure vendors, the financial and investment community, system integrators, application providers, device manufacturers, and enterprises.

The purpose of the white paper is to advocate for the broadband sector and to demonstrate the value of broadband in multiple areas and to multiple stakeholders. It seeks to demonstrate how the demand for broadband is evolving and how it will continue to evolve in the future. It also assesses the supply side of broadband and looks at the World Broadband Association's Next-Generation Broadband Roadmap. It considers the lessons that different stakeholders can learn from the evolution of broadband network capabilities. The white paper looks at investment in broadband from several different perspectives, for example, from the point of view of governments, investors and the financial community, and operators. It offers a list for these different bodies to consider of issues around broadband investment and provides some best practice and recommendations.

### KEY FINDINGS

- Stakeholders need to be aware of how quickly broadband demand is evolving. Broadband speeds and other critical metrics such as latency and reliability have improved, and this is correlated with the increase in fiber-to-the-premises (FTTP) coverage in different countries.
- Broadband demand is likely to continue to evolve over the coming years as new applications become more common and the number of connected devices continues to grow.
- The supply side of broadband also continues to rapidly evolve, reflecting, for example, continuing innovation in Passive Optical Network (PON) FTTP networks. However, the evolution of broadband networks is very wide ranging and encompasses several other dimensions such as sensing capabilities and trustworthy and green characteristics.
- Stakeholders must keep pace with these enhancements in broadband supply characteristics. For instance, when setting forward-looking targets for broadband speed coverage and adoption, governments and policymakers must be aware of the rapid evolution of network performance.
- Governments must understand the means by which they can shape the broadband market through policy and regulation. In addition there is a wealth of options for governments in how they seek to fund broadband rollout in underserved areas.
- Investors need to be aware of the specific nature of investing in fiber broadband access networks. This includes understanding the very long asset life of such networks as well as ways to reduce rollout risks, such as demand aggregation.

# A GROWING NEED FOR FIBER EVERYWHERE

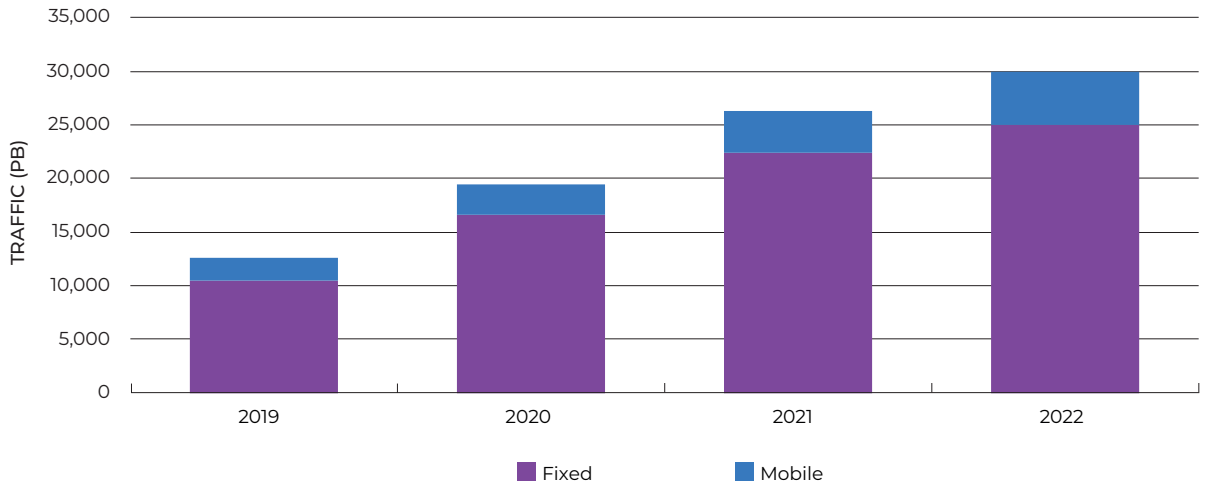
Any discussion of the value of broadband must analyze the economic benefits that better-quality broadband can deliver. Broadband access is important because industries that use it can derive additional revenue or cost savings from its use. Whole industries can benefit from the digital transformation that better quality-broadband brings. Fiber connectivity can also provide the bedrock for advanced smart cities (see the case study ***Beijing all-optical smart city***).

In addition to the clear economic benefits that result from the deployment and take-up of next-generation broadband access, there are wider societal benefits of broadband. For example, broadband is an enabler of home working and the social benefits that this can deliver such as increased leisure and family time.

## FTTP OFFERS THE PROMISE OF UNLIMITED DATA THANKS TO ABUNDANT CAPACITY

One very important aspect of FTTP and other fixed broadband technologies is their ability to provide unlimited data plans thanks to the very high capacity they can supply. In practice this means that broadband traffic is a very high proportion of total broadband plus mobile traffic in many markets. For example, in Chile in 2022 fixed-line traffic was 24,969 petabytes (PB) compared with just 4,952PB on mobile networks. There is also little evidence that over time mobile traffic will account for a growing share of total traffic, because in many markets mobile and fixed traffic growth rates are broadly comparable.

FIGURE 1: CHILE FIXED AND MOBILE DATA TRAFFIC, 2019–22




SOURCE: OMDIA

Moreover, as broadband penetration increases overall data consumption grows, which means that developed countries with the highest broadband penetration levels have the highest average data consumption levels. Without broadband investment, countries risk condemning their citizens and businesses to a digital drought. Where broadband investment is low, users may be limited to only using capped mobile data plans with a consequent negative impact on customer experience.

Fiber connections are also well placed to deal with sudden and prolonged increases in traffic. This is demonstrated by the strong performance that high-capacity fiber networks were able to provide during pandemic lockdowns.

## THE RELIABILITY THAT FIBER BROADBAND CAN PROVIDE IS INCREASINGLY CRITICAL

Consumers and enterprises increasingly see the reliability of their broadband connection as vital. As fiber broadband replaces copper, the number of faults per line should fall as indicated by various operator pronouncements. Openreach in the UK notes that its full-fiber network has fault rates that are 70–80% lower than for connections that use technologies that rely on a combination of copper and fiber. In addition, Verizon has previously stated that fiber is 70–90% more reliable than copper. Broadband resilience is vital, and FTTP is well placed to address this requirement, for instance, because passive fiber networks can fare well during extreme weather events. Chorus in New Zealand notes that during the recent Cyclone Gabrielle extreme weather event, copper customers were 8× more likely to lose service than fiber customers, and it took twice as long on average to restore service to copper customers. Fiber testing and monitoring

can also help ensure the reliability of fiber networks and reduce the number of repeat visits required for fiber installations (see the case study ***Building "first time right" quality in FTTx networks***).

### HIGH-SPEED AND LOW-LATENCY FIBER CONNECTIVITY CAN ENABLE A NEW WAVE OF APPLICATIONS

In addition to its capacity and reliability, fiber still holds its traditional advantage of high speeds. In reality, capacity and reliability and speed and latency are intrinsically linked, since broadband networks must be able to provide high speeds and low latency at peak times such as the evening, when there is heavy usage across multiple applications on multiple devices. One good indication of this is that the European Electronic Communications Code defines a very high capacity network as one that is capable of delivering similar speeds and latencies even under peak-time conditions.

High-speed fiber connectivity is capable of acting as an enabler of a new wave of applications that require high bandwidth. For instance, in order for applications such as the metaverse and extended reality (XR) to work effectively, high-bandwidth connectivity will be required. In addition, this high bandwidth will need to be delivered not just over the fiber access network but also inside the home in order to deliver these applications to end users. To this end, home-networking technologies will need to keep pace, and fiber to the room is one potential solution for increasing in-home network capacity. Fiber can also offer the benefits of low latency.

### FIBER OFFERS ENERGY EFFICIENCY

A further crucial point to note is that deploying fiber can be energy efficient. It is important to stress the low energy consumption per line of FTTP connections relative to other technologies, including cellular access. Good-quality FTTP connections can also serve as an enabler for home working, which in turn can deliver benefits in terms of reduced carbon emissions.

### FIBER CAN CATER TO THE NEEDS OF ENTERPRISES

There is also a need for broadband to cater to the specific requirements of enterprises. FTTP networks with either PON or point-to-point architectures can support service-level agreements (SLAs) to deliver connectivity to enterprises. For example, on PON networks SLAs can be delivered by various means such as optical line terminal (OLT) and optical network terminal (ONT) redundancy and by deploying multiple fibers to the splitter. In addition, fiber is well placed to meet enterprise connectivity requirements because it can deliver symmetrical speeds. High-speed FTTP is a necessity for some enterprises whose work involves downloading and uploading extremely large files.

## BROADBAND DEMAND

### BROADBAND DEMANDS TODAY

The concept of better broadband can be looked at in various dimensions, and it is important to take a holistic view by looking at a range of performance metrics. The most obvious metric is speed, but it is necessary to consider performance on both the downstream and upstream sides. Average speeds might reflect very high speeds received by only a small percentage of customers, so median speeds can give a better impression.

The speeds subscribers are receiving via today's broadband networks are captured by Ookla's Global Speed Index. (For more information on Ookla data see the case study ***Hong Kong and Macao, driving greater adoption of fiber services in advanced telecom markets***). This data first shows that there are considerable variations in broadband speeds between countries/regions. Such variations are also not necessarily correlated with income levels, and some lower-

and middle-income countries perform well. One indication of this is that Chile ranked first in Ookla's Global Speed Index for November 2022 with a median download speed of 216Mbps. Another country that performed well was Thailand, which achieved fourth place with a median download speed of 206Mbps.

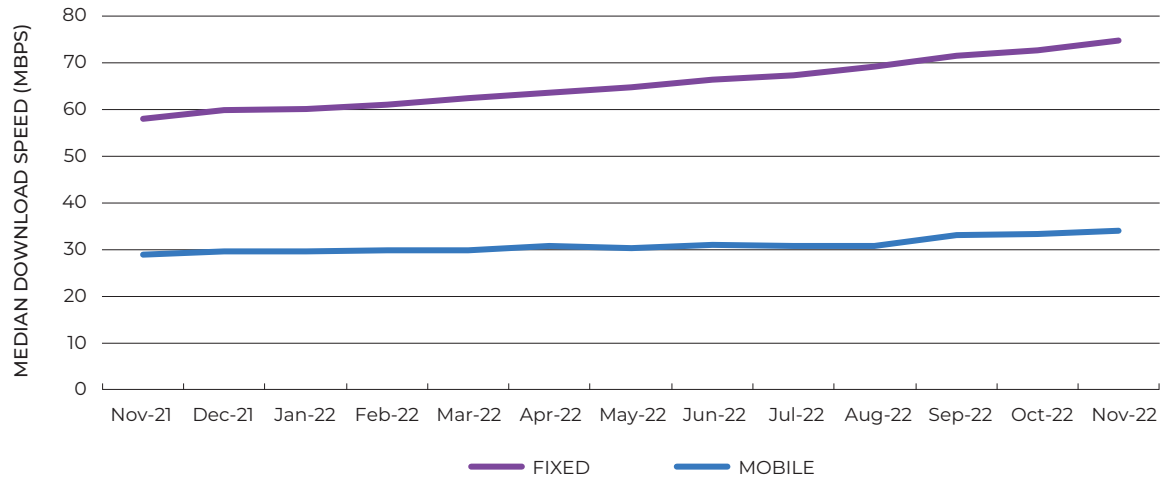
TABLE 1: TOP 10 COUNTRIES/REGIONS WITH FASTEST MEDIAN FIXED BROADBAND DOWNLOAD SPEEDS, NOVEMBER 2022

| COUNTRY/REGION | MEDIAN FIXED BROADBAND DOWNLOAD SPEED (MBPS) |
|---|---|
| CHILE | 216.46 |
| CHINA | 214.58 |
| SINGAPORE | 214.23 |
| THAILAND | 205.63 |
| HONG KONG (SAR) | 194.35 |
| US | 189.48 |
| DENMARK | 188.35 |
| UAE | 186.76 |
| MONACO | 181.26 |
| ROMANIA | 170.25 |

SOURCE: OOKLA GLOBAL SPEED INDEX

In addition, the Global Speed Index shows that over the last few years there have been considerable improvements in the speeds subscribers receive. For example, in the period from November 2021 to November 2022, Ookla's Global Speed Index noted a 28% increase in global median broadband download speeds with the figure reaching over 70Mbps. Median speeds on fixed-line connections grew more rapidly than on mobile networks, a fact that reinforces the value of a fixed broadband connection.

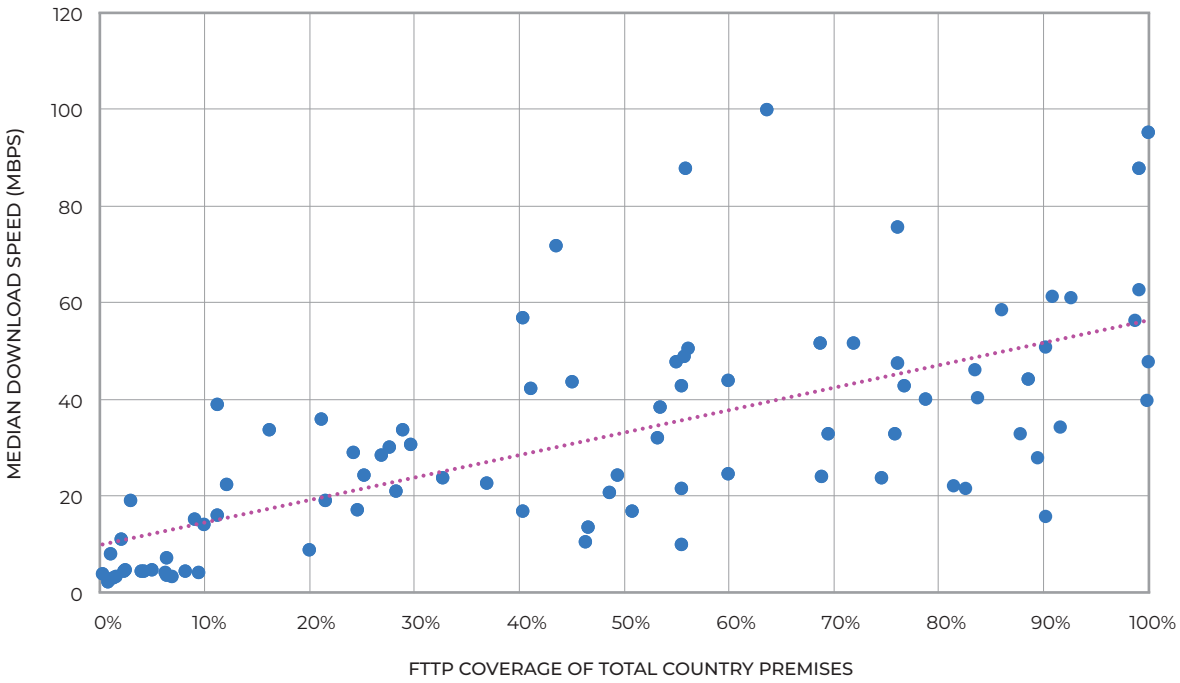
FIGURE 2: GLOBAL MEDIAN DOWNLOAD SPEEDS, FIXED-LINE AND MOBILE NETWORKS, NOVEMBER 2021 – NOVEMBER 2022




SOURCE: OOKLA

There is a clear correlation between strong performance for a country in terms of broadband speeds and national FTTP coverage. This reflects the superior broadband experience that fiber connections can deliver.

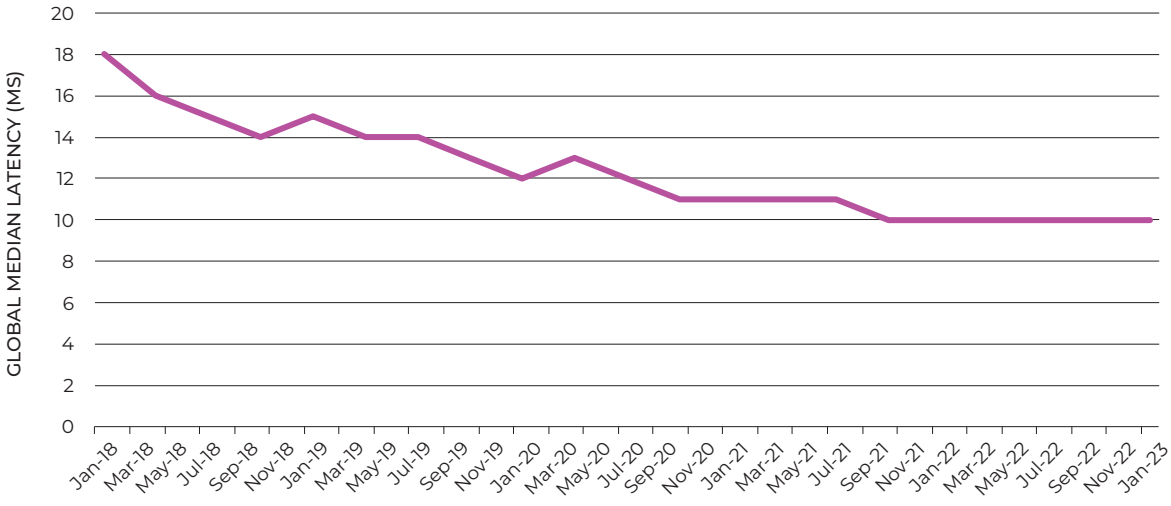
FIGURE 3: FTTP COVERAGE OF TOTAL COUNTRY PREMISES AS OF JANUARY 1, 2022, AND MEDIAN DOWNLOAD SPEED AS OF JUNE 2022




SOURCE: OMDIA (FTTP COVERAGE), OOKLA (MEDIAN DOWNLOAD SPEED)

A further consideration is demands on broadband for reliability and consistency in addition to latency. It is worth noting that global median latency has fallen considerably over recent years, from over 18ms at the start of 2018 to around 10ms at the start of 2023.

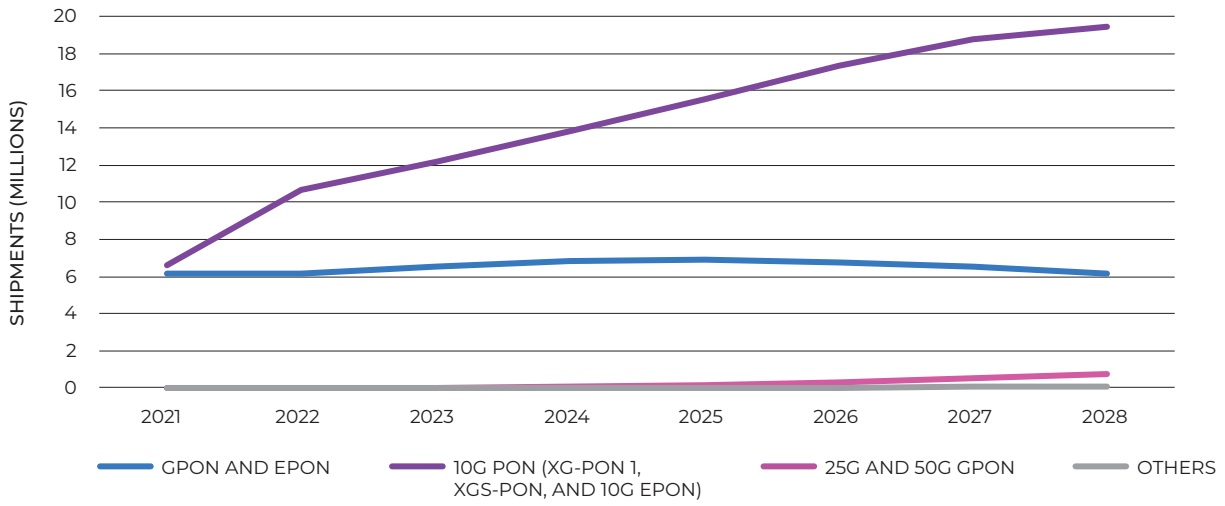
FIGURE 4: GLOBAL MEDIAN LATENCY, FIXED-LINE NETWORKS, JANUARY 2018 – JANUARY 2023




SOURCE: OOKLA

The data from Ookla that shows improvements in broadband performance also reflects the fact that demand for next-generation PON FTTP technologies is growing rapidly. This is demonstrated by Omdia data showing OLT port shipments by PON technology generation. For example, Omdia data shows that in 2022, 64% of total global OLT port shipments were for 10G PON (i.e., XG-PON 1 plus XGS-PON plus 10G EPON).

FIGURE 5: GLOBAL PON OLT PORT SHIPMENTS BY PON TECHNOLOGY, 2021–28




SOURCE: OMDIA

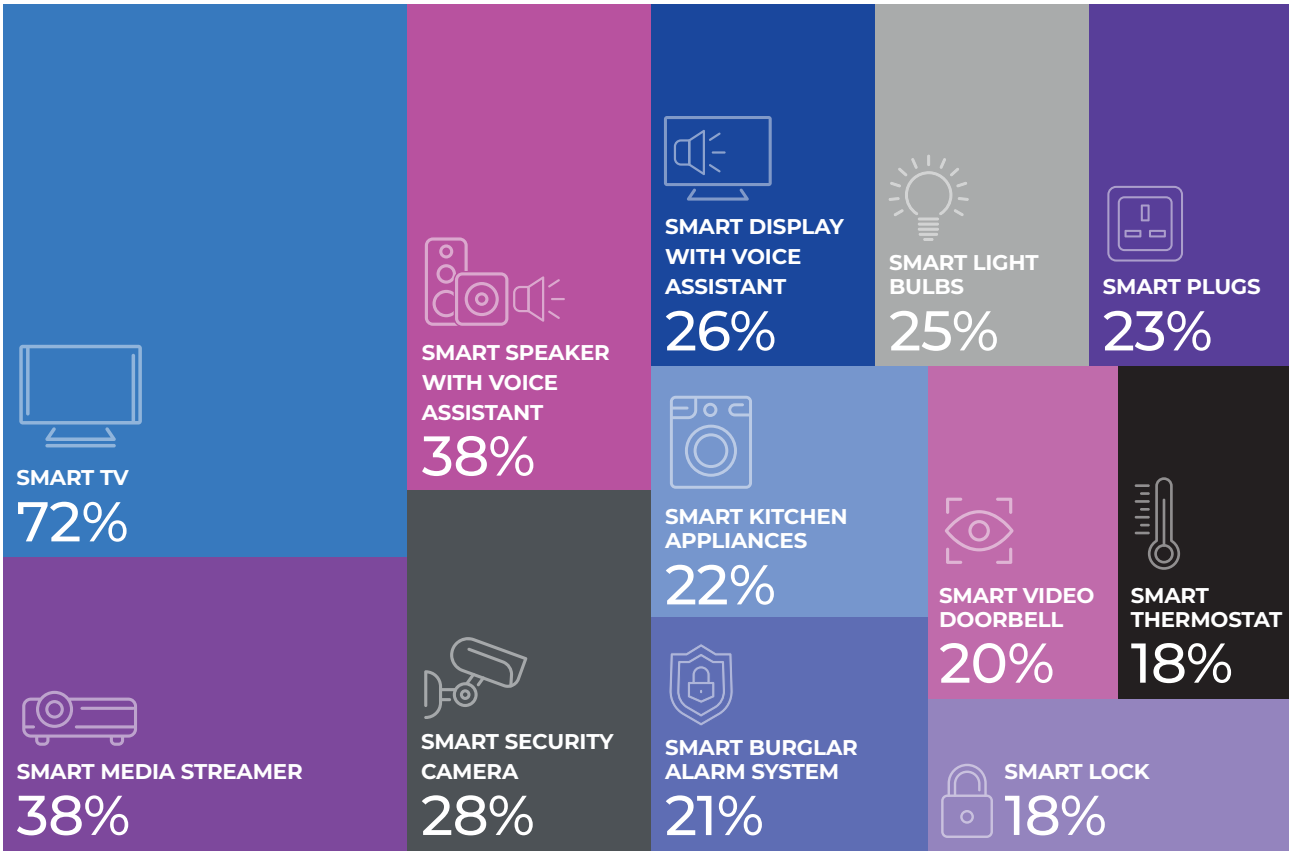
## APPLICATION DEMAND

The rapid development in broadband performance generated by the rollout of technologies such as different PON FTTP and Wi-Fi generations has in turn acted as an enabler for new applications including videoconferencing. Enterprises can also benefit from video monitoring solutions that are enabled by high-speed technologies (see the case study ***E-Surfing video networking***).

The impact of the growth in working from home and video calling driven by the global pandemic is also important when the demands on today's broadband networks are being considered. Working from home and video calling are important because they affect both residential subscribers and businesses. The move to working from home is, moreover, a broad societal phenomenon that has an impact beyond the telecom sector: it impinges on different areas such as commuting and public transportation. This helps demonstrate the importance of good-quality broadband because it has spillover effects in other areas. Working from home and video calling require high-speed connections with good uplink capacity but also need reliable connections so that, for example, there are no interruptions during business video calls.

It is also true that demand for next-generation broadband is being driven by the greater proliferation of connected devices in consumers' households. The results of Omdia's Digital Consumer Insights survey (conducted in Australia, Brazil, China, France, Germany, Indonesia, Malaysia, Mexico, South Africa, Spain, the UK, and the US) demonstrate the wide array of connected devices used by households across different markets. Across all the countries covered by the survey, which represent a mix of developed and emerging economies, 72% of respondents stated that they had a smart TV. This is significant because the larger screens of these devices mean that viewers want higher-resolution video such as 4K video. This can then drive the need for higher speeds but also drives overall fixed-line traffic and demonstrates the importance of uncapped fixed broadband connections.

FIGURE 6: RESPONSES TO THE QUESTION: "WHICH CONNECTED DEVICES DO YOU CURRENTLY HAVE?"




SOURCE: OMDIA DIGITAL CONSUMER INSIGHTS SURVEY 2022

## EVOLUTION OF BROADBAND DEMANDS

The emergence of future applications will further drive the demand for high-speed broadband. Over time, in addition to changes in application usage by households the requirements of enterprises and industries will also change. Use cases will emerge that require low latency as well as improved network resilience.

There are a number of promising candidates for applications that require high bandwidth and low latency that could achieve mass adoption over the coming years. XR and metaverse applications are likely to be enjoyed by fixed broadband users in indoor home or business environments, for instance, because of the potential need for headsets in some circumstances. The throughput demands of virtual reality (VR) are likely to be considerable, because a high number of frames per second may be required, for instance, for VR gaming. In addition, the video delivered over the network will need to be in an even higher resolution than the viewer can observe because the field of view is higher for VR. In other words, it is possible that the video delivered over the network will need to be at 8K resolution in order for the viewer to see 4K-quality video. It is possible that for one VR user, maximum throughput of more than 1Gbps would be required. Latency requirements will also be demanding with, for instance, maximum interactive latency of 10ms. These requirements will need to be accommodated by both the broadband access network and the in-home network.

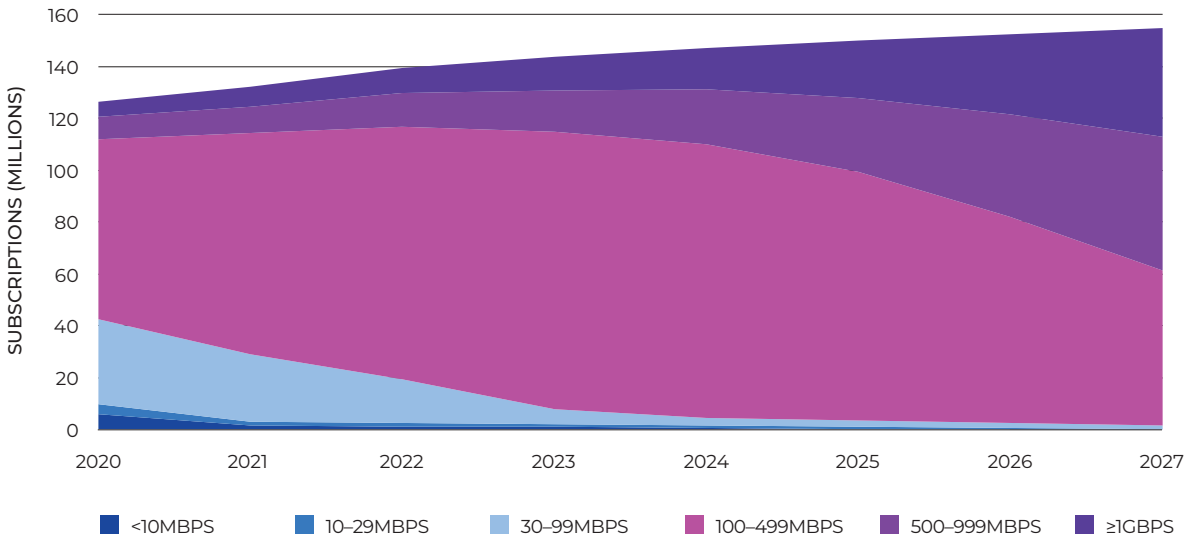
The growth of metaverse-type applications will also have consequences in terms of the need to reduce latency with edge computing (see the case study ***Enabling broadband at the edge cloud***). There will be opportunities for operators to include storage and computation capabilities at access node locations as well as in residential customer premises equipment.

It is possible for governments to play a role in shaping and directing demand for broadband. One way this can be achieved is through the setting of objectives, for instance, for the adoption of gigabit speeds.

## BROADBAND SPEED EVOLUTION

The demand for these new applications will be one factor that will help explain the growth in fixed broadband speeds received by subscribers. This is demonstrated by Omdia's residential broadband speed forecasts. The forecast indicates that in North America by the end of 2027, 27% of consumer broadband subscriptions will have download speeds greater than or equal to 1Gbps, which represents a strong increase from 7% at the end of 2022.

FIGURE 7: NORTH AMERICA, CONSUMER BROADBAND SUBSCRIPTIONS BY SPEED, 2022–27



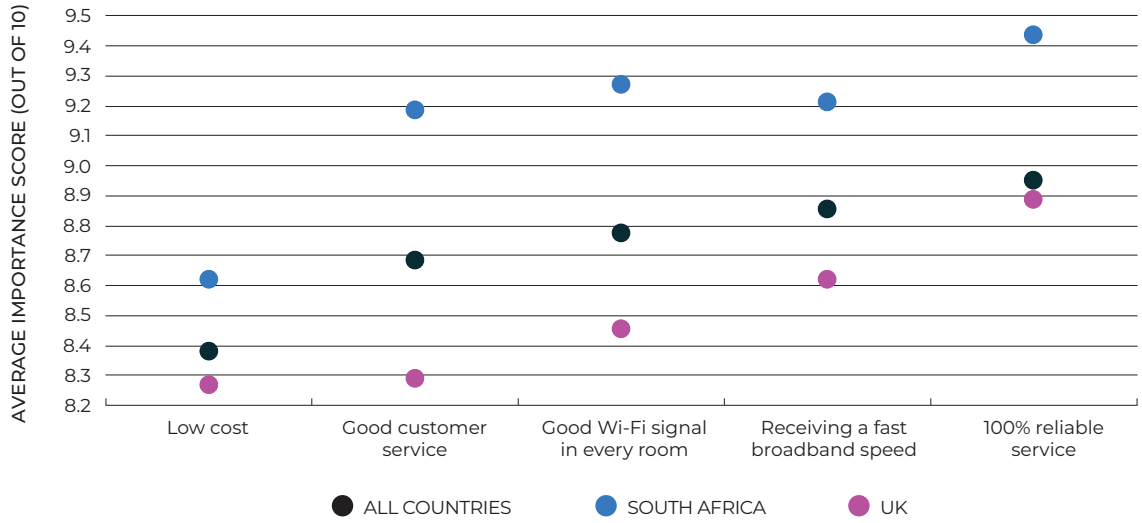

SOURCE: OMDIA

Broadband speeds will also increase in emerging market regions but will still lag those in the most developed markets. For example, in Africa just 0.2% of consumer broadband subscriptions had speeds of 1Gbps and above at the end of 2022, and while this percentage will increase more than 10-fold by the end of 2027, it will reach only 2.4% by then.

## BROADBAND RELIABILITY AND LATENCY EVOLUTION

As well as the demand for broadband speed, it is also important to consider other performance attributes. We expect a continuing improvement in broadband reliability over time, reflecting the fact that in many cases broadband reliability is the consumer's primary concern. This is demonstrated by the results of Omdia's Digital Consumer Insights survey. As part of the survey respondents were asked: "How important are the following features of your broadband service?" and were asked to rank the options on a scale of 1–10, where 10 is most important. Survey respondents across all the surveyed countries combined ranked "100% reliable service" as the most important feature. This result also applied across different individual countries: for example, in both the UK and South Africa "100% reliable service" was regarded as the most important feature. Improvements in broadband reliability will be driven by the continued migration of subscribers to FTTP and by improvements in the management of home Wi-Fi connections (see the case study ***Service provider managed mesh Wi-Fi***).

FIGURE 8: RESPONSES TO THE QUESTION: "HOW IMPORTANT ARE THE FOLLOWING FEATURES OF YOUR BROADBAND SERVICE?"




SOURCE: OMDIA DIGITAL CONSUMER INSIGHTS SURVEY 2022

Latency is another area that broadband users will view as increasingly important. This reflects, for example, the growing number of gamers. As part of Omdia's Digital Consumer Insights survey, respondents were asked if they would be willing to pay extra on top of their monthly broadband bill for different services. One option was an "online gaming service where gaming traffic is prioritized to offer best quality," and across all the surveyed countries 48% of respondents stated they would be prepared to pay more for such an offering.

### KEY DEMAND-SIDE TAKEAWAYS

- End-user demands have grown considerably in recent years. This is partly due to the emergence of new applications such as videoconferencing. It also reflects continuing traffic growth because of more online video, more file downloads, more simultaneous usage by different household members, and the growing number of connected devices.
- Though broadband speeds are clearly fundamental, other performance attributes such as reliability and latency are becoming more important. This, for example, is demonstrated by the results of consumer surveys, which indicate that broadband reliability is a key concern for many users.
- With the number of users and business volumes for new kinds of applications growing significantly, requirements for network capacity, bandwidth, latency, storage, computing, intelligence, and security are increasing.
- Fiber is best placed to meet these continually changing demands and provides a long runway for continued performance improvements, for example, with GPON, XGS-PON, and beyond. Operators in many markets are now moving to deploy XGS-PON and the increased speeds and capacity it can provide.

# BROADBAND SUPPLY

### THE NEXT-GENERATION BROADBAND GENERATION ROADMAP

The next-generation broadband roadmap focuses on categorizing broadband across six dimensions: ultra-enhanced speeds, greater intelligence, ultra-reliable and consistent, trustworthy and green, enhanced connectivity, and greater sensing capability. *Ultra-enhanced speeds* refers to continual enhancements in speeds across backbone networks, PON access networks, and home Wi-Fi networks. The *greater intelligence* dimension is based on the integration of computing into the network and the level of autonomous operation of the network. *Ultra-reliable and consistent* refers to metrics such as latency, jitter, and packet loss, which will be important as optical networks are extended to, for example, industrial locations. A *trustworthy and green network* is one that is secure, with rapid problem detection and response, and is energy efficient.

*Enhanced connectivity* is focused on the entire all-optical network that is divided into backbone, metro, access, and data center interconnect (DCI) optical networks as well as fiber use for growing numbers of Internet of Things (IoT) connections. Finally, *greater sensing capability* in the network means enabling awareness from the network to its surrounding environment; one application could be early sensing of earthquakes through optical submarine cables.

The specific characteristics of each broadband technology generation across these dimensions are shown in **Table 2**.

TABLE 2: BROADBAND GENERATION NETWORK CHARACTERISTICS

| | BB3 | BB4 | BB5 | BB5.5 | BB6 |
|---|---|---|---|---|---|
| **RESIDENTIAL SPEED** | Up to 30Mbps | Up to 100Mbps | Up to 1Gbps | Up to 10Gbps | Up to 50Gbps* |
| **ENTERPRISE SPEED** | Up to 1Gbps | Up to 10Gbps | Up to 100Gbps | Up to 400–800Gbps | Up to 1.6–3.2Tbps |
| **INTELLIGENCE** | No automation | Partially autonomous (L2) | Conditionally autonomous (L3) | Highly autonomous (L4), fast provisioning times | Fully autonomous |
| **RELIABILITY & LATENCY** | 99.9% / n/a | 99.99% / 10ms | 99.999% / 5ms consistent latency / low jitter | 99.999% / 1ms latency (hard guarantee) / very low jitter | Deterministic reliability / <1ms latency (hard guarantee) / very low jitter |
| **TRUSTWORTHY & GREEN** | n/a | 2× better per bit energy efficient | 5× better per bit energy efficient | 10× better per bit energy efficient, fast problem detection and response (minutes) | 10×-plus better per bit energy efficient, very fast problem detection and response (seconds) |
| **CONNECTIVITY** | Copper to the home | Fiber to the home | Fiber to the room/desk, slicing in Gbps granularity** | Fiber to the machine, fine granular (Mbps level) slices, 10 times IoT connections | Fiber sensors, 10 times more IoT terminals |
| **SENSING CAPABILITY** | n/a | n/a | n/a | Sensing for optimized O&M, application and computing awareness, AI | Fiber sensing for applications, application and computing awareness, AI |

Note: * Speeds listed are speculative given the timeframe, and further work by the WBBA will explore this in more detail in future reports. ** Managed mesh Wi-Fi also included.

Further information:
https://worldbroadbandassociation.com/wp-content/uploads/2022/09/Next-Generation-Broadband-Roadmap-World-Broadband-Association-White-Paper.pdf
https://www.etsi.org/images/files/ETSIWhitePapers/etsi_wp_41_FSG_ed1.pdf
https://www.etsi.org/deliver/etsi_gr/F5G/001_099/001/01.01.01_60/gr_F5G001v010101p.pdf

SOURCE: WORLD BROADBAND ASSOCIATION

It is clear that operators are already moving to generation 5.5 in terms of the ultra-enhanced speed dimension because of the rollout of multigigabit access enabled by XGS-PON-based FTTP. Many operators globally have launched multigigabit access: prominent examples include AT&T in the US and Chorus in New Zealand. In addition there is also early interest in 25G and 50G PON, for example, through commercial trials from different operators.

## THE IMPORTANCE OF THE BROADBAND ROADMAP FOR DIFFERENT STAKEHOLDERS

The next-generation broadband roadmap is important because it can provide useful context for the decision-making process of various stakeholders in the broadband market:

- In the first instance, governments setting targets for broadband speed adoption need to be aware of how quickly speeds can increase. Governments need to be conscious of the fact that PON technology continues to evolve, and investing only in GPON risks subscribers receiving lower speeds and overall performance than elsewhere.

- As well as basic connectivity parameters, governments must also look at the wider benefits of next-generation broadband. This could include assessing the economic benefits of sensing capability applications such as enhanced digital 3D map generation and indoor robot navigation in smart factories.
- Operators need to understand the next-generation broadband roadmap in order to avoid the risk of investing in legacy technologies, including earlier PON generations, since the broadband access landscape is evolving quickly. FTTP overbuild is growing, so there is a risk that competitors will have invested in next-generation PON rollouts.
- It is not enough for operators to only provide high-speed and low-latency networks. It is also necessary to provide a high-quality service for cloud, artificial intelligence (AI), storage, and computing in order to ensure normal business processing, transmission, and good user experience under high network concurrency conditions.
- Application and service providers need to be aware of the potential for rapid evolution in broadband speeds and performance. Designing applications that require higher speeds than are commonly available today is possible given the next-generation broadband technology roadmap.
- The next-generation broadband roadmap is important for device manufacturers that need to understand how quickly access network capabilities will evolve. This will help guide their roadmaps for incorporating connectivity into their devices, for example, in terms of different Wi-Fi generations.
- Enterprises must be aware of the next-generation broadband roadmap. For example, fiber connections could play a very important role in delivering low-latency applications in industrial environments. The security of next-generation broadband connections is also likely to be an important area of interest for enterprises.

# BROADBAND INVESTMENT

## CONSIDERATIONS FOR GOVERNMENTS

In terms of overarching themes related to broadband, governments must consider several perspectives. They must assess how to encourage investment and innovation in the broadband sector and across the wider economy. In addition, governments also need to encourage competition in the broadband market. It is vital to note that there will be no one-size-fits-all optimal approach for governments in different countries. In some circumstances and countries, it might make sense to have a single broadband access network with competition between multiple retail service providers. Elsewhere, overlapping fixed broadband access networks may be economically viable, so the focus may be on competition between these different infrastructures.

### POLICY AND REGULATION

Government-driven policy and regulation have an important role to play in shaping broadband market investment that can then lead to benefits for citizens. One function of policy and regulation is to smooth the path for investment in next-generation broadband networks. An example of this is how in certain markets such as Spain, Portugal, and the UK, regulated access to incumbent ducts and poles has helped enable FTTP rollouts from alternative network operators (altnets). Government policy also needs to ensure that needless barriers to more rapid broadband network rollout, such as cumbersome permissions processes when deploying FTTP, are removed. Furthermore, governments need to keep abreast of how consumer broadband usage is changing, for example, in terms of speed take-up and application usage. This can then help governments formulate policies such as broadband universal service obligations, which may require modifications over time.

Governments also have an important role to play in the evolution of broadband through the setting of targets and the development of broadband plans. In this way governments can influence where and how investment is directed into broadband. Such plans and objectives can look beyond the access network and so, for example, could seek to enhance the backbone network (see the case study ***Fiber backbone infrastructure deployment in The Gambia***) and establish new international connectivity nodes. In addition, governments can set objectives

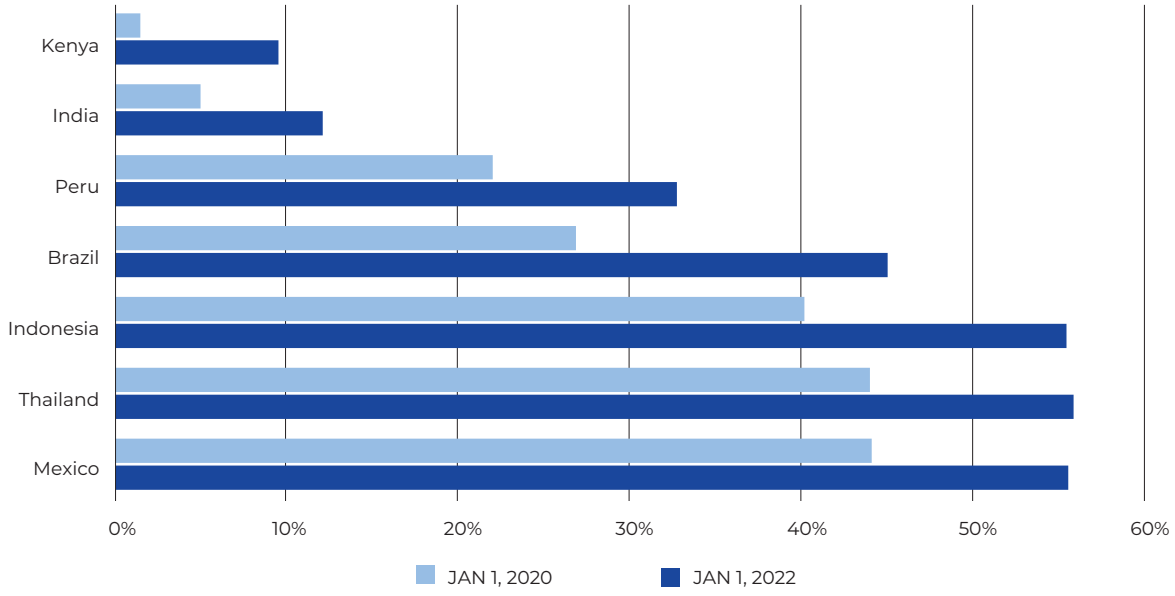
that direct investment into new areas such as the development of VR hardware, which in turn can help shape the future evolution of broadband demand. Some government plans also set targets for the take-up of different broadband speeds. One example of this is the target from the Chinese Ministry of Industry and Information Technology and Ministry of Housing and Urban-Rural Development that by the year 2025 there will be 60 million gigabit broadband subscriptions, an objective that has already been met.

## GOVERNMENT FUNDING: SUPPLY-SIDE INITIATIVES

A further area of consideration is government funding for broadband network rollout. In the first instance, government funding may not always be required. The government can allow private actors to earn a reasonable return on investments in those projects where they accept all the risks. When it is decided that some form of government funding is required, one option for governments is to develop public-private partnerships, which could take a number of different forms such as build–operate–transfer and build–operate–own. One specific kind of public-private partnership is the public-private community partnership. In such partnerships one of the partners involved is the local community, and there is an emphasis on the need for local participation and local development. Consideration of the geographical areas where government could provide funding for broadband rollout is also important. For example, many initiatives in developed markets are looking to increase FTTP coverage to near 100% of the country's premises by rolling out in more rural areas. Without such government funding there is a risk of in-country digital divides.

Governments must also keep abreast of developments in broadband network rollout in peer countries. For example, governments in emerging markets need to be aware that in some peer countries FTTP coverage is already high, so more urgency may need to be placed on broadband network rollout. Omdia's Fiber Development Index tracks FTTP coverage levels across multiple markets and clearly demonstrates the impressive progress achieved in some emerging markets. In Kenya, FTTP coverage increased from 2% of the country's total premises at the start of 2020 to 10% at the start of 2022. In many countries in South-Eastern Asia, such as Thailand and Indonesia, strong progress has also been made in increasing FTTP coverage. This is also the case in other regions such as Latin America, and for example, in Mexico FTTP coverage of total premises stood at 56% at the start of 2022 compared with 44% at the start of 2020.

FIGURE 9: SELECTED COUNTRIES, FTTP COVERAGE OF TOTAL PREMISES, JANUARY 1, 2020 AND JANUARY 1, 2022




SOURCE: OMDIA, FIBER DEVELOPMENT INDEX

### GOVERNMENT FUNDING: IMPACT ON BROADBAND DEMAND

If governments provide funding for improving broadband coverage and delivering better-quality broadband, this itself is likely to result in an uptick in broadband penetration. For example, if uncapped and high-speed broadband becomes available, households that had previously relied only on smartphone mobile data plans might be tempted to subscribe to fixed broadband. Governments themselves might also be important users of broadband and so, for example, funds could be directed to improving connectivity in educational establishments. Chile is one example of a market where government intervention has helped drive the broadband market (see the case study ***Chile: Successful broadband development***).

There is growing awareness that in some circumstances government funding might be required to drive the demand for broadband and the adoption of next-generation access technologies. This, for example, could be achieved through government subsidy programs that reduce the cost of retail broadband packages and, sometimes, connected devices such as laptops. In Europe, for example, there are examples of schemes to subsidize retail broadband plans in Italy and Greece. In the US, the Affordable Connectivity Program provides lower-income households with discounts of up to $30 on internet service including fixed broadband access. For those households that are eligible there are discounts of up to $100 for the purchase of laptops, desktops, or tablets. The scheme has proved very popular, and as of mid-March 2023 more than 16.75 million households were benefiting from it, which has helped drive an increase in fixed broadband net additions across the US market.

### DRIVING CONSUMER AWARENESS OF BROADBAND

Governments must also help drive consumer awareness of broadband. One example of how this could be achieved is to encourage consumers to use speed tests to understand broadband performance and quality. Speed tests could be made available on regulators' websites, for instance. Governments can ensure there is regular reporting and testing of the actual performance of broadband connections. Furthermore, governments can put in place broadband advertising standards to ensure operators market the speeds they are able to offer in the real world rather than theoretical maximum speeds.

## CONSIDERATIONS FOR INVESTORS

Investors need to be aware of the very long asset life of fiber networks. In many cases, investment in fiber networks is well suited to investors that look for long-term investments, the classic example being the Ontario Teachers Pension Plan. Long-term investors should not be unduly affected by shorter-term macroeconomic trends that have only limited consequences on the underlying attractiveness of investing in assets such as fiber broadband networks. Investors in FTTP networks also need to understand the high upfront costs of rolling out the fiber network and that subsequent investments, for example, to upgrade to the latest PON generation, will be much smaller.

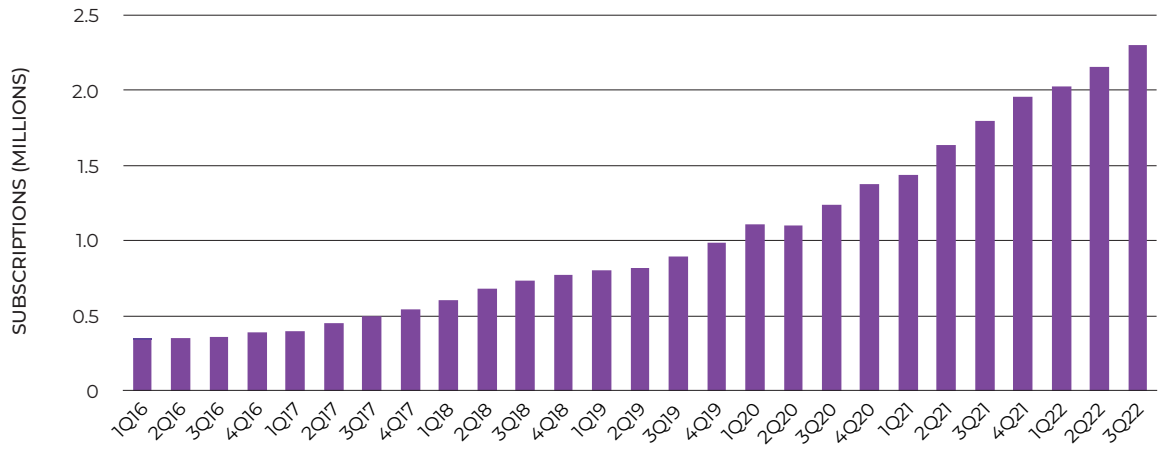
A further area that broadband investors need to be aware of is how to reduce the deployment risks that are associated with the very high upfront costs of rolling out networks. There are various ways in which deployment risks can be reduced, and one such area is around demand aggregation. This means that the network will only be deployed once a certain percentage of premises have made a commitment to subscribe to the broadband service. For wholesale-only open access network providers, one way of reducing risk is to secure the commitment of an important internet service provider (ISP) as an anchor tenant to help drive subscriptions take-up on the network.

Investors interested in achieving a return on their investment in fixed broadband networks consider metrics such as net present value and payback period derived from their business modeling and planning. Investors also need to take care to understand the fundamental variables behind the business case for fixed broadband network rollouts. For example, for FTTP rollouts an understanding is required of costs per premises passed and how this might change over time as coverage extends to less dense geotypes or as an operator gains more experience in the best practice for deploying fiber. In addition, revenue metrics used in broadband network

rollout plans must be realistic and, for example, must take due account of risks such as overbuild from other operators.

Investors need to be aware of the overall environment for investment in broadband networks globally and where the opportunities lie. It is clear that investment in broadband networks is currently substantial. There is considerable interest from private entities in rolling out FTTP in emerging markets. In such markets FTTP costs per home passed are low, and consumer and enterprise willingness to pay for uncapped broadband is good. Consumer perceptions of the value of broadband have grown as a result of lockdowns during the COVID-19 pandemic. In addition, the pandemic also highlighted the importance of broadband for home working, which can be particularly important in lower-income countries that may lack adequate transport infrastructure. As a result, there has been an acceleration in fixed broadband net additions in many emerging markets since the pandemic. Nepal is one good example of this.

FIGURE 10: NEPAL, TOTAL FIXED BROADBAND SUBSCRIPTIONS, 1Q16–3Q22




SOURCE: OMDIA

The strong potential for fixed broadband in emerging markets is reflected by the fact that subscription take-up rates for FTTP rollouts in emerging markets can often be strong. For example, in Kenya Safaricom's FTTP subscription take-up rate stood at 55% at the end of 3Q22, a figure that puts the operator among the best performers in the world. This helps to demonstrate that the business case for FTTP rollout in emerging markets is generally good, so investors should be looking at such projects.

At the same time it is evident that there is huge interest from the investment community in altnet FTTP in many developed markets. This again represents a promising opportunity, because in many cases the market will be able to support overlapping fiber infrastructures.

# CONSIDERATIONS FOR OPERATORS

Operators rolling out new broadband networks must assess all the different aspects of the business case in a realistic fashion. For example, if the broadband market is competitive, rolling out FTTP might not deliver higher retail ARPUs even though subscribers will receive substantially higher speeds. Cost elements need to be considered when investing in new broadband networks, and this could include potential opex savings from running FTTP networks.

Another area that operators must consider when investing in new broadband networks is the business model that they intend to use. Some players will prefer to run a closed and vertically integrated network; others may prefer to offer both retail and wholesale access. Though wholesale access offers lower ARPUs, it could be a way to increase overall network utilization and discourage potential competitors from overbuilding the operator's network. Alternatively,

operators could consider a wholesale-only model that allows different players to focus on their own specialisms. Structural separation of operator network divisions could also result in higher business valuations.

Operators considering investing in broadband networks must consider whether they are in a position to conduct the rollout themselves. This could reflect concerns about an operator financing a rollout itself because of the significant capex requirements. In addition, partnering with another entity for fiber rollout by creating a fiber carveout could be important in creating a neutral entity and encouraging access seekers to take wholesale access on the network. This could then improve the overall business case for the broadband network rollout.

Operators must follow the progress of their peers in broadband network rollout and subsequent subscriber adoption of next-generation access. For example, developed-market incumbents need to be aware that their peers are now firmly behind FTTP and are rolling out at scale. Moreover, in many cases good initial take-up rates are breeding confidence for further rollouts.

# CASE STUDY SUMMARIES

World Broadband Association (WBBA) collects broadband success stories (case studies) from its members all over the world in order to gain insights from empirical experience. However, because regulatory policies, the economic environment, and user demands vary in regions, some cases may not be fully applicable to all regions. The WBBA advises readers to carefully evaluate conditions in their target regions before making investments.

## BEIJING ALL-OPTICAL SMART CITY

Beijing has set the goal of "building a global benchmark city for the digital economy," building the "six highlands" (innovation, transition, data sovereignty, governance, synergy, and incubation), and leading the development of the global digital economy with the Beijing model acting as a benchmark for other cities to follow. These goals have set the guidelines for the network construction of the "Beijing all-optical smart city," enabling the digital economy.

## BUILDING "FIRST TIME RIGHT" QUALITY IN FTTX NETWORKS

Governments should actively support the deployment of broadband fiber because it plays a crucial role in stimulating economic growth and fostering innovation. As part of its industry-leading full-fiber program for the UK, Openreach has committed to delivering 25 million homes passed with FTTP by the mid-to-late 2020s. Following a competitive tender process, Openreach awarded EXFO a contract to supply Remote Fiber Testing and Monitoring (RFTM), a centralized cloud-native solution featuring optical test heads and switches that enables automated and on-demand testing of 100% of fibers during network buildout.

## CHILE: SUCCESSFUL BROADBAND DEPLOYMENT

The Chilean government has implemented an ambitious national digital development plan to bring technology and telecommunications to the center stage of the country's public agenda. The general objectives are to boost economic growth, reduce the digital divide, and promote social inclusion by investing not only in high-speed broadband but also in ICT skills that will transform the nation into a true digital economy. Chile has achieved great results in terms of broadband deployment and speed take-up and fixed broadband development practice.

## ENABLING BROADBAND AT THE EDGE CLOUD

Cloud-network integration is a core feature of digital information infrastructure. The edge cloud is one of the main development directions of broadband network services in the future. The edge cloud can improve network performance in terms of network architecture and network traffic. China Telecom's enabling of broadband at the edge cloud will be introduced as one of the successful case studies in this white paper.

### E-SURFING VIDEO NETWORKING

The Chinese government is promoting a “digital China” strategy that regards the digital home, smart communities, digital villages, and digital government as the most important sectors to develop. In order to provide a clearer understanding of the development of broadband-related industries in China, including investment direction, technological innovation, development trends and investment returns, we include China Telecom’s successful e-Surfing video networking service as one of our case studies.

### FIBER BACKBONE INFRASTRUCTURE DEPLOYMENT IN THE GAMBIA

The advancement of social, economic, and personal development depends on broadband connectivity. The ICT sector is one of the key drivers of sustainable economic growth, inclusivity, and development in The Gambia, because such broadband connectivity is one of the priorities of the government. Gamtel has developed several projects for the rollout of digital infrastructure, including deployment of a fiber backbone infrastructure in The Gambia, which offers a case study in investment opportunities and best practices.

### HONG KONG AND MACAO, DRIVING GREATER ADOPTION OF FIBER SERVICES IN ADVANCED TELECOM MARKETS

Hong Kong and Macao are advanced markets in terms of fixed network development and adoption, characterized by low levels of connection growth and strong fiber penetration. The development of fixed broadband networks in Hong Kong and Macao is predominantly driven by market forces; however, the government of Hong Kong has sought to intervene by subsidizing the deployment of fiber networks in remote locations with a view to reducing digital inequality and helping boost the growth of the digital economy. Ookla is driving greater adoption of fiber services in these advanced telecom markets.

### SERVICE PROVIDER MANAGED MESH WI-FI

A broadband service is only as good as the weakest point, which is usually the last few meters, namely the in-home Wi-Fi network. Nokia’s service provider managed mesh Wi-Fi provides the tools to manage both legacy and new Wi-Fi assets and provide a premium broadband service all the way to the connected device.

# CASE STUDIES

### BEIJING ALL-OPTICAL SMART CITY

*AUTHORS: CREST ZOU AND JORGE BONIFACIO – HUAWEI*

#### INTRODUCTION TO THE CASE STUDY

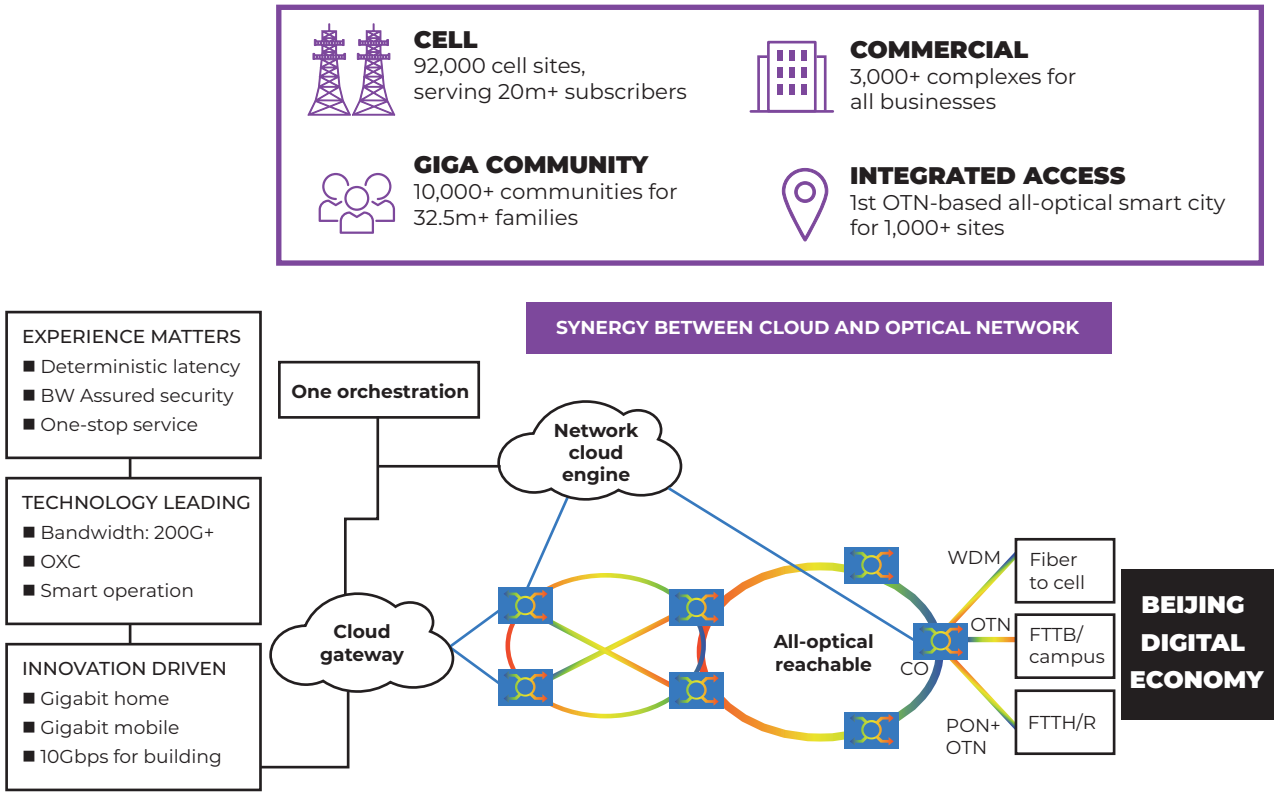
China’s national “14th Five-Year Plan” emphasizes the need to accelerate the construction of new infrastructure, promote and upgrade gigabit optical networks, increase the construction of 5G networks and gigabit optical networks, and enrich the ways in which such infrastructure can be used. Based on this, the Chinese Ministry of Industry and Information Technology (MIIT) launched an initiative to deploy gigabit optical-fiber networks in a comprehensive manner and accelerate the extension of optical transport network (OTN) equipment to integrated access nodes and user-side devices.

At the same time, Beijing has set the goal of “building a global benchmark city for the digital economy,” building the “six highlands” (innovation, transition, data sovereignty, governance, synergy, and incubation), and leading the development of the global digital economy with the Beijing model acting as a benchmark for other cities to follow. These goals have set the guidelines for the “Beijing all-optical smart city” benchmark project to enable Beijing's digital economy.

## PROJECT SOLUTION AND INNOVATIONS

Within nearly one year of deployment, the project team has built the world's first all-optical metropolitan area network (MAN) with more than 1,000 OTN nodes to serve more than 3,000 buildings, 10,000-plus communities, 3,000,000-plus residential users, and more than 90,000 wireless sites (to support more than 20 million mobile subscribers) with high-quality connection services, whether for enterprise or residential customers.

FIGURE 11: STRUCTURE OF THE BEIJING ALL-OPTICAL NETWORK




SOURCE: HUAWEI

Beijing is also the most important exchange hub in China and is the core hub for government and corporate customers with international leased-line services. The effective interworking, cooperation, and synergy between the metro and backbone network means it can offer any service and respond to any customer under any scenario.

This project has the following four aspects of technical innovation:

- **Simplified architecture:** there are only two layers, backbone and metro, which are OTN based. This enables latency of 0.1ms in the core area, 0.25ms within the central urban area, 0.5ms within the core area to the secondary urban center, and 2ms within the entire area.
- **Ultra-high bandwidth:** the project has deployed 200G services in both urban and suburban areas to meet the ultra-high-bandwidth transmission requirements of various users and to address energy consumption challenges.
- **Flexible grooming:** 25 all-optical switching nodes are deployed in core urban areas. Optical and photonics integration technology is used to support the high granularity and high SLA service requirements based on virtual container optical transport networks (VC-OTN).
- **Intelligent management and control:** the project team introduced new technologies such as AI and big data and deployed an intelligent optical management, control, and analysis (MC&A) platform to fully meet the differentiated service requirements of government and corporate customers.

The project has built an all-optical MAN as a solid foundation for various networks and services, including 5G, home broadband, data center interconnect, and leased-line services for corporate customers. Three typical applications for this benchmark project are described below.

***PREMIUM CONNECTION WITH ULTRA-HIGH BANDWIDTH***
Over-the-top (OTT) service provider ByteDance's headquarters has a large number of live broadcasts, for example, during the Spring Festival Gala, Red Envelope emergency assurance, and multiscenario services such as Lark, VR interaction, and e-commerce. The headquarter campus also needs dedicated network-level service assurance. The project provided all-optical intelligent network services with 100G bandwidth and 99.999% reliability. In addition, the project provides visible and manageable end-to-end network SLAs, enabling customers to receive a diamond-level service experience.

***ZERO FRAME FREEZING EXPERIENCE FOR ULTRA-HIGH-DEFINITION LIVE VIDEO SERVICES***
Beijing Shangyicheng Culture Group provided the 8K large-screen live broadcast service for the Beijing Winter Olympics 2022. These 8K (UHD) services require video transmission over the network with zero frame freezing and zero packet loss. The overall solution involved "8K live broadcast + premium leased line," directly connecting 16 outdoor screens in Beijing city. This provided very-high-quality UHD live broadcasting throughout the event, which was widely recognized and praised by audiences and users.

***PREMIUM LEASED LINE WITH ULTRA-LOW LATENCY AND ULTRA-RELIABLE SLA SERVICES FOR CORPORATE CUSTOMERS***
China Construction Bank (CCB) has headquarters with networking requirements for interconnecting with branches across the country and to support important online services such as portals, online banking apps, and commemorative coin issuing. This project has provided more than 300 premium leased lines for the CCB head office and Beijing branch, providing services such as connections with guaranteed quality of service (QoS), digital encryption, and on-demand bandwidth.

## ECONOMIC, BUSINESS, AND SOCIAL BENEFITS

The Beijing all-optical smart city benchmark project has been widely recognized, not only for the improved level of information infrastructure capability and for setting up a model for an all-optical smart city but also for the economic, industrial, and social benefits to Beijing.

***ECONOMIC BENEFITS***
This benchmark project has offered more than 150,100 gigabit leased lines, including Tencent, Baidu, and Alibaba, helping customers for the digital transformation, with direct service revenue of CNY6bn and indirect annual revenue of CNY18bn.

***BUSINESS BENEFITS***
This benchmark project also focuses on intraregional and cross-regional collaborative deployment of computing power (computing nodes cover all types of data centers in the city) and network connections. The objective is to actively carry out nationwide innovative projects such as the "East Data, West Storage and Computing" program in order to drive the digitalization of government, finance, and all industry sectors.

***SOCIAL BENEFITS***
This benchmark project fully serves Beijing's digital government, digital healthcare system, and events such as the 70th anniversary of the People's Republic of China and the 100th anniversary of the Communist Party of China.

## SUMMARY AND PROSPECT

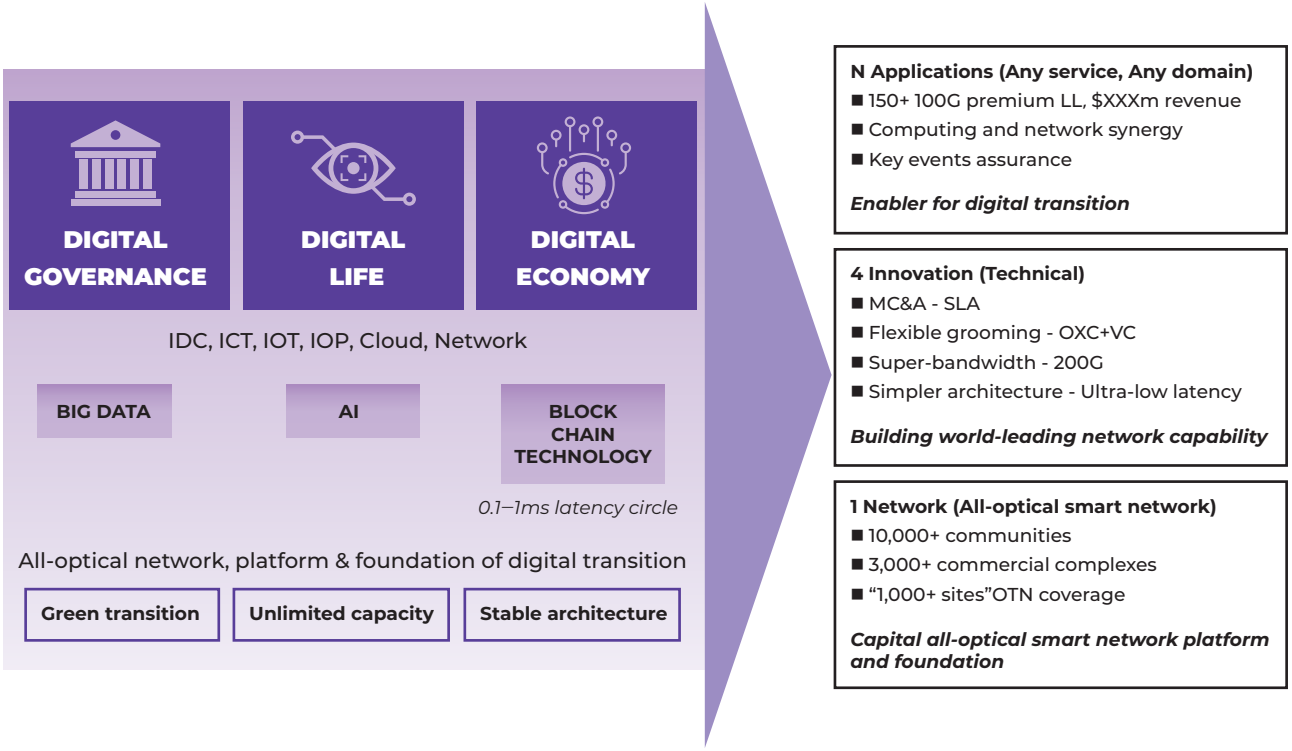
The achievements of the "Beijing all-optical smart city" benchmark project have been widely recognized in the industry and society as demonstrated by the following three awards:

- "All-optical Smart City Excellent Benchmark Award" by the MIIT in 2021
- "Enablement Technology Award" by World Smart City in 2011
- "Top Ten Solutions" award at the Digital China Summit jointly organized by the National Development and Reform Commission, Ministry of Science and Technology, and MIIT in 2022.

Based on this benchmark project, a "1+4+N" system was created, which can be promoted nationwide and globally for better life and a sustainable society:

- 1: one all-optical MAN (more than 1,000 OTN sites) as the foundation
- 4: four technical innovations (simple architecture, flexible grooming, super-bandwidth, and intelligent MC&A) to provide the network capability
- N: Many industry sectors can enjoy a high-quality service experience and the economic and societal benefits based on the 150+ 100G premium leased lines from the above one network and four innovations in order to facilitate digital transformation.

FIGURE 12: THE 1+4+N MODEL




SOURCE: HUAWEI

## FURTHER INFORMATION

https://finance.sina.cn/2022-09-07/detail-imqqsmrn8167619.d.html (Chinese-language site)

https://www.cnii.com.cn/gxxww/rmydb/202209/t20220913_413546.html (Chinese-language site)

https://finance.sina.com.cn/tech/2021-08-12/doc-ikqciyzm0985803.shtml (Chinese-language site)

https://www.thepaper.cn/newsDetail_forward_19169007 (Chinese-language site)

# BUILDING "FIRST TIME RIGHT" QUALITY IN FTTX NETWORKS

*AUTHOR: PAUL MORRISSEY – EXFO*

## MARKET CONTEXT

Governments should actively support the deployment of broadband fiber because it plays a crucial role in stimulating economic growth and fostering innovation. Expanding fiber broadband infrastructure ensures widespread access to high-speed internet, which not only enhances connectivity but also promotes the development of new businesses, educational opportunities, and digital services. This investment in digital infrastructure paves the way for the creation of jobs, both directly through network construction and indirectly through the growth of technology-driven industries. Furthermore, the increased availability of broadband fiber enables remote work, bridging the urban-rural divide and allowing for a more inclusive workforce. By prioritizing the deployment of broadband fiber, governments can drive digital transformation, enhance global competitiveness, and ensure that their economies are well positioned to thrive in the increasingly digital world.

The UK Gigabit scheme is a government-led initiative that aims to provide access to gigabit-capable broadband to homes and businesses across the UK. The scheme offers funding to ISPs to support the cost of installing new broadband infrastructure, with the goal of ensuring that as many people as possible have access to high-speed internet.

The main benefit of the UK Gigabit scheme is improved internet connectivity, which is essential for accessing many of the services and resources that people rely on in their daily lives. High-speed internet can improve productivity and enable people to work from home more easily, which has become increasingly important since the COVID-19 pandemic. Faster internet also allows for smoother videoconferencing, online learning, and streaming services.

In addition to the benefits of improved internet connectivity, the UK Gigabit scheme can also help to reduce the digital divide by providing access to high-speed internet in areas that may have previously been underserved. This can help to improve social and economic outcomes for individuals and communities, because access to the internet is increasingly seen as a basic necessity.

However, there are also barriers to the implementation of the UK Gigabit scheme. One major barrier is the cost of installing new broadband infrastructure, which can be prohibitively expensive for smaller ISPs or those operating in rural areas. Additionally, the physical logistics of laying new cables and other infrastructure can be complex and time consuming.

Another challenge is the issue of internet access inequality, which means that even with the gigabit scheme in place, some people may still not have access to high-speed internet because of factors such as socioeconomic status or geographic location.

Despite these challenges, the UK Gigabit scheme has the potential to provide significant benefits to UK citizens by improving internet connectivity and reducing the digital divide. The success of the scheme will depend on the ability of ISPs to effectively implement new broadband infrastructure and the government's ability to address barriers to access and equality.

Under the UK Gigabit scheme, EXFO has partnered with more than 20 altnet operators, including City Fiber, Gigabit Networks Limited, Hyperoptic Limited, KCOM, and Netomnia, enabling it to provide various implementations across the UK broadband landscape.

## INTRODUCTION TO THE CASE STUDY

As part of its industry-leading full-fiber program for the UK, Openreach has committed to delivering 25 million homes passed with fiber to the premises by the mid-to-late 2020s. As of early 2021, after five years of work, Openreach had reached 4.5 million homes passed. It wanted to achieve the next 20 million homes passed in the same amount of time, a monumental task. Key to the financial success of Openreach's initiative is delivering live service and generating

revenue at the same time as deployment ramps up. This requires flawless execution with extremely low defect rates to ensure that customer activations go right the first time.

To achieve its goals, Openreach turned to thousands of contractors to build out and turn up the full fiber network. However, in moving to a contractor model, Openreach lost visibility on progress in deploying the network and had to rely on others for quality control. As a result of this new distributed workforce, initial rates of defects climbed, leading to high failure rates during customer activations. These required significant rework at additional cost to rectify. This in turn delayed network monetization, which put at risk Openreach's goal of generating revenue at the same time as it deploys and thus jeopardized the overall economics of the initiative.

Following a competitive tender process, Openreach awarded EXFO a contract to supply RFTM, a centralized cloud-native solution featuring optical test heads and switches that enables automated and on-demand testing of 100% of fibers during network buildout.

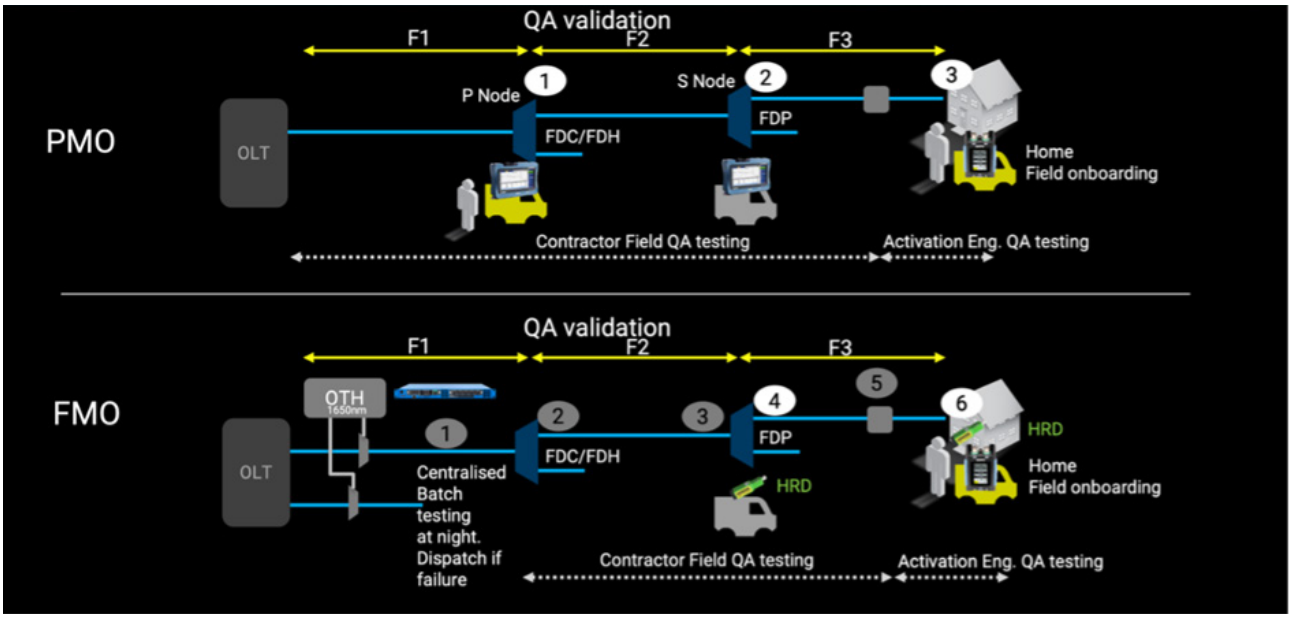
## PROJECT SOLUTION AND INNOVATIONS

Automated testing can take place during off hours, such as overnight or over a weekend, with the results of tests available the next day, with impairments clearly flagged and located to within a meter or two. Optical test heads can easily be redeployed to new sectors as old sectors are fully built out and activated.

RFTM can be used in conjunction with EXFO's suite of portable testing devices to provide additional test capabilities. In addition, a smartphone app in conjunction with a low-cost high-reflectance demarcation (HRD) device can be used to trigger ad hoc tests that execute within seconds, making self-supported customer installs possible.

**Figure 13** describes the present mode of operations (PMO) at Openreach prior to the deployment of RFTM. This then became the future mode of operations (FMO).

FIGURE 13: MODES OF OPERATION BEFORE AND AFTER THE DEPLOYMENT OF RFTM




SOURCE: EXFO

Under the PMO, only a portion of fibers were being tested at the F1 and F2 splitters by technicians using portable test devices. Portable devices could have tested 100% of fibers, but in practice only a subset were tested because of cost and delay concerns. As a result, defects as a percentage of overall fibers reached double-digit levels. During customer activation, there was a nonnegligible chance of a defect, whether that was a fiber impairment because of a bad splice or a fiber having been bent too much during installation. The inability to activate a customer on

the installation date led to poor customer satisfaction. In addition, subsequent truck rolls were required to locate the source of the impairment, repair it, and then retest it from the customer premises.

Under the FMO, leveraging its use of RFTM's application programming interfaces (APIs), Openreach was able to enable automated tests of all fibers coming out of the OLTs in batch mode. This is typically done at night. Failed tests are flagged, and technicians are dispatched to repair as required. Automated and on-demand testing then takes place at the fiber distribution cabinet (F2 splitter) and the fiber distribution panel (F3 splitter), again covering 100% of the fibers. An Openreach technician using a smartphone app and an HRD device can trigger on-demand tests from any point after the F1 splitter, including the customer premises during activation. These take as little as five seconds to execute and deliver results immediately.

Since tests are executed so quickly, the test head is liberated quickly as well, enabling it to perform a high volume of tests during a typical workday. As a result of this high test velocity, under the FMO, technicians are able to test the network as they build it out, knowing that there is essentially no downtime required for testing. They can test 100% of the fibers, which leads to extremely low levels of initial quality defects.

The deployment model for RFTM is extremely flexible. As areas are built out, test heads and optical switches are easily moved to where they are needed next.

## ECONOMIC AND BUSINESS BENEFITS

Thanks to proactive testing of 100% of fibers with RFTM, Openreach expects to achieve defect levels of less than 1% and reduce the need for costly truck rolls as it meets its target of 75,000 homes passed per week. This pace is up significantly, to nearly twice the pace prior to adoption of RFTM.

Thanks to a mix of automation and fast execution for on-demand test requests, it is actually feasible to test 100% of fibers at a lower overall cost per test than the previous approach of manually testing a subset of fibers. However, what really drives the economics of the solution is the reduction in opex necessary to go back and fix fiber defects. RFTM helps to significantly reduce the need for expensive dispatches of trucks and technicians.

The ability to trigger a test with a smart app and HRD device enables activation by customers themselves. This self-activation is an extremely cost-effective alternative to turning up service and monetizing connections.

RFTM's centralized reporting capability enables Openreach to view build progress in real time. Test data is aggregated and correlated for presentation in reports.

Openreach also intends to use RFTM for its ongoing fiber-monitoring needs. During the initial characterization of a fiber, a "birth certificate" for the fiber is generated automatically. This birth certificate is then referred to subsequently following performance monitoring tests. Where there is a significant deviation from expected performance, an alert for proactive maintenance is generated. RFTM can also be used for real-time performance monitoring of fiber bundles to detect fiber breaks or impairments due to Mother Nature, small animals, or construction among other factors.

As a result of adopting RFTM, Openreach can more confidently deliver "right first time" fiber installations, measure its progress in real time, and make projections about future results. The solution achieved a positive return on investment and payback within a few months of deployment.

In addition, the new mode of operations that is enabled by EXFO's RFTM solution, the FMO, enables Openreach to be more effective in the way that it deploys field personnel. This is particularly useful in a tight labor market where there is a premium on skilled personnel and there are pressures to contain costs.

# CHILE: SUCCESSFUL BROADBAND DEVELOPMENT

*AUTHORS: CREST ZOU AND JORGE BONIFACIO – HUAWEI; KEVIN HASLEY – OOKLA*

## INTRODUCTION TO THE CASE STUDY

The Chilean government has implemented an ambitious national digital development plan to bring technology and telecommunications to the center stage of the country's public agenda. The general objectives are to boost economic growth, reduce the digital divide, and promote social inclusion by investing not only in high-speed broadband but also in ICT skills that will transform the nation into a true digital economy. Chile is nowadays a technological leader in the region. Its prosperous economy and the overall state of its institutions, policies, and productivity make Chile one of the most competitive countries in the world and the most competitive in Latin America.

## PROJECT SOLUTION AND INNOVATIONS

Since the late 1990s, Chile has recognized the need to promote a national digital development plan as part of policies to boost economic growth and promote social inclusion. Some of the different initiatives promoted at national level in this regard are "Chile towards the Information Society," "Digital Agenda 2004–2006," "Digital Strategy 2007–2012," "Agenda Digital Imaging Chile," and most recently "Digital Agenda 2020."

The implementation of these initiatives enabled the creation of several public-private partnerships that supplement the efforts to finance investment projects aimed at improving and increasing the capacity for data transmission at international level, boosting national fiber-optic coverage, and reducing end users' costs. The results achieved highlight the important role that governments can have in promoting a structured and effective evolution to a digital society.

The following most relevant initiatives highlight the means used to promote national broadband development.

### *CONNECTIVITY FOR EDUCATION*

This project began in 2011 and within a year had provided around 8,800 public and municipal schools with subsidized broadband access. This represented 96% of the country's school enrollment, equivalent to 3.1 million students.

### *"TODO CHILE COMUNICADO" PROJECT*

This project was launched in 2012 and has so far been the largest initiative for digital connectivity in Chile. The project provided 3G mobile broadband to 1,474 rural locations, benefiting more than 3 million Chileans. This project represents a total investment of $45m, 65% of which ($29m) corresponds to subsidies and public investment, financed in equal parts by the FDT and the regions.

To this is added the allocation of radio spectrum for 4G services, in the 2.6GHz band, which includes mandatory mobile broadband service for another 543 isolated locations. In addition, subsidies will enable the incorporation of 360 locations into ongoing mobile phone and data expansion projects. All this will allow the expansion of connectivity to 98% of the country's population.

### *FIBER OPTIC AUSTRAL (FOA)*

The FOA is a multimillion-dollar initiative launched in 2015 to benefit the areas of Aysén, Puerto Montt, and Punta Arenas, seeking to interconnect the Lakes region with the Magallanes and Antarctica through a 3,000km cable deployment (one submarine and three terrestrial). The project involves an investment of close to $78.5m. The project includes the installation and operation of submarine optical channels and terrestrial optical channels and guarantees open and nondiscriminatory access as well as the provision of infrastructure capacity for the service and exclusive use of public bodies at a preferential rate. This project was successfully concluded in the first quarter of 2022, connecting 536,000 users and serving 19,000 enterprises in the areas covered.

### *NATIONAL OPTICAL FIBER PROJECT (FON)*

The FON project is a backbone network that originates in regional capitals and reaches out to communal capitals (municipalities). The project involves the deployment of 10,000km of fiber-optic lines across the country. It is structured around six macro zones that cover 13 of the 16 regions of the country, including 202 nodes located in 186 municipalities. For this project the state granted a subsidy of $120m. The subsidy is intended to incentivize the industry to participate in bringing access to hard-to-reach areas. In October 2019, SUBTEL opened a tender for the project, which was awarded in early 2020.

### *TRANS-PACIFIC CABLE/ASIA–SOUTH AMERICA DIGITAL GATEWAY*

This project was undertaken by the government of Chile and aims at preparing the country to better face the digital revolution and facilitating the installation of data centers that will turn Chile into a digital hub for Latin America. It will connect South America to the Asian continent through the deployment of a 24,000km fiber-optic submarine cable with four potential landing points: Japan, Singapore, China, and South Korea. The $3m feasibility study will be financed by the CAF, an institution with which the Ministry of Transport signed a financing agreement in July 2019. The objective was to start deployment works by the second half of 2021. Investment requirements for the project are estimated at $500–600m.

### *LAST-MILE INVESTMENTS*

The government is also launching some last-mile fiber-optic investment projects in locations where there is limited access. Among these investments is the extension of the ChileGob Wi-Fi program, which includes government-run hotspots that provide free Wi-Fi in underserved areas with a total base investment for the evaluation model of $3–3.5bn.

### *DIGITAL MATRIX PLAN*

Launched in 2018, the Digital Matrix plan aims to accomplish the following:

- Guarantee minimum levels for speed and quality of internet services.
- Reutilize or decommission unused national networks.
- Reduce tariffs for mobile telephony.
- Eliminate tariffs for international roaming with Argentina, Peru, and Brazil.
- Create a unique emergency number (such as 911 in the US).
- Roll out the FON and FOA projects.
- Create the digital roadmap for the Asian–South America Gateway.
- Increase national investment in telecommunications by 30%.
- Implement 5G technology nationwide.
- On the demand side, the Digital Matrix Plan aims to ensure that all public educational establishments have access to the internet and are interconnected. Data from the regulator indicates that 8,721 educational establishments have already been connected.

## ECONOMIC AND BUSINESS BENEFITS

The initiatives of the government leverage the competition in Chile's fixed-line market. Chilean ISPs are focused on expanding the number of homes passed and migrating to more advanced fiber access. The relatively late launch of 5G networks in the region has enabled operators to focus more heavily on fiber deployment with a view to increasing fixed broadband adoption and also supporting 5G networks. At present, Chile has a combined operator total of 8.5 million FTTP homes passed.

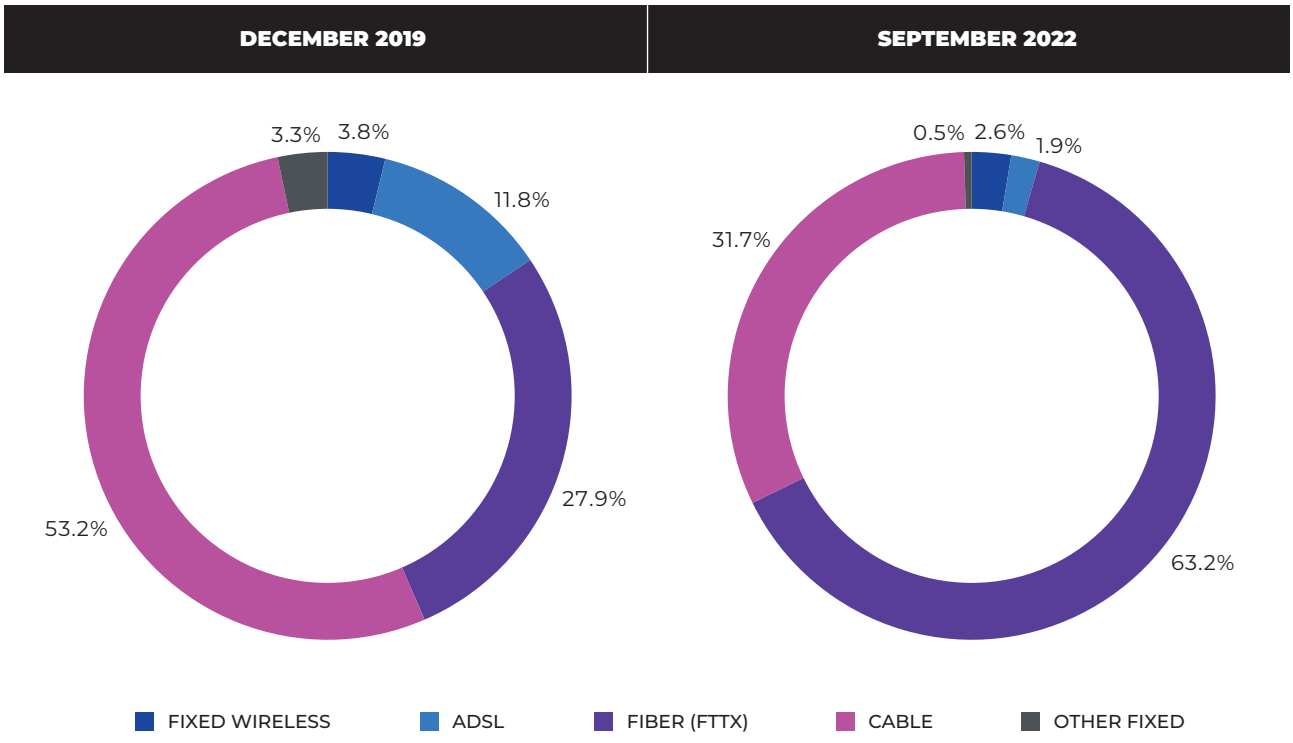
In terms of subscription numbers there has been a strong migration from hybrid fiber–co-axial (HFC) and ADSL to fiber broadband connections, bringing a major and rapid transformation of the Chilean fixed broadband market. COVID-19 pandemic lockdowns in the country forced people to stay at home, and ADSL and HFC connections experienced severe service connectivity issues due to the sudden surge in home broadband traffic. As the new normal has changed the way most companies operate, more and more people are adapting to the work-from-home culture, which further increases the demand for quality home broadband connectivity. Emerging high-bandwidth applications such as 4K video streaming, VR gaming, videoconferencing, and live streaming also play a huge role in the evolution of home broadband in Chile.

With the increasing demand for high-speed internet, operators in Chile are offering higher-bandwidth packages. At present, more than 80% of fixed broadband packages offered in Chile are above 500Mbps, and more than 30% of available packages have 1Gbps speeds. Subscriptions to high-bandwidth packages are increasing, and more than 80% of subscribers in Chile took speeds of at least 100Mbps in 2022. The number of subscribers for 1Gbps packages is also increasing rapidly.

Chile has been a regional leader in fixed-line performance in Latin America since 2016, and since then it has continually widened its advantage over its regional peers. Over the past three years, Chile has seen median download speed increase from 50.23Mbps in 1H20 to 205.96Mbps in 2H22. This makes Chile a clear outlier among Latin American markets because it has closed the performance gap to the top-performing fixed-line markets worldwide during 2022.

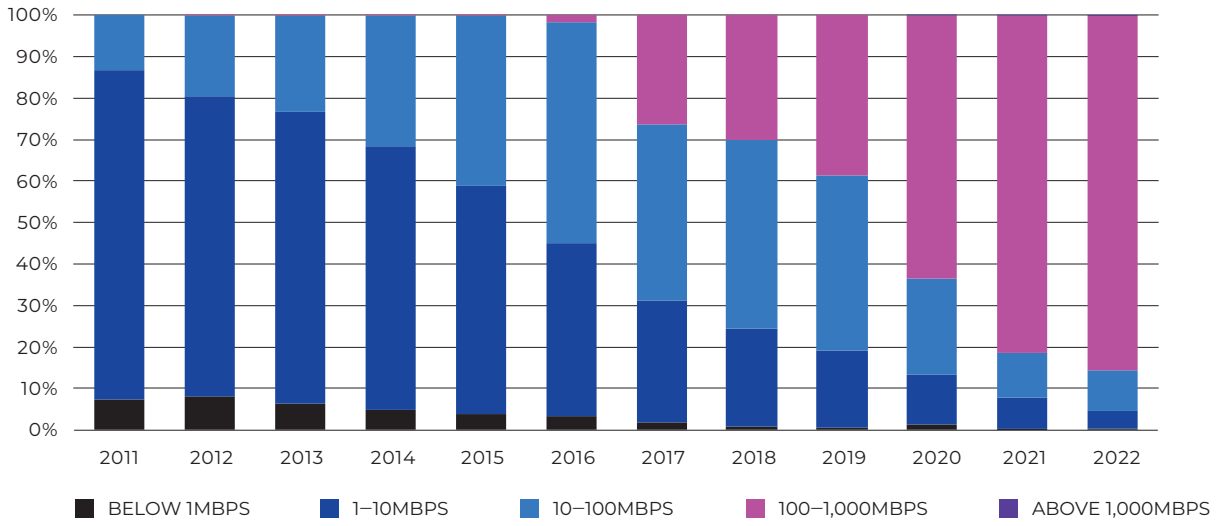
The creation of a national infrastructure plan, supported by strong commitment and financial incentives from the government of Chile, has enabled the creation of a very comprehensive broadband plan aimed at helping to develop the country's economy and placing Chile as one of the most connected nations in the world. Chile is a good illustration of the positive role that governments can have in propelling the broadband development of a country in close cooperation with private investment.

FIGURE 14: CHILE, FIXED BROADBAND CONNECTIONS BY TECHNOLOGY, DECEMBER 2019 AND SEPTEMBER 2022




SOURCE: SUBTEL

FIGURE 15: CHILE, FIXED BROADBAND SUBSCRIPTIONS BY DOWNLOAD SPEED, 2011–22




SOURCE: SUBTEL

## ENABLING BROADBAND AT THE EDGE CLOUD

*AUTHORS: LUYING SHANGGUAN, ZHONGHUA CHEN, AND JIANPING SUN – CHINA TELECOM*

Shanghai is one of the largest city-level communication network and cloud-network integrated service centers in China. Through the service model of "connection + computing power + platform + application" and integrated online and offline services, fixed-line voice, mobile communication, broadband internet access, satellite communication, and full-service comprehensive intelligent information services including internet TV and information applications are provided to end users; the number of online service customers exceeds 25 million.

Cloud broadband is deployed on the edge cloud. Cloud gateways based on general cloud software move the forwarding and control capabilities of the original end-user gateway to the edge data center. Depending on business characteristics, network and terminal capabilities, and the operating environment, non-real-time complex computing and storage originally performed by the end-user terminal can be transferred to the cloud or edge computing node. In addition, cloud and edge collaboration aims to realize all-round collaboration between cloud resources and the edge cloud in terms of infrastructure resources, application platforms, and business services and data.

### INTRODUCTION TO THE CASE STUDY

Cloud broadband access gateways, application gateways, and other traffic-forwarding network elements in the China Telecom edge cloud are deployed in a cloud-based manner.

Edge-based IT services such as cloud network-attached storage (NAS) and cloud monitoring in the e-Surfing Cloud are also delivered. The unified control and orchestration system of the cloud and network capabilities in the province allows for the orchestration and traffic scheduling of user service connections.

The rich service applications and massive processing capabilities in the e-Surfing Cloud are superimposed to enable innovative evolution from "optical broadband" to "cloud-network broadband."

## PROJECT SOLUTION AND INNOVATIONS

The cloud broadband solution includes a traffic-forwarding component (vswitch), a broadband service component (vCPE) that has terminal identification capabilities, DPI probe, L2TP protocol support, and other basic functions. In addition, value-added services such as security scanning are dynamically deployed.

The cloud broadband model offers a number of benefits:

- **In-home equipment cost reduction.** With cloud-based cloud broadband gateways the requirements for home gateways are reduced. The in-home device required for cloud broadband will instead have lower costs. The cost of an IPTV set-top box can also be saved. The cloud broadband model instead allows IPTV functions to be delivered via the subscriber's smart TV.
- **Moving beyond providing only internet access.** In addition to internet access, the cloud broadband model provides differentiated and personalized applications such as security, storage, AI, and faster access times. In a traditional deployment model, cloud services such as China Telecom's Tianyi Cloud Disk are constrained because the uplink speed is limited by bandwidth and the response speed cannot avoid high latency. Through cloud-edge collaboration, the delay from the cloud can be reduced to less than 5ms, the uplink speed of the intelligent hard disk can reach 500Mbps, the interception rate for accessing fraudulent websites can reach 99%, and the access time for opening overseas websites can be shortened to one-fifth of the previous time.
- **High security and levels of control.** Relying on the e-Surfing Cloud 4.0 developed by China Telecom, the cloud broadband model uses physical isolation of the edge cloud to enable higher security and controllability. With the cloud broadband model, users can customize and configure at any time features such as the speed of cloud broadband and access to applications. The traditional network can be automatically switched to the cloud network in three minutes in order to fulfill a seamless upgrade according to the cloud gateway's instructions. This means 98.9% of users can upgrade to the cloud network without onsite processing by engineers. During the deployment of new applications, only the cloud gateway needs to be intensively upgraded.

## ECONOMIC AND BUSINESS BENEFITS

The benefit to end users is that cloud broadband stores data, applications, and computing power in the cloud. At the same time, functions of the end-user gateway are moved up to edge cloud nodes. When users use cloud services, traffic no longer enters the metro network as happens with traditional broadband. Instead, traffic directly accesses the nearest edge cloud and forms a closed and optimized loop. Because cloud applications are deeply integrated with the broadband access network, the user's online experience is further enhanced. The time required to deploy application services on cloud broadband is only one-third the time required for the traditional method.

Cloud broadband applies the "cloud first and then network" architecture, introduces edge cloud control nodes, and uses virtualization to build cloud-network capabilities, which greatly simplifies the deployment of value-added applications based on users and traffic and provides rapid and subsequent broadband enrichment.

China Telecom has a natural advantage over internet companies thanks to its abundant edge node resources. Because the edge cloud is strengthened, applications with high-bandwidth and low-latency requirements will have an improved user perception.

China Telecom's fiber access network has entered the gigabit era, but performance is limited by long end-to-end connection links that limit the bandwidth advantage. However, the edge application of cloud broadband can remove this speed constraint and can provide Layer 2 network services in order to achieve high-speed, LAN-like functional performance.

The features of cloud broadband such as nearby access, ubiquitous computing power, ultra-low latency, in-cloud security, and fixed-mobile integration can meet the needs of emerging applications such as cloud gaming, AI, and XR. In addition, they can support intelligence on a large scale, for instance, with vehicle-road collaboration and even metaverse-like applications.

### SOCIAL BENEFITS

Cloud broadband redefines broadband and moves it from a traditional service to a combination of the trinity of connectivity, computing, and application. It is a new broadband architecture, new technology, and new business, which combines communication and information technologies. At present, though fiber bandwidth has entered the gigabit era, the problem of lengthy end-to-end connections and high latencies still exists. Relying solely on the traditional broadband model cannot meet users' personalized needs. Cloud broadband should improve the application experience substantially through the deep integration of edge cloud and network intelligence, superimposed with cloud business applications and massive processing capacity.

Compared with traditional broadband, cloud broadband has an evolved and innovative architecture. Functions such as traffic forwarding and various kinds of control performance in the home gateway can be realized in the cloud based on network functions virtualization (NFV) and software-defined networking (SDN) technologies. When users access services deployed on the edge cloud, the cloud gateway on the access side is activated in order to achieve edge-cloud collaboration. It can be said that the architecture of cloud broadband breaks the boundary between the network and the cloud from the traditional broadband model and enables the evolution from "optical broadband" to "cloud broadband."

Shanghai had absorbed 100,000 new users one month after the launch of cloud broadband. With the rapid growth in users cloud broadband is gradually becoming the mainstream choice, and the innovative nature of the cloud broadband model will bring new value. For example, cloud broadband will help enable AI, games, and security and will help key industries.

In the field of AI, the cloud broadband model will make computing power ubiquitous and move it to the edge. In the games sector, a platform-as-a-service (PaaS) service offering real-time video rendering and based on edge-cloud GPU computing power and synchronous stream output to terminal devices will provide benefits such as extremely high image quality and extremely low delay.

In the security field, the edge-cloud model offers flexibility to the security business so that security services can be used at any time.

## E-SURFING VIDEO NETWORKING

*AUTHORS: LONGJIE XU, PEIWEI GUO, AND GUQIAO ZHU – CHINA TELECOM*

China Telecom launched its e-Surfing video networking service in the context of rapid development in new technologies such as IoT, AI, and cloud computing. The Chinese government has also released policies to support the research and development of advanced broadband-related technologies. In this context, and with its nationwide gigabit FTTP network in place, China Telecom launched the e-Surfing video networking service, which today is the largest video integrated service network worldwide. The service integrates video networking with AI and optical access technologies, allowing it to be used across a wide variety of applications. The service is a comprehensive solution that includes cloud and network resources, cloud storage resources, AI technologies/algorithms, and customized video terminals.

### INTRODUCTION TO THE CASE STUDY

The e-Surfing video networking service is successfully providing service to both government and private users. The service has a wide variety of applications and is used in areas such as healthcare, campus safety, food safety supervision, and construction site safety. The e-Surfing webcam is an example of where China Telecom's investment in areas such as fiber broadband access networks has enabled the development of applications that are then used to help drive digitalization in different industries while at the same time generating a commercial return for the operator.

## PROJECT SOLUTION AND INNOVATIONS

### *SYSTEM ARCHITECTURE*

The e-Surfing video networking service uses an intensive operation system based on cloud-network integration. Through the innovative design of the hierarchical and distributed "4+31+x" system architecture, the storage, transmission, and processing efficiency of video services have been greatly improved over traditional centralized construction solutions. For example, the video streams for two local users that are using the service only need to be transmitted through the local network. They are processed by the local node and do not need to be transmitted to the central node and back to the other user. Importantly, the service supports exabyte-level media storage recovery backup. Cloud-edge collaboration, elastic expansion, and AI capability can be injected from one point and shared by the whole network.

### *SYSTEM NETWORKING*

China Telecom's e-Surfing video networking service uses China Telecom's CN2 virtual private network (VPN) as well as the public internet network 163. This makes it easier to utilize the video service with either type of network. As a result, users that already have broadband access can directly subscribe to the service without the need for construction of a dedicated network. Communication between central and provincial nodes gives priority to the use of the dedicated internet VPN network for video services based on CN2 data center interconnection, which ensures the efficient, stable, and safe transmission of signaling and data between the platform nodes.

### *INTELLIGENT MAINTENANCE*

The e-Surfing video network also has a one-stop digital operation and maintenance platform. This is important because it supports the rapid deployment of central and provincial nodes and the standardization of mass loading through intelligent inspection, all-round monitoring, and the full coverage of business links. The digital operation and maintenance platform is deeply integrated with frontline customer service and equipment maintenance personnel in 31 provinces, which means that operation and maintenance efficiency is greatly improved.

### *SMART OPERATION*

The e-Surfing video network is an end-to-end cloud-network service with features such as unified management of multiple platforms, network scheduling across the whole network, unified equipment access, customer virtual networking, and other service capabilities across the whole network. The nationwide e-Surfing video network service enables full-scene video services across multiple industries through a series of AI and video integration innovations.

## ECONOMIC AND BUSINESS BENEFITS

China Telecom's e-Surfing video networking service has subscribers across several industries with many applications such as healthcare, campus safety, food safety supervision, and construction site safety. The e-Surfing video networking service is an example of how China Telecom has benefited from its investment in advanced broadband access networks that have the capacity to deal with huge traffic volumes. The introduction of the service has enabled China Telecom to derive substantial economic benefits and enhance its social reputation.

The e-Surfing video networking service helps China Telecom to diversify its revenue sources while stimulating user demand for a higher-quality broadband service. To date the cumulative number of video networking terminals connected to China Telecom's platform has exceeded 41.88 million across all kinds of user types including households, government, communities, and business users. Furthermore, these users have generated revenue of CNY3.5bn for China Telecom with an ARPU of CNY16 per month.

Moreover, the service has been deployed and is run in a cost-effective manner. Construction, operation, and maintenance costs of the service are 52% lower than for such services implemented in a traditional fashion. China Telecom has reduced costs through the deployment of innovative architecture, intelligent storage and computing power scheduling algorithms, and hybrid networking technology. In addition, the e-Surfing video networking service can also promote the growth of other China Telecom business lines such as smart broadband, cloud storage, and smart terminals.

The success of China Telecom's service has also generated considerable economic benefits for the whole of the video networking terminal industry. China Telecom has worked with more than 50 partners to produce around 315 categories of video networking terminals, which has helped to drive growth across the whole industry.

In addition, by implementing the service China Telecom has boosted the broadband industry by increasing the number of new broadband users. Around 45% of service subscribers are new broadband users.

### SOCIAL BENEFITS

There are significant wider societal benefits generated by the success of China Telecom's e-Surfing video networking service. The service can help with goals across several industries. Safety-based applications, for instance, for the construction industry, can help reduce workplace accidents. AI algorithms can analyze videos in order to help warn of violations in construction regulations. The welfare of citizens can also be improved with the e-Surfing video networking service, because it has important applications in areas such as disaster prevention and rescue. Government use of security cameras is also widespread in many countries and can act as a deterrent to antisocial behavior and crime.

### FURTHER INFORMATION

http://szb.handannews.com.cn/wbpaper/pc/content/202212/13/content_212549.html (Chinese-language site)
https://new.qq.com/rain/a/20211112A0945T00 (Chinese-language site)

## FIBER BACKBONE INFRASTRUCTURE DEPLOYMENT IN THE GAMBIA

*AUTHOR: PA TOURAY – GAMTEL*

### INTRODUCTION TO THE CASE STUDY

The advancement of social, economic, and personal development depends on broadband connectivity. Gamtel is a state-owned company that is a critical enabler in the Gambian ICT sector. It provides affordable and reliable core telecommunication services to all mobile operators and ISPs through a variety of dependable, secure, and cost-effective broadband technologies that meet both local and international standards. Gamtel's main strength is the fiber-optic ring (National Backbone) that runs through the length and breadth of the country and makes it one of the most ICT-connected countries in Africa.

Gamtel, with the support of the government of The Gambia, IDB, and EXIMBANK of China, deployed a terrestrial fiber-optic backbone network completed in 2016, commonly referred to as the ECOWAN network; a National Broadband Network; and a 100-gigabit dense wavelength division multiplexing (DWDM) OTN network aimed at closing the digital divide. Currently, the minimum bandwidth Gamtel is offering on the G-Fiber product profile is 10Mbps. The national Broadband Policy 2020–2024 states that the deployment of the network can assist in achieving the objective of "Connectivity that is always-on and that delivers a minimum of 5Mbps to every user, home, and businesses in The Gambia for high-speed access to voice, data, video, and applications and through interactive network with secure, quality, and affordable services within the next five years."

### PROJECT SOLUTION AND INNOVATIONS

Broadband connectivity is one of the priorities of the Gambian government. It has developed policies and regulation aimed at developing ICT infrastructure and digital development, which will help to turn The Gambia into a knowledge-based economy and information society. Such policies and regulation include Gambia National Broadband Policy and Strategy 2020–2024, the Gambia ICT for Development 2018–2028 Policy Statement, the Universal Access and Service Policy of 2020, the E-Government Strategy 2021–2024, the Private Sector Development and

Empowerment Strategy 2021–2024, the Draft Communications Act of 2023, and the Gambia National Cybersecurity Policy 2020–2024.

In this context, Gamtel has developed a number of projects for the rollout of digital infrastructure that can help meet the objectives laid out in government policies.

The Ecowas Wide Area Network (ECOWAN) is a 947km 24-pair fiber-optic backbone network across 20 districts from Banjul to Passamasse in the north bank area of the country and 26 districts from Banjul to Fatoto in the south bank area. The network consists of four rings that provide reliable broadband services to residential and nonresidential customers and backhaul services to mobile network operators (MNOs) and ISPs. The countrywide ECOWAN fiber network provides seamless protection within the fiber rings connecting the north and south bank regions.

The National Broadband Network (NBN) project was implemented by extending the ECOWAN backbone networks from 31 central office sites to communities away from the main fiber rings. This project aimed to contribute toward minimizing the cost of access to broadband infrastructure. In addition, it aimed to increase the geographic reach of broadband access away from the main rings with a total of about 420km of additional fiber-optic cables for last-mile distribution networks among settlements within reach of the network in order to enable high-speed broadband access networks and digital transformation. 107 fiber distribution terminals were deployed to serve identified coverage areas, and 358 fiber access terminals were deployed to extend connections to homes, businesses, and offices for Gamtel retail subscribers.

The Cross Gambia Fiber Cable 2 (CG2) is a 100-gigabit DWDM OTN infrastructure of 25km between the border with Sénégal to the north (Keurayip) and the border with Sénégal to the south (Senoba). The CG2 serves as a backhaul and backup route to Gamtel's upstream providers (IP transit).

The ECOWAN, NBN, and CG2 networks are critical enablers in The Gambia's digital ecosystem and provide backhaul and broadband access to all MNOs and ISPs, businesses, schools, residents, and nonresidents. The CG2 is especially important because it is the only available backup route when there is an outage on the Africa Coast to Europe (ACE) cable. In case of an ACE outage, the CG2 is the only international bandwidth capacity fiber-optic cable for the country. The projects also achieved the following:

- Next-Generation Network deployment to replace all of Gamtel's obsolete communications infrastructure
- Replacement or upgrade of power and environment systems in 16 critical locations
- Implementation of a unified network operating center
- Deployment of a Tier 2 national data center for use by government, Gamtel, and other businesses
- Increased the Greater Banjul Area 622Mbps transmission capacity to 10Gbps and the rural transmission capacity from 155Mbps to 2.5Gbps
- Reduced the cost of broadband infrastructure access
- Increased Gamtel's customer base and maximized revenue
- Provided bandwidth capacity to operators
- Provided IP transit and redundancy to the country

The ECOWAN and the NBN fiber infrastructure projects are critical and help provide The Gambia with much-needed broadband services. However, these projects also need to be supplemented with massive rollouts to address last-mile connectivity and enhance broadband equity.

In view of the above, the Gamtel/Gamcel board and management through its line ministry (MOCDE) crafted a turnaround strategy in 2020 to enhance the utilization of the existing infrastructure, maximize shareholder value, keep up with the accelerating pace of technology in order to help productivity and profitability, and achieve the national broadband policy targets,

which include increasing access to broadband coverage to more than 90% of the population by 2024; ensuring every Gambian has affordable access to robust broadband service by 2024; ensuring every public institution has affordable access to at least 5Mbps broadband service to anchor institutions such as schools, hospitals, and government buildings by 2024; and achieving an increase in digital literacy in schools to 75%.

As a result, the following project concepts aim to address the gaps and drive the digital economy:

- **Fixed wireless broadband access to be financed via a public-private-partnership (PPP) approach.** The output of this project includes the development, procurement, and deployment of fiber-to-the-antenna (FTTA) technology (EURO-DOCSIS) and TWS. To this end, Gamtel is continuing engagement with the Ministry of Finance and Economic Affairs Public-Private Partnership Directorate and with potential partners for collaboration.
- **Transmission network modernization.** The objective of the project is the procurement and deployment of DWDM equipment to expand the transmission capacity from 40Gbps to 300Gbps in order to meet consumer demand (e.g., that resulting from GPON and EPON access). To this end, Gamtel is continuing engagement with vendors.
- **Data center to be financed via a PPP approach.** The objectives of this project are to appraise and upgrade the NBN data center to Tier 4 and the procurement and deployment of a disaster recovery site to provide business-critical applications and to enhance the digital economy. To this end, Gamtel in collaboration with MOCDE is developing data center standardization and continuing engagement with potential partners.

## ECONOMIC AND BUSINESS BENEFITS

Access to broadband is critical for socioeconomic development. The ICT sector is one of the key drivers of sustainable economic growth, inclusivity, and development in The Gambia, according to the country's new National Development Plan (2023–2027).

The government intends to transform the country into a digital economy for rapid socioeconomic development by leveraging broadband technology and digital transformation, as outlined in the national development plan and national broadband strategy and policy. This is intended to deepen the ICT development gains of previous years in order to achieve a fully digital and broadband-connected nation for equitable development.

The successful project implementation has enhanced the nation's broadband connectivity access as well as Gamtel's productivity and operational efficiency. Furthermore, the project has provided cost-effective and reliable internet services to the operators and consumers it serves.

According to The Gambia Bureau of Statistics, the ICT industry generated a gross value added of about GMD3.1bn in 2020, accounting for 3.7% of GDP, compared with GMD2.8bn in 2019, 3.5% of GDP.

## FURTHER INFORMATION

http://gamtel.gm/site/fiber/

https://www.commscope.com/blog/2023/2023-predictions-the-demands-of-tomorrows-broadband-networks/

https://www.commscope.com/blog/predictions-for-the-future-of-broadband-networks/

https://advocacy.consumerreports.org/press_release/consumer-reports-survey-on-broadband-affordability-accessibility-and-quality-of-service-in-the-united-states/

https://acaconnects.org/broadband-infrastructure-study/

https://www.weforum.org/impact/digital-inclusion/

# HONG KONG AND MACAO, DRIVING GREATER ADOPTION OF FIBER SERVICES IN ADVANCED TELECOM MARKETS

*AUTHOR: MARK GILES – OOKLA*

## INTRODUCTION TO THE CASE STUDY

Ookla recently presented at the Communications Association of Hong Kong's Symposium 2022, "Challenge and Opportunities for Fiber Gigabit Economy." Hong Kong and Macao are advanced markets in terms of fixed network development and adoption, characterized by low levels of connection growth and strong fiber penetration, and Ookla's Speedtest Global Index™ ranks Hong Kong 5th and Macao 12th on median fixed download speeds as of November 2022. The development of fixed broadband networks in Hong Kong and Macao is predominantly driven by market forces; however, the government of Hong Kong has sought to intervene by subsidizing the deployment of fiber networks in remote locations, with a view to reducing digital inequality and helping to boost the growth of the digital economy.

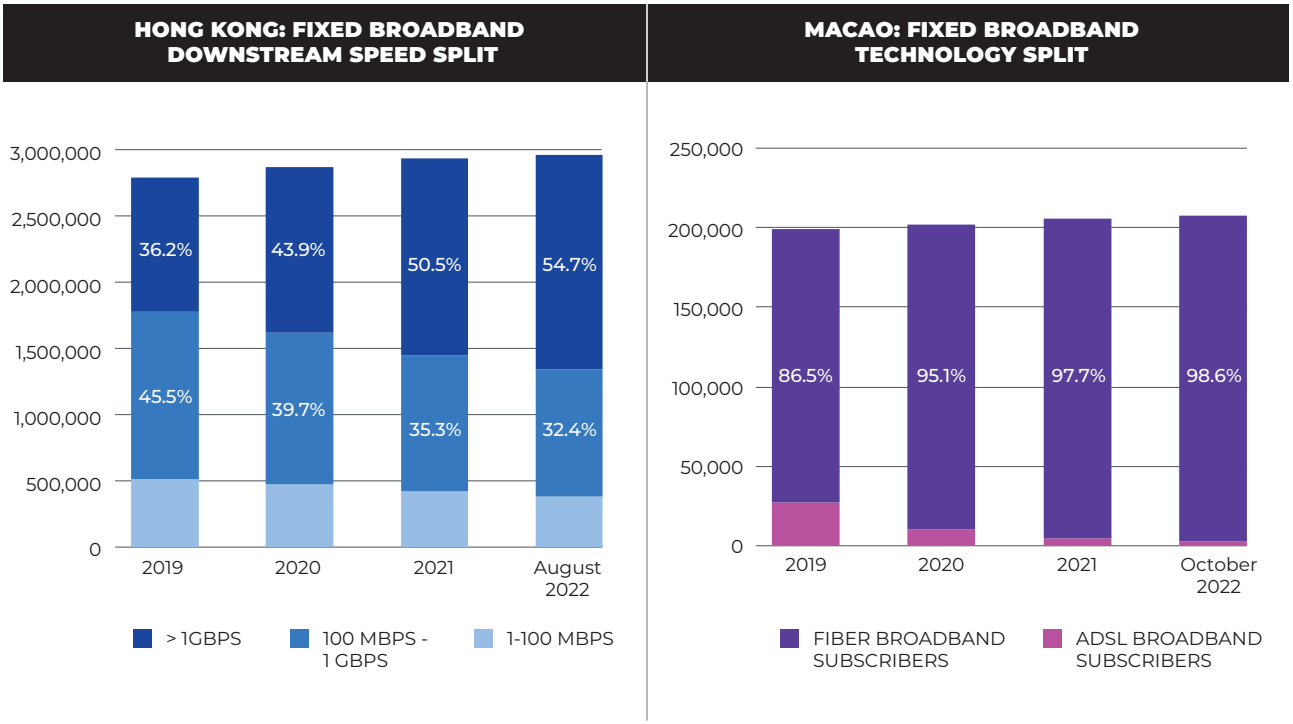
## PROJECT SOLUTION AND INNOVATIONS

### *ADVANCING TOWARD A GIGABIT DIGITAL ECONOMY*

To track broadband adoption, the Office of the Communications Authority (OFCA) in Hong Kong monitors broadband adoption by advertised speed and technology mix, while the Macao Post and Telecommunications (CTT) monitors broadband adoption by technology. Based on the latest data they have provided for 2022:

- The number of broadband subscriptions in Hong Kong rose by 0.7% during the first eight months of 2022 to reach 2.95 million. Fiber-to-the-home/building (FTTH/B) penetration stood at 84.6%, and 87.1% subscribed to packages with a maximum download speed equal to or greater than 100Mbps.
- Macao saw fixed broadband subscriptions increase by 1.1% during the first 10 months of 2022 to reach 208,000, with a fiber penetration rate of 98.6%.

FIGURE 16: HONG KONG AND MACAO, FIXED BROADBAND SPLITS

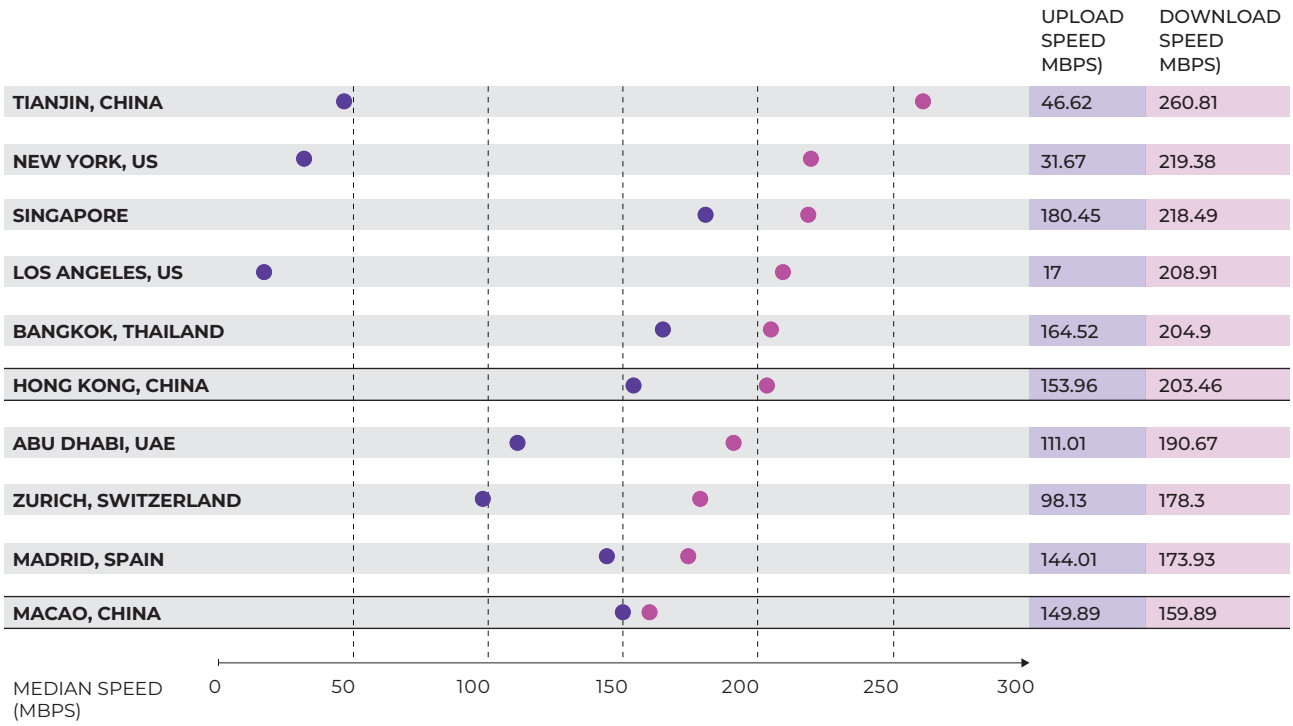



SOURCE: OFCA, CTT

### *GLOBAL COMPARISON*

Using Ookla's Speedtest Intelligence data, we compared broadband performance for Hong Kong and Macao with that of other major cities globally. Hong Kong recorded median Wi-Fi download speeds of 203.46Mbps in 3Q22, up from 184.79Mbps in 4Q21. Macao, on the other hand, lags behind its peers in terms of its median download speed performance, recording 160.13Mbps in 3Q22, up from 136.89Mbps in 4Q21. Median Wi-Fi upload speeds in Hong Kong lagged behind download performance at 153.96Mbps, while Macao recorded a more symmetrical median upload speed of 148.73Mbps. Greater penetration of fiber in broadband access networks gives providers the ability to offer more symmetrical upload and download speeds.

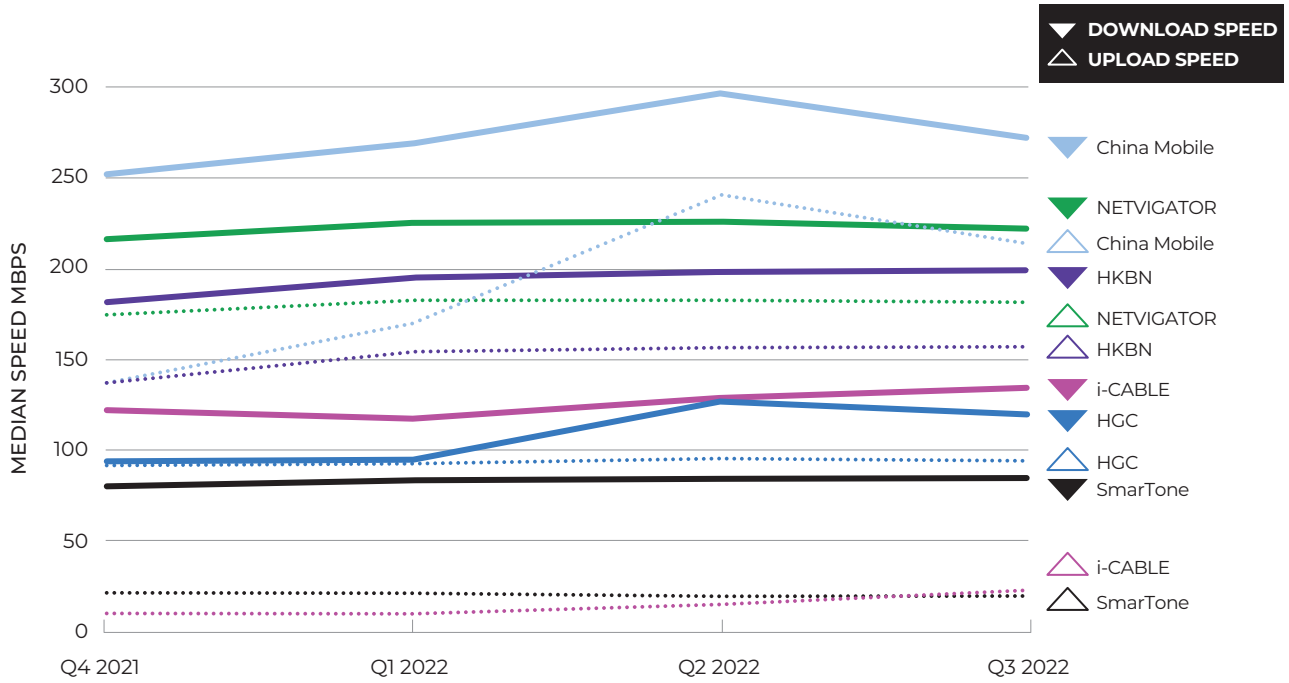
FIGURE 17: HONG KONG AND MACAO, RELATIVE WI-FI PERFORMANCE




SOURCE: OOKLA

We examined fixed Wi-Fi performance in Hong Kong, excluding any 5G fixed wireless internet connections from the analysis. Providers in Hong Kong offer a range of broadband packages based on network speeds but are also starting to differentiate through additional services such as the provision of fiber to the room and security services. Strong competition continues to drive innovation in the market, with China Mobile Hong Kong (CMHK) offering dual-gigabit fiber connections for additional capacity, and the incumbent HKT with its NETVIGATOR brand offers a multiuse broadband service, which provides bandwidth on multiple channels (up to four) with separate IP addresses, to allow consumers to divide their activities between channels. The availability of higher-speed subscription tiers depends on the provider's footprint and whether fiber connectivity is to the premises (FTTP) or to the building (FTTB), with some buildings utilizing copper as part of the last mile. Migrating Hong Kong's remaining FTTB connections (17.8% of total as of August 2022) to FTTH (66.8% of total) would help boost median speeds.

FIGURE 18: HONG KONG, COMPARISON OF PERFORMANCE OF FIXED WI-FI PROVIDERS

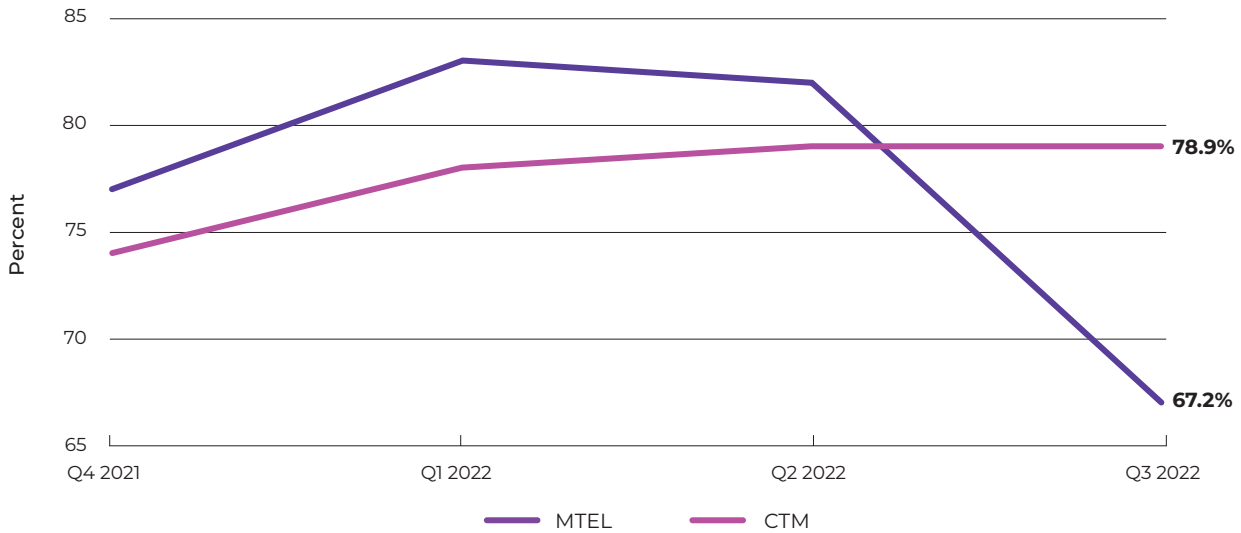



SOURCE: OOKLA

Examination of fixed broadband Wi-Fi performance in Hong Kong shows that CMHK was the fastest provider overall during 3Q22, with a median download speed of 271.99Mbps, followed by NETVIGATOR with 221.79Mbps. Though providers continue to market broadband based primarily on download speeds, services such as video calling and online gaming are driving the importance and growth of upload speeds. CMHK also led the market based on median upload speeds at 213.93Mbps during 3Q22, followed by NETVIGATOR and HKBN.

Macao lagged behind Hong Kong on fixed Wi-Fi performance for both median download and upload speeds during 3Q22, despite the regulator CTT reporting widespread adoption of fiber in the market. Providers CTM and MTEL offer a range of fiber broadband plans for residential users, segmented by speed, with download speeds ranging from 150Mbps to 10Gbps for CTM and from 25Mbps to 600Mbps for MTEL.

FIGURE 19: MACAO, FIXED WI-FI PROVIDERS




SOURCE: OOKLA

In order to maintain or improve their position among top-performing cities globally, providers in Hong Kong and Macao need to drive greater availability of higher-speed broadband services and newer routers while encouraging existing customers to upgrade to faster speeds. For Hong Kong in particular, improving the penetration of routers that support 5GHz Wi-Fi could help those providers that currently lag behind in the market on overall performance.

More broadly, it is also important to note the position of Hong Kong and Macao on a global level and how very fast fixed broadband speeds mark them out as world leaders and developed economies. In 2020, the speed of the fixed broadband internet connection was on average higher than the speed of the mobile broadband internet connection within all groups of economies, except the least developed countries (LDCs). This difference was less accentuated within the developing and transition economies, but for developed economies, the average speed of the fixed connection was as much as twice the speed of the mobile connection. The divide in the quality of internet connection is very significant between the developed economies and other economies. The observed average fixed broadband speed in developed economies was almost 8× that of LDCs, reflecting infrastructure and technological gaps (e.g., in the diffusion of optical fiber).

## SERVICE PROVIDER MANAGED MESH WI-FI

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A broadband service is only as good as its weakest point, which is usually the last few meters, namely the in-home Wi-Fi network. Service provider managed mesh Wi-Fi gives operators the tools to manage both legacy and new Wi-Fi assets and provide a premium broadband service all the way to the connected device. Ensuring that subscribers have good-quality Wi-Fi ties into operators' investments in broadband access networks. As broadband access networks are upgraded, in-home connectivity must keep pace.

### INTRODUCTION TO THE CASE STUDY

Operators deliver brilliant broadband to homes and businesses using various access technologies such as FTTH, copper (VDSL2), or fixed wireless access. In many countries, residential customers can subscribe to 1Gbps broadband access services. However, the broadband experience is only ever as good as the in-home Wi-Fi. If the Wi-Fi network performance is below par, the whole experience is bad, regardless of how good the service to the home is. Wi-Fi coverage is an important parameter in the broadband experience, especially because family members are often spread out around the home, all needing a fast broadband connection at the same time. In this way high-performing, whole-home Wi-Fi has become essential for communications service providers (CSPs) to be successful in offering broadband services, especially higher-tier services.

### PROJECT SOLUTION AND INNOVATIONS

#### *SERVICE PROVIDER MANAGED MESH WI-FI*

The objective of a service provider managed mesh Wi-Fi solution is to help customers get the most from their Wi-Fi. The majority of Wi-Fi households have a single access point (AP), likely integrated into their residential gateway or tethered to their broadband modem via Ethernet. A single-AP home may benefit from the latest Wi-Fi technology, such as Wi-Fi 6, which would require new hardware deployments. Alternatively, it can be optimized with a managed Wi-Fi service or extended with a second AP, commonly known as mesh Wi-Fi or whole-home Wi-Fi. Mesh Wi-Fi improves Wi-Fi coverage and the quality of the customer experience. However, the need for Wi-Fi management grows exponentially with mesh Wi-Fi (multiple mesh APs) because it adds another layer of complexity that requires management of the mesh backhaul between two mesh access points.

A service provider managed mesh Wi-Fi solution ensures the best possible broadband experience by

- Automating the Wi-Fi optimization process as much as possible, resulting in a self-optimizing network
- Dynamically adjusting Wi-Fi settings to mitigate any potential issues and provide the highest throughput to all devices
- Giving CSPs the tools to effectively manage Wi-Fi-related problems when they occur

This requires two levels of Wi-Fi optimization: local optimization in the in-home Wi-Fi network and remote, cloud-based optimization.

### *LOCAL WI-FI OPTIMIZATION*

Wi-Fi is a dynamic medium. The wireless environment constantly changes: think of interference from neighboring Wi-Fi networks, household appliances that can also interfere with Wi-Fi being switched on and off (e.g., microwave ovens, Bluetooth devices, baby monitors), users moving around, and so on. A lesser-known issue is with radar. If, for example, weather radars start scanning, regulations in many countries state that Wi-Fi access points in the neighborhood need to back off from the frequencies being used (dynamic frequency selection or DFS channels).

Wi-Fi APs need embedded algorithms to detect and mitigate issues like these in real time. In the case of interference, a different channel needs to be selected. Band steering and client steering need to happen in real time, and this is what we refer to as real-time, reactive Wi-Fi optimization or self-optimizing Wi-Fi.

### *CLOUD-BASED WI-FI OPTIMIZATION*

Additional algorithms in the cloud can complement local optimization with a more thorough, proactive Wi-Fi optimization through data collection and computational power. The data is collected anonymously without any correlation to personal data (GDPR compliant), and the algorithms will analyze the data and take action, changing Wi-Fi parameters or even enforcing certain policies, and providing alerts and reports. In addition, the cloud brings visibility of neighboring Wi-Fi APs, so the impact of one AP on another can be mitigated. Typical examples of proactive Wi-Fi optimization include transmit power control, long-term frequency planning, and load balancing across channels and bands. Managing various types and brands of AP is facilitated by the industry transition toward TR-369, also called User Services Platform, as a common communication protocol between access points and the cloud platform.

### *WI-FI MANAGEMENT*

Mesh Wi-Fi or nonmesh Wi-Fi networks can be managed with either local or cloud-based optimization. There are a number of scenarios where such management can be valuable.

### *MANAGING NEW DEPLOYMENTS*

Operators always like to consider the future. Deploying devices today that have local intelligence combined with cloud-based optimization avoids complex and costly updates further down the line. For new deployments operators can balance the activities that need to be done locally (reactive actions in real time) against those that can be done proactively in the cloud.

### *MANAGING LEGACY DEPLOYMENTS*

The majority of Wi-Fi APs in homes today are Wi-Fi 5 capable. However, in terms of client devices, the situation is far less predictable: most webcams still only support Wi-Fi 4. If a CSP can manage Wi-Fi networks from the cloud and optimize them for the way client devices connect, then the CSP does not have to immediately replace APs. Prolonging the life of those devices equates to valuable capex savings.

It is equally important to be able to manage from the cloud legacy APs that do not have self-optimizing embedded algorithms, optimizing all the Wi-Fi parameters of the AP. This means CSPs can manage all Wi-Fi APs regardless of technology or vendor. Some of the actions that need to be taken are as follows:

- Enforcing use of the correct channels (e.g., only using channels 1, 6, or 11 on the 2.4GHz band) to minimize neighboring interference
- Driving client devices as much as possible to the 5GHz band
- Ensuring client devices use a channel width of 80MHz (if they support it)

In addition to the two-level Wi-Fi optimization, a cloud platform can bring two more benefits:

- **Give helpdesk agents real-time visibility.** A managed Wi-Fi platform can give agents real-time visibility of the in-home network, giving information about the network topology, the connected devices, traffic patterns, and so on. This information allows help-desk agents to pinpoint anomalies and solve customers' issues very quickly. In this way, both the time needed to solve an issue and the number of truck rolls can be reduced.
- **Obtain network wide KPI reporting to track Wi-Fi network performance.** A CSP can also obtain detailed reports about the performance of all of its Wi-Fi networks. These reports can then be used to detect anomalies offline and manually step in and further optimize performance. Another useful tool is an AP ranking system that gives a list of, for example, the 100 APs that have been rebooting the most or that are most susceptible to interference, again to enable further investigation and performance optimization.

## ECONOMIC AND BUSINESS BENEFITS

A service provider managed mesh Wi-Fi solution can optimize Wi-Fi performance for all customers, both those with the latest Wi-Fi technology (ensuring that this technology is used to the maximum effect) and those with older Wi-Fi (giving these devices an improved performance and extended life). The key component of this Wi-Fi optimization is a cloud platform from which both types of devices can be managed and optimized. Combining this with embedded algorithms in the Wi-Fi APs, CSPs can bring the best performance to their customer base, ensuring the best overall broadband experience.

A managed mesh Wi-Fi solution ensures that customers are more satisfied with their broadband service and have faster broadband throughout the whole home with far fewer issues with the Wi-Fi connectivity. As a result, a managed mesh Wi-Fi solution reduces customer churn and has the potential to increase the Net Promotor Score (NPS) by 10–40 points. In addition, customers will be more likely to upgrade to higher-tier broadband subscriptions. We estimate that this can result in 30–45% more premium customers. A managed mesh Wi-Fi solution can also reduce Wi-Fi-related help-desk calls by 30% and truck rolls by 30%.

Market momentum can be demonstrated by the following reference cases:

- An Asian Tier 1 operator measured a 20 percentage point increase in NPS between the users of Nokia Mesh and the overall base.
- A Western European Tier 2 operator manages 1.2 million Wi-Fi points with the Nokia cloud platform, resulting in a 66% increase in peak-hour throughput.
- A US Tier 3 operator indicated that the Nokia cloud platform enabled a large number of operational efficiencies, decreasing the installation time and providing easy troubleshooting. It helped it to deliver on customer satisfaction.

## FURTHER INFORMATION

https://www.nokia.com/networks/in-home-connectivity/

https://www.nokia.com/networks/fixed-networks/home-wi-fi/

https://www.nokia.com/networks/fixed-networks/nokia-wifi-cloud-controller/

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