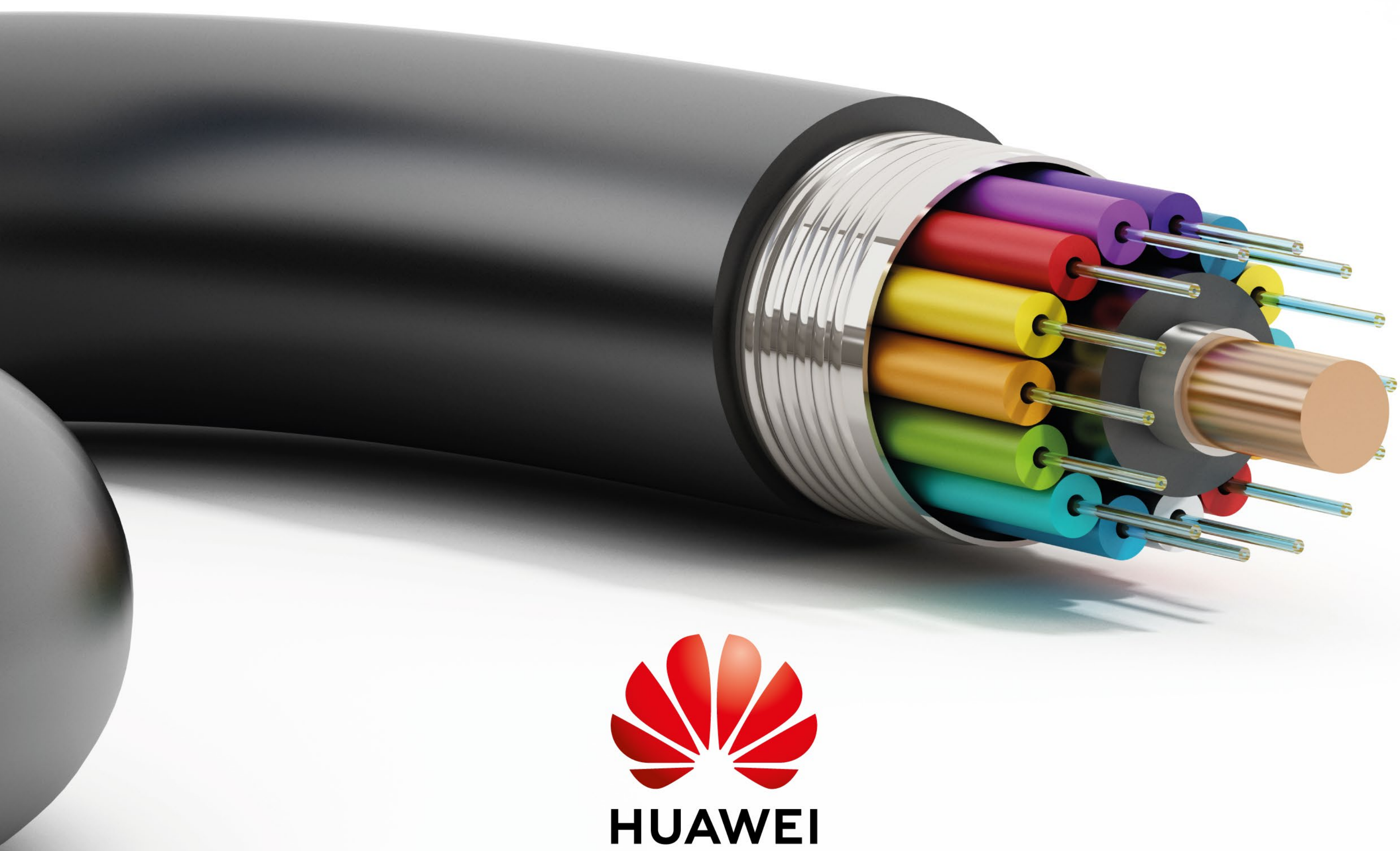
INSTITUTO FEDERAL DE
TELECOMUNICACIONES

ENABLING DIGITAL SOCIETY IN MEXICO

WITH OPTICAL FIBER BROADBAND NETWORKS DEVELOPMENT



HUAWEI

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I. Summary and key messages

With the rapid development of digital society, broadband has become an indispensable requirement of people's lives and a fundamental part of countries infrastructure, equivalent to other utilities, such as water, electricity, and gas. Optical fiber broadband networks provide sustainable and cost-effective connectivity with high bandwidth, stability, reliability, and reduced latency, promoting long-term economic growth by enabling development of advanced digital services and applications for users, businesses, and industries.

In this context, this document provides an analysis of the recent evolution of broadband infrastructure in Mexico and on key international trends. This document aims to provide insightful information on the progress as well as challenges of fiber network developments in Mexico to support Digital Mexico development in a broader context.

Key messages:

- With the increasing number of home and enterprise applications and services, such as Virtual Reality (VR), Augmented Reality (AR), Extended Reality (XR) and live video, higher requirements are imposed on broadband infrastructure resulting in necessary upgrades to legacy broadband access networks.
- Fiber-optic broadband brings significant socio-economic benefits. Research shows that broadband Internet access is a key driver of economic growth and industry competitiveness, playing an increasingly transformative role in all economic sectors and society in general.
- Relevant industry standards, e.g. ETSI ISG F5G (5^{th} Generation of Fixed Network), define future networks as related to Gigabit all-optical fiber networks.
- In Mexico, according to the analysis of the current infrastructure, the focus is on several key areas: increasing broadband coverage in remote areas, promoting technology upgrades (such as copper and cable migration to fiber), and urban fiber broadband take-up rate acceleration, among others.
- Mexico's possible alternative is to achieve greater digital transformation by developing high-capacity networks that deliver innovative products, services and applications to all citizens and businesses.

II. Future Network Requirements

Future digital applications will demand higher bandwidth and higher speeds. Therefore, future networks need to be faster, more reliable, secure, and flexible to support emerging technologies and to meet the evolving demands of users and applications. Achieving these requirements requires ongoing innovation and collaboration among stakeholders in the telecommunications industry and investment in future-proof technologies such as fiber. Investing in fiber infrastructure is an investment in the long-term viability of broadband networks. Fiber networks are essential for meeting the growing demands of modern communication, data transmission and new immersive applications (VR, AR, XR). Fiber offers superior speed, reliability, sustainability, and security while enabling the development of new technologies and supporting economic growth.

XR devices require high-quality connectivity.

Today, Augmented Reality glasses and Mixed Reality (MR) headsets are still relatively rare with only 2.3% Virtual Reality headset household penetration on a global basis according to Omdia's research. However, VR headsets are becoming more common, largely driven by increased investment from hyperscalers bridging existing consumer experiences into new immersive environments. VR/MR headsets utilize multiple full-HD video streams per session and heavily rely on cloud-based content and applications. The technology will place heavy demands on broadband networks with regard to bandwidth and latency, with high levels of reliability and consistency needed for it to work seamlessly. According to Omdia's forecast, standalone VR connected devices installed base will grow from 20 million in 2022 to 25 million in 2028[1].

Industry digitalization pushes higher speed and QoS guaranteed enterprise connectivity

As businesses rapidly digitize, the demand for broadband connectivity within the enterprise sector has increased significantly and it is only expected to continue to rise. Major factors that are driving enterprise connectivity include cloud and Artificial Intelligence (AI).

[1] Source: Omdia, Consumer VR Headset and Content Revenue Forecast, 2023

Companies need faster and more reliable Internet to meet their customer experience requirements and to stay competitive.

- By Gartner estimation, more than 85% companies will move part of their operations and service to cloud by 2025.
- By Flexera research, 76% of people reported using the public cloud, including multiple clouds, in 2022. This up from 56% in 2021[2].
- By IDC estimation, by 2026, AI-driven features will be embedded across business technology categories with 60% of organizations using them to drive better outcomes without relying on technical AI talent[3].
- By IDC estimation, 85% of enterprises will combine human expertise with Artificial Intelligence (AI), Machine Learning (ML), Natural Language Processing (NLP), and pattern recognition to help augment foresight, increasing worker productivity by 25% in 2026[4].
- By Gartner estimation, >50% of enterprises will use industry cloud platforms to accelerate their business initiatives by 2027[5].
- By Godman Sachs estimation, all industries will be impacted by AI by 2030.

The development of AI, cloud, and big data will boost national economy and growth of service providers and requires a high-performance network. Generative AI initiates an evolution of productivity. For any enterprise or individual who wants to access the AI to boost their productivity, it is essential to be connected to the massive computing power behind the AI.

[2] Source: 2022 State of DevOps report, Flexera.
[3] Source: IDC FutureScape: Worldwide Artificial Intelligence and Automation 2023 Predictions, doc #US49748122, October 2022
[4] Source: IDC FutureScape: Worldwide Artificial Intelligence and Automation 2023 Predictions, doc #US49748122, October 2022
[5] Source: Gartner® ebook, Gartner's 2023 Top Strategic Technology Trends, 2022.

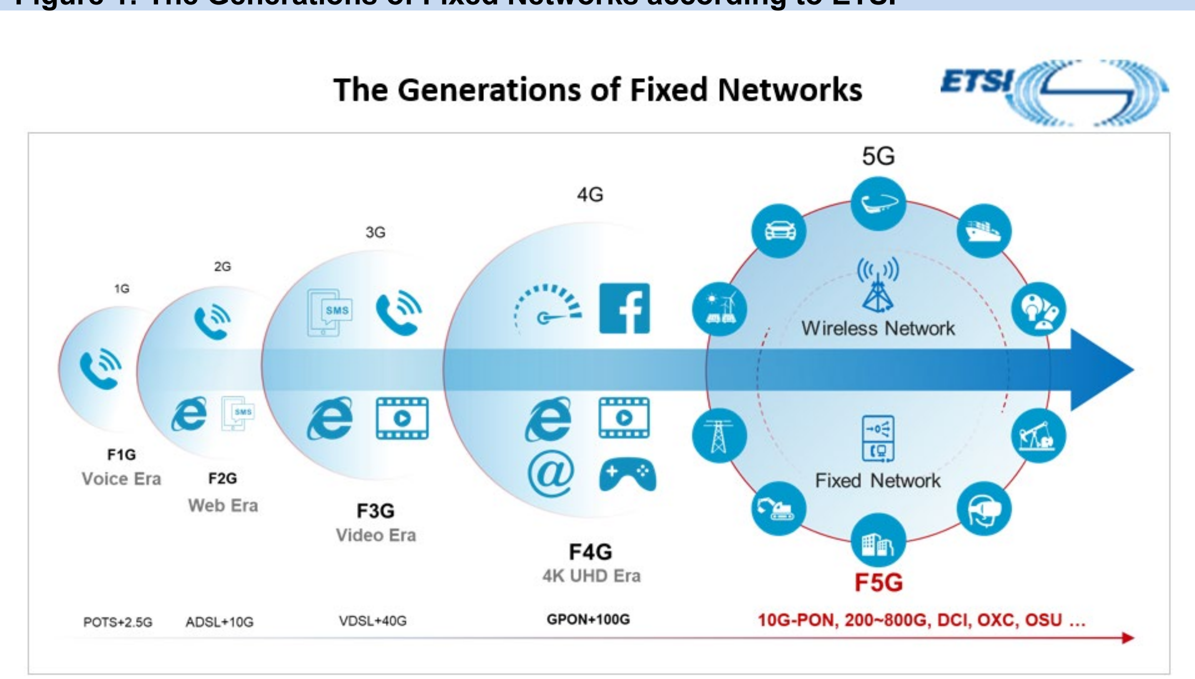
III. Fiber technology enables the move to Gigabit society.

We are entering a new era of communication, where fixed networks, which have historically always offered the highest bandwidth and reliability, will play an essential role. The development of a full-fiber solution will help support the most demanding applications, such as ultra-high definition video streaming, telemedicine, and virtual reality (VR) gaming.

Moreover, the next generation of fixed network needs to complement 5G wireless networks and support the growing number of cloud services requiring high bandwidth and/or low latency connections. Built on previous generations of fixed networks, the 5th generation of fixed network (F5G) is being defined by ETSI ISG to provide the evolution required to match and further enhance the benefits that 5G has brought to mobile communications.

The focus of the F5G specifications is on telecommunication networks which consist fully of optical fiber elements up to the connection serving locations (user, home, office, base station, etc.). In the near future, all fixed networks will adopt end-to-end fiber architectures: Fiber to Everywhere.

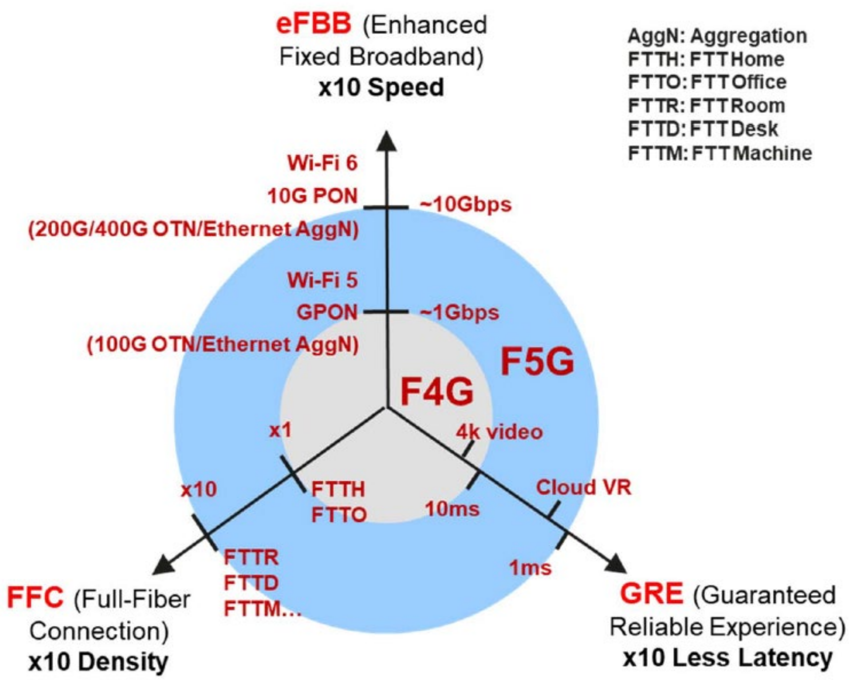
Figure 1: The Generations of Fixed Networks according to ETSI



Source: ETSI

ETSI ISG F5G will upgrade previous solutions, and the new characteristics of the 5th generation fixed network will address three main features indicated in the chart below:

Figure 2: Fixed network generations



Source: ETSI

In the beginning, fixed networks were designed for delivering voice services to consumers via copper networks. Copper networks evolved throughout the 20th century to deliver also video and broadband content as well, supported mainly on DSL (Digital Subscriber Line) technologies and later on G. fast.

In the beginning of the 21st century, fibre networks started to be deployed on the access network, especially with PON (Passive Optical Networks) point-to-multipoint technologies, initially with GPON and later with 10G-PON technologies.

Meanwhile, Next Generation PON technologies (NG-PON) began to be researched and developed. All these technologies can be mapped to a certain generation. The five generations of fixed broadband have not developed at a constant pace. The infrastructure and its deployment have become an important constraint to broadband development. The first generation with voice services lasted for more than a century, for example, while ADSL lasted only a decade.

Based on the international copper line telephone network infrastructure established in the first-generation, the second-generation fixed network could realize the transition from narrowband to broadband by replacing only network equipment at the network and customer premises, which was every economical and quick. In the early 20th century, global major operators have implemented fixed broadband networks in just four or five years.

The original copper line telephone network could not support the 3rd generation of systems. Both the third generation, "fiber-deep", and the fourth generation, "all-optical broadband," required major adjustment of the infrastructure.
A large number of access optical fibres needed to be laid out in the existing infrastructure, replacing the copper cables. These two generations of fixed networks had been developing for 8 to 10 years.

Over time, 3rd generation networks fiberized the feeder portions of the network, while 4th generation networks fiberized the distribution and drop portions. Global carriers faced many economic challenges and the Return On Investment was insufficient, and the payback period was too long.

Therefore, the development of fixed networks around the world has happened at a deliberate pace. The good news is that once the network is fiberized, one can look forward to another century of use of this infrastructure. The 5th generation fixed network is based on the 4th generation's 100 Mbit/s optical fibre broadband. At this time, optical fibres have been largely extended to homes, broadband applications are continuously enriched, and content quality is continuously increasing. The information technology development requirements of various industries have been increasing sharply. The infrastructure is either in place or needs minor extension. Especially for home broadband, only network device upgrade is needed to improve service experience significantly. Operators are facing the "singularity" of fixed network investment, and the golden age of fixed network development will come again.
In the Table 1, Fixed Networks Generations represent a brief resume about the main changes between one generation and other and remarks the main technical characteristics between them as reference.

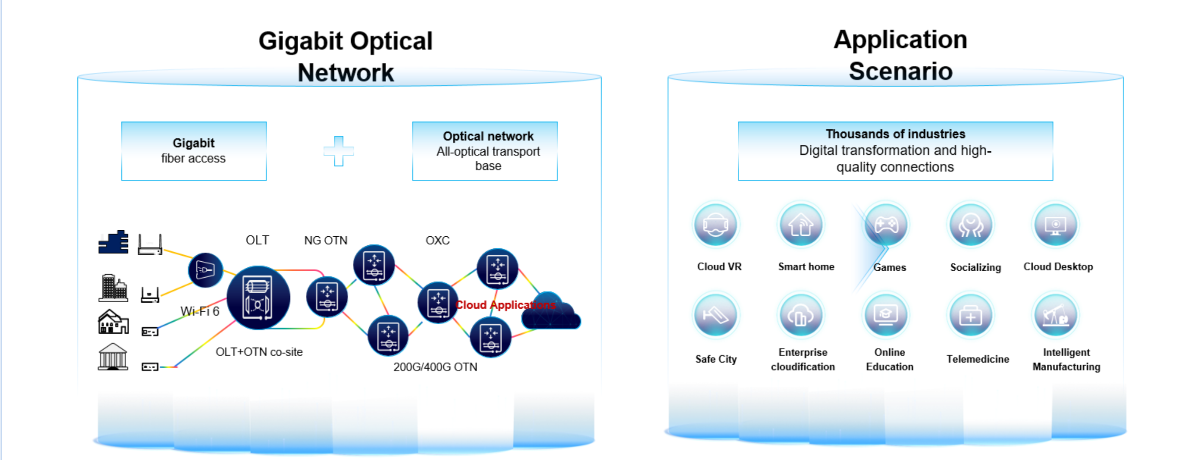
Table 1: Fixed networks generations

Fixed Network Generation	F1G	F2G	F3G	F4G	F5G
Reference Wave	Kilobits	Megabits			Gigabits
Reference Downstream Bandwidth per User	<2 Mbps	2-30 Mbps	30-100 Mbps	100-1000 Mbps	**1-10 Gbps**
Reference Upstream Bandwidth per User	<2 Mbps	1/2 Mbps	15-100 Mbps	50-500 Mbps	**1-10 Gbps**
Reference Services	Voice (PSTN/ISDN) Dial Internet	High Speed Internet (HSI) SD Video	HD Video	UHD 4K Video	**VR Video Cloud Gaming Smart City**
Reference Characterization	Narrowband (NB)	Basic Broadband (BBB)	Fast Broadband (FBB)	Ultra Fast Broadband (UFBB)	**Gigabit Broadband (GBB)**
Reference Architecture	CO LE	CO DSLAM	FTTC/FTTB	FTTH/FTTdp	**FTTH/FTTR**
Access Network Technology Reference	PSTN/ISDN	ADSL/ADSL2+	VDSL2	GPON/G.fast	**10GPON**
Technical Specifications Reference	I.100-I.699	G.992.x	G.993.x	G.984.x G.9701	**G.987.x (XG-PON) G.9807.x (XGS-PON)**
On-Premise Network Technology Reference	RJ11/RJ45	FE+ WiFi1/WiFi2 (802.11b/802.11a)	FE+ WiFi3 (802.11g)	FE/GE+WiFi4/WiFi5 (802.11n/802.11ac)	**GE/10G+WiFi6 (802.11ax)**
Radio Frequency (RF) Video over Fibre (LAN Coaxial) Reference	No	No	No	Yes	**Yes**
Specification Timeline Reference	1988-1993	1999 (ADSL) 2003 (ADSL2+)	2006	2006 (GPON) 2014 (G.fast)	**2017**
Production Timeline Reference	1990	2000	2007	2010-2012 (GPON) 2016 (G.fast)	**2018**

Source:https://www.etsi.org/deliver/etsi_gr/F5G/001_099/001/01.01.01_60/gr_F5G001v010101p.pdf

The evolution of the Access and Transmission Technologies like Gigabit Fiber Access plus All Optical Network are evolution into Gigabit Optical Network Concept that bring more Application capabilities scenarios to the industries development based on Digital Transformation, like Cloud Virtual Reality, Online Education, Smart Home, Intelligent Manufacturing between others.

Figure 3: Gigabit Optical Network = Gigabit Optical Fiber Access + Full Optical Transmission Base, Empowering the Digitalization of Thousands of Industries

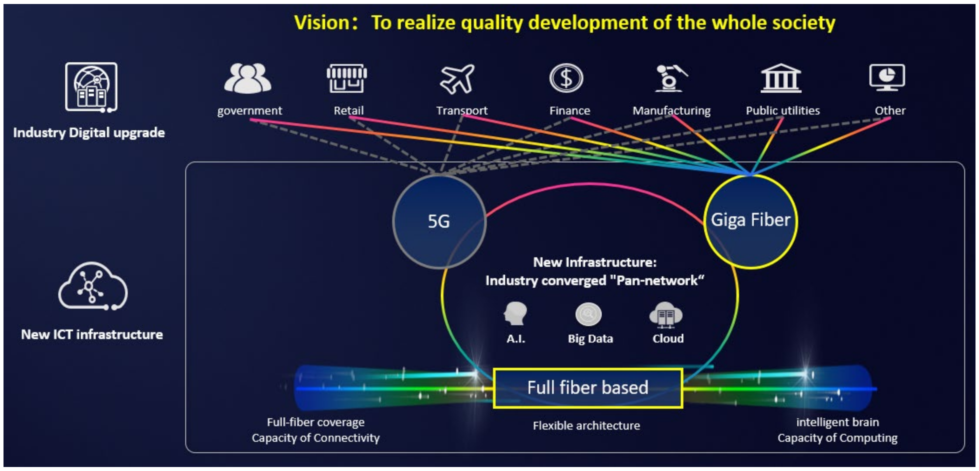


Source: CAICT

3.1. Gigabit City

Gigabit city refers to a city that has widespread access to high-speed internet connections, delivering speeds of 1 Gbps or higher. It implies that the infrastructure and network capabilities in that city are designed to support extremely fast Internet connectivity. The goal of a smart city is to leverage technology and data to create a sustainable, efficient, and livable urban environment that improves the well-being, safety, and quality of life for its residents while promoting economic growth and environmental stewardship. Gigabit cities attract businesses, startups, and entrepreneurs looking for advanced digital infrastructure. High-speed Internet fosters innovation, entrepreneurship, and the development of new technologies, leading to economic growth, job creation, and investment opportunities. Furthermore, technology plays a key role in the environment and sustainability – for example, Gigabit city features include energy conservation and environmental efficiencies, such as streetlights that dim when the roads are empty. Such smart grid technologies can improve everything from operations to maintenance and planning to power supplies, as well as waste management and sanitation via internet-enabled rubbish collection, bins, and fleet management systems. Fiber connectivity is essential for Giga cities, including for example, smart transportation systems and emergence for Connected Autonomous Vehicles (CAV). Driverless cars, trucks and buses can be intrinsically connected to vital information that reduces traffic and makes driving on roads safer.

Figure 4: Optical fiber networks are the core support of ICT infrastructures, facilitating the growth of the digital economy



Source: CAICT

3.2. Fiber home network

Premium Quality of Experience is key

The home network plays an important role in the way consumers experience the delivery of their home broadband services. As network operators deploy all-optical fiber networks capable of delivering multiple gigabits of bandwidth into the home, such investment needs to be complemented with intelligent home broadband solutions (such as smart Wi-Fi and real-time traffic monitoring) to address any connectivity bottlenecks in the home. In fact, according to the statistics and analysis of telecom carriers' complaints about home broadband quality and problem location and resolution, the home network factor accounts for more than 70% of the complaints. According to the statistics and analysis of related problems, the impact of home networks on service experience is mainly caused by the quality of Optical Network Terminal (ONT), home routers, Wi-Fi network construction, Internet Protocol Television (IPTV) and video Set Top Box (STB) performance.

Some typical problems and causes include:

- The ONT model is old and does not support high-bandwidth access services.
- The Wi-Fi rate of the 2.4 GHz single-band router is low due to the performance limitation of the router.

– Cable Category 5 (CAT5) network cables are deployed inside a home. Due to cable distribution and quality problems, the maximum bandwidth is 100 Mbit/s. If a self-purchased router is connected to a home broadband network through a network cable, the subscribed user rate cannot be achieved.

According to service provider statistics, Wi-Fi related problems account for about 60% of these problems. Therefore, solving the home broadband Wi-Fi issues will greatly improve user experience.

Key steps to provide high-quality home network experience

In the future, the products used by homes will be more diversified. Various smart devices will rely on networks to interconnect and form smart homes. To build a high-quality experience network, users can try to solve the problem by themselves or seek help from their service provider's customer service team. For example, home end users can:

- Select a home broadband subscription rate of 1 Gbps and use ONTs with Gigabit Passive Optical Network (GPON) high-speed service.
- Optimize home Wi-Fi network settings to achieve overall high-quality Wi-Fi signal coverage and ensure high-quality user experience.

In terms of home Wi-Fi network, the dual-band 10GPON + Wi-Fi 6 ONTs with 2.4 GHz and 5 GHz frequency bands can be used with corresponding extenders or Access Points based on three different scenarios: small-sized to cover areas less than 90 m², medium-sized cover areas beyond 90 m² and up to 240 m², and villa areas to cover beyond 240 m². Home end users can also consult the service provider's customer service team and purchase the most suitable home broadband service and technical support plan to accommodate their connectivity needs and improve the quality of experience of the home network.

Use high-quality consumer premise equipment (CPE) to ensure service experience and select professional emerging service application products and solutions. Use STBs and TVs that support 4K video to improve TV picture quality and experience comfort. For users of emerging home broadband services, such as Cloud VR, online games, and home cloud, it is recommended that they obtain professional and reliable products and solutions from guaranteed service providers.

Deploy Cable Category 6 (CAT 6) network cables that support Gigabit Ethernet for distances up to 100 meters, or optical fibers to each room, fiber-to-the-room (FTTR) if possible that support Gigabit speed without not distance limited. When the home gateway is connected to devices that require high-quality network capabilities, such as Wi-Fi routers, extenders, STB and TVs, the wired mode such as network cables or optical fibers is preferred to ensure high-quality user experience.

IV. Importance of fiber broadband connectivity

4.1. Fiber broadband enables economic growth and social wellbeing

Analysis by the International Telecommunications Union (ITU) of more than 200 studies on broadband impact concluded that a 10% increase in broadband penetration yields an increase in Gross Domestic Product (GDP) ranging between 0.25-1.5%.

In its own study, the World Bank also estimates that for every 10% increase in fixed broadband penetration increases GDP in economically developed areas by 1.21% and by 1.38% in developing areas. Furthermore, the Organization for Economic Cooperation and Development (OECD) estimated that for every 10% increase in broadband penetration can raise labour productivity by 1.5%, and a European Investment Bank (EIB) study asserts that every doubling of broadband speed can result in a further GDP growth of 0.3%[6].

Fiber broadband enables smart manufacturing in Mexico

Mexico has been attractive to foreign investment, which is heavily driven by global supply chain adjustments. More companies choose Mexico as the manufacturing centre of markets in Americas. As a United States-Mexico-Canada Agreement (USMCA) signatory, Mexico has had a great transport and customs advantage compared to other Latin American markets.

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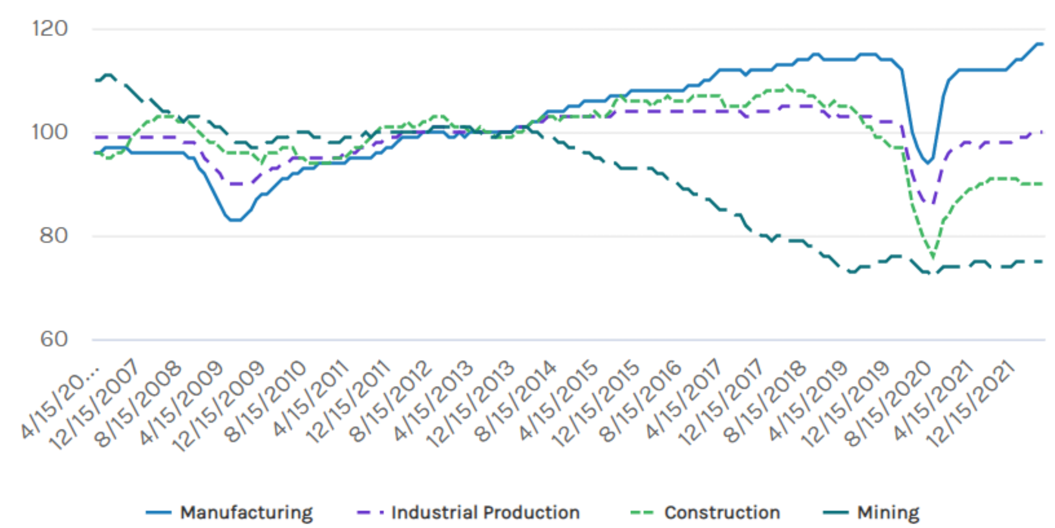
6 *ITU source*: https://www.itu.int/dms_pub/itu-d/opb/pref/D-PREF-EF.BDT_AM-2019-PDF-E.pdf
Worldbank source: *https://documents1.worldbank.org/curated/en/178701467988875888/pdf/102955-WP-Box394845B-PUBLIC-WDR16-BP-Exploring-the-Relationship-between-Broadband-and-Economic-Growth-Minges.pdf*
OECD source: https://www.ofcom.org.uk/__data/assets/pdf_file/0025/113299/economic-broadband-oecd-countries.pdf

Figure 5: Manufacturing leads Mexico economic growth



Source: Haver analytics, Morgan Stanley Research forecasts

Manufacturing exports currently represent about 40% of Mexico's $1.3 trillion economy. This estimated surge, represents more than 10% of GDP[7]. Meanwhile, new investment driven by nearshoring could reach about USD $46 billion in the next five years, helping boost Mexico's annual GDP growth to around 3% from 2025 to 2027.

Information and Communication Technology (ICT) enables smart manufacturing with industrial all-optical networks. Smart manufacturing is an in-depth integration of next-generation ICT and manufacturing technologies. It aims to build a new network infrastructure that connects people, machines, and things through full connectivity centred on data and an industrial all-optical network base[8].

Fiber optical networks are a prerequisite for the upgrade of all industries including manufacturing. In smart factories, an optical fiber network implements real-time monitoring

[7] Morgan Stanley, https://www.morganstanley.com/ideas/mexico-nearshoring-gdp-growth
ITU source： https://www.itu.int/dms_pub/itu-d/opb/pref/D-PREF-EF.BDT_AM-2019-PDF-E.pdf
Worldbank source： *https://documents1.worldbank.org/curated/en/178701467988875888/pdf/102955-WP-Box394845B-PUBLIC-WDR16-BP-Exploring-the-Relationship-between-Broadband-and-Economic-Growth-Minges.pdf*
OECD source： https://www.ofcom.org.uk/__data/assets/pdf_file/0025/113299/economic-broadband-oecd-countries.pdf

[8] Ernst & Young, Global Optical Communications Industry White Paper, 2021

and scheduling with high bandwidth, massive connections, and high reliability, and supports remote monitoring and precise control with low latency and packet loss rate.

All of these require optical fiber networks with high bandwidth as well as low latency and jitter. In the actual manufacturing process, jitter for remote monitoring and precise control in the engineering domain must be kept below one millisecond.

Figure 6: Three core scenarios of smart manufacturing

	Big data collection	Remote monitoring	Precise control
Characteristics	Connected devices and closed-loop from production to sales	Devices enabled by fiber optic networks for real-time remote monitoring of working status and fault detection	High-frequency multi-antenna technology and millisecond-level latency for efficient and precise industrial control
Bandwidth	≥50Mbps	≥500Mbps	~1Gbps
Latency	≤100ms	<10ms	1-10ms
Jitter	-	<1ms	<100μs

Source: Expert interviews, Desk Research, EY Analysis (figure 11)

4.2. High bandwidth and low latency

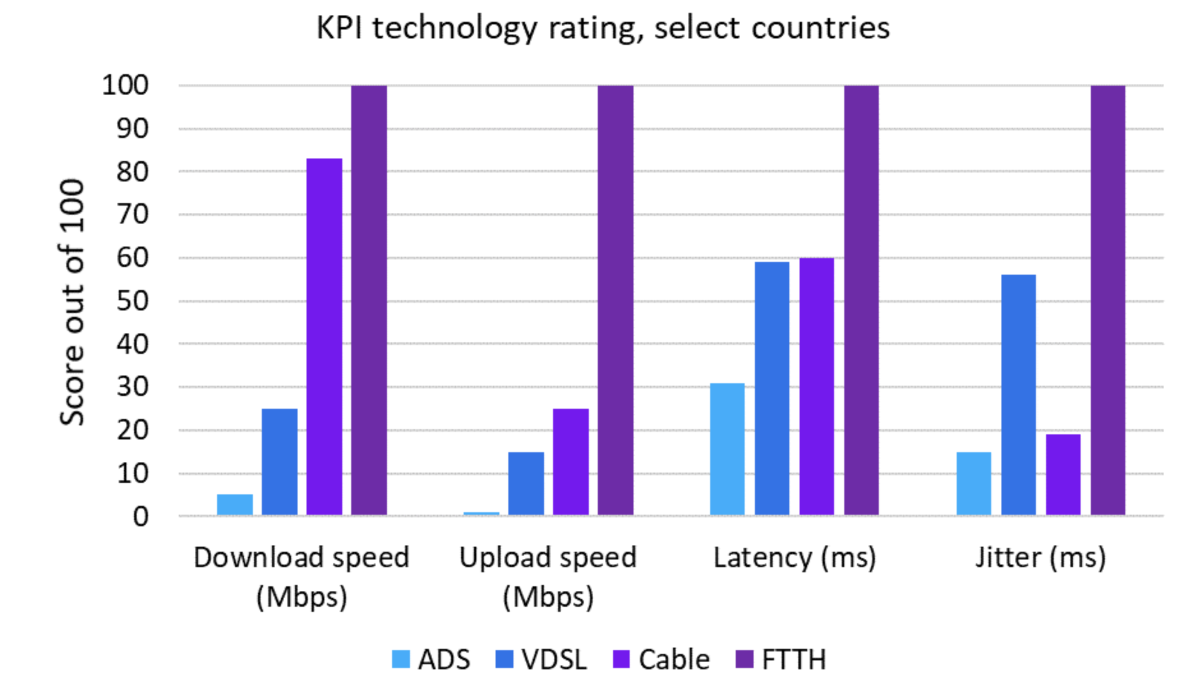
All-optical fiber-based networks are recognized as providing sustainable and cost-efficient communications networks with high bandwidth, stability, reliability, and reduced latency.

Based on real network data from Medux's report "Residential fixed broadband in Europe", Figure 7 illustrates how fiber outperforms other technologies in all areas. Such quality of service (QoS) key performance indicators (KPI) have a significant impact on application quality of experience (QoE). Web browsing, video streaming, gaming and cloud services experiences may all be heavily impacted depending on actual or average/median values, but most importantly on the stability of those KPIs over time, especially during peak hours. As an all-optical fiber-based network not only outperforms other technologies on all QoS metrics, but also has superior network consistency properties, it is proven to offer the customer the best service QoE.

This overall enhanced customer experience has provided fiber-to-the-home (FTTH) operators with a competitive advantage over other forms of broadband competitor in the form of superior net promoter scores (NPS) and reduced customer churn. NPS is a market research metric that is based on a single survey question asking respondents to rate the likelihood that they would recommend a company, product, or a service to a friend or colleague. For Internet service providers, NPS is an important indicator of customer loyalty and satisfaction with their broadband service. For example, in 2019, the Spanish operator Masmovil topped the network quality rankings with its fiber-to-the-premises (FTTP) network, enabling it to boast an NPS ahead of its competitors at that time. Similarly, Swiss fiber broadband alternative provider Salt, which entered the market in 2018 to challenge the incumbent Swisscom and cable operator UPC, achieved the highest score among Swiss broadband providers within one year of launching its full-fiber service.

As with consumer services, fiber-to-the-building (FTTB) ensures enterprises with an optimal network performance ensuring a more reliable, stable and faster service, providing a future-proof network to maximize operational efficiencies, as long as it can be provided at the right cost.

Figure 7: FTTH networks provide a truly high-end experience



Source: Medux, Omdia (includes Germany, Spain, Greece, Ireland, Italy, Portugal, United Kingdom and France)

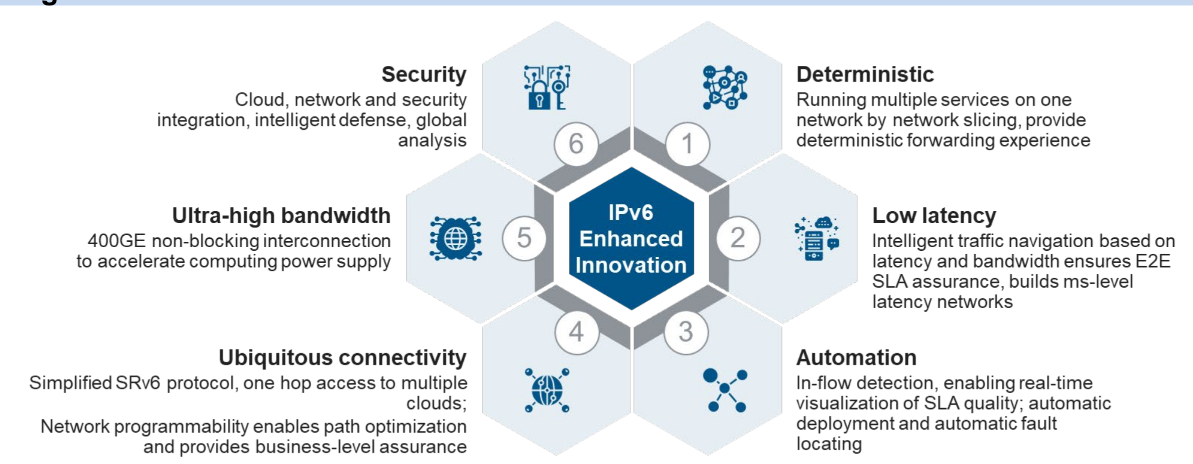
4.3. Better quality connections in more diversified scenarios

One direct positive consequence of the mass adoption of fiber broadband networks is that it allows more devices to be connected concurrently in the same household with no impact on the quality of experience, such as multiple devices accessing high-definition video streaming services at the same time. Soon, Internet-of-Things (IoT) devices will require more IP addresses, and the adoption of Internet Protocol Version 6 (IPv6) will be unavoidable in order to support the increasing number of connections.

In addition to more connections, the new use cases enabled by the adoption of fiber broadband networks will have higher requirements on these connections in terms of quality of experience (e.g. Metaverse, naked-eye 3D, autonomous vehicles, etc.). Collectively known as IPv6 Enhanced, there is a series of innovative standard protocols that aim to offer better quality of service to the connections in more diversified scenarios.

The improvements in quality can be obtained in the following six dimensions: ultra-broadband, ubiquitous, determinism, low latency, automation, and security, benefiting services for governments, operators, and enterprises in various industries and usage scenarios, as well as residential services.

Figure 8: IPv6 enhanced innovation



Source: IPv6

Key innovation technologies include Segment Routing over IPv6 (SRv6), Network Slicing, In-Situ Flow Information Telemetry (IFIT), Bit Index Explicit Replication (BIERv6), Application-aware IPv6 Networking (APN6), etc., all of them are developed in international standardization bodies such as Internet Engineering Task Force (IETF).

4.4. Green low carbon and sustainability

Sustainability is increasingly becoming a key priority. According to GeSI's SMART 2030 report, the adoption of ICT solutions in essential sectors and services like energy, transport, commerce, and building were to reduce global carbon emissions up to 15% and save up to 600 million EUR while creating 15 million green jobs.

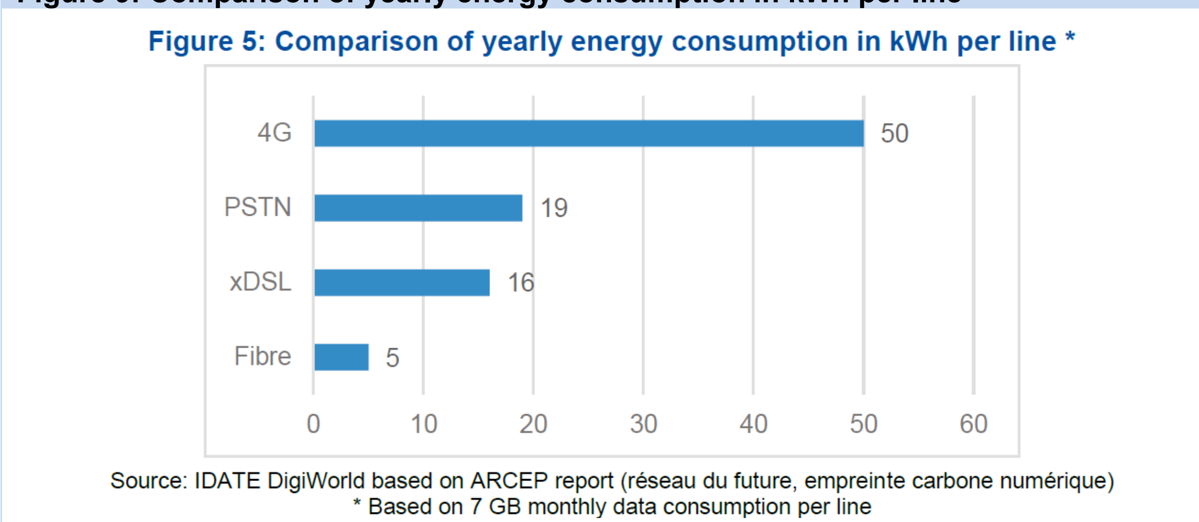
The green agenda has become an important topic for national governments as well as private enterprises. Many broadband service providers have already adopted environmental elements to their list of corporate values. Moving to a 100% optical fiber network can help with such initiatives as fiber has several inherent properties that make it more environmentally friendly compared to copper-based networks.

All-optical fiber networks require much less active equipment in the field to power them, significantly reducing energy consumption. An optical distribution network (ODN) requires zero electrical power. In addition, due to fiber's significantly higher bandwidth capacity at a fraction of the size and weight of copper wiring, it requires significantly less power per bit. Typically, according to equipment vendor Huawei, for every 10,000 access connections that evolve from copper access to a FTTH GPON, the operator saves over 1,500kWhs of power.[9]

In 2019, Telefónica (Spain) stated that its FTTH network was 85% more energy efficient than its old copper infrastructure, and it had reduced energy consumption by 208 GWh over three years, representing a reduction of 56,500 tons of CO_2 emissions[10].

Moreover, according to Idate report[11], energy consumption of fiber broadband is 3 times lower than that of xDSL and 10 times lower than that of 4G mobile technology.

Figure 9: Comparison of yearly energy consumption in kWh per line



Source: IDATE DigiWorld based on ARCEP report (figure 5) / February 2022

White Paper information reference: https://en.idate.org/content/uploads//2022/02/White-Paper_Fiber-for-a-sustainable-future.pdf

[9] Source: Idate DigiWorld, Fiber for a sustainable future, 2022

[10] Source: Idate DigiWorld, Fiber for a sustainable future, 2022

[11] Source: Idate DigiWorld, Fiber for a sustainable future, 2022

4.5. Durable and reliable

All-optical fiber networks are future-proof. From a technical perspective, the optical fiber capacity is 1000 times higher than that of copper (life of copper networks average in ideal conditions more than 40 years) and cable (life of coaxial networks may vary but in ideal conditions more than 40 years) and will depend on maintenance conditions as well. The service life of an optical fiber network is 30 years, and it can support smooth upgrade of different generations of optical technologies.[12]

Backbone capacity determines the performance ceiling of a national backbone network. Fiber optical technologies provide sufficient capacity for network evolution. With one-time investment in fiber backbone, a national backbone network is future-proof and ready to integrate generations of various access technologies.

The development of AI, cloud and big data will boost national economy and growth of service providers, but it also requires a high-performance network. Generative AI improves productivity, yet for any enterprise or individual who wants to use AI to boost their productivity, it is essential to be connected to a network that can support the massive computing power behind AI. Given the fact that such computing power normally exists in computing nodes throughout a country and on cloud, the quality of connection determines the extent to which any entity or individual will be able to utilize and benefit from this next generation productivity tool.

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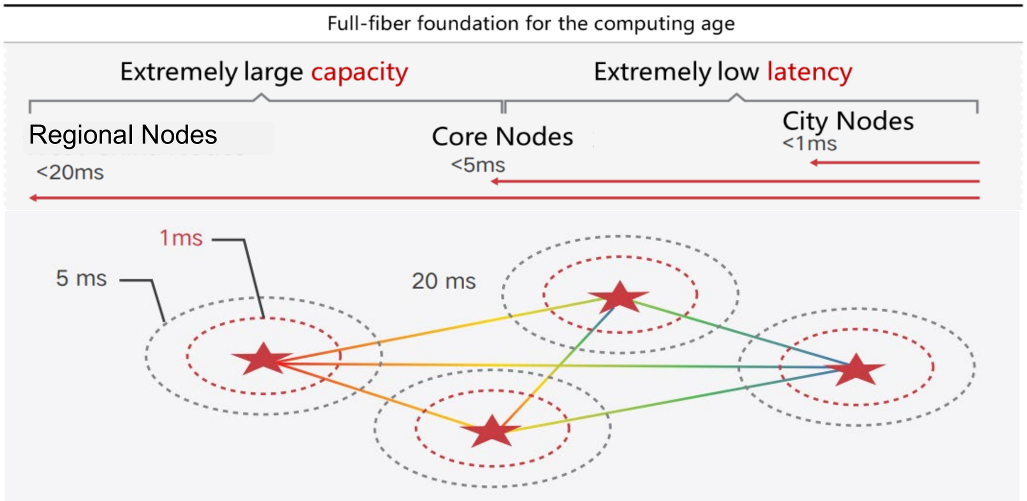
[12] (EY, The Backbone of Digital Economies: The Revolution of Global Industries through Optical Communications)

Figure 10: Full-fiber foundation for the computing age



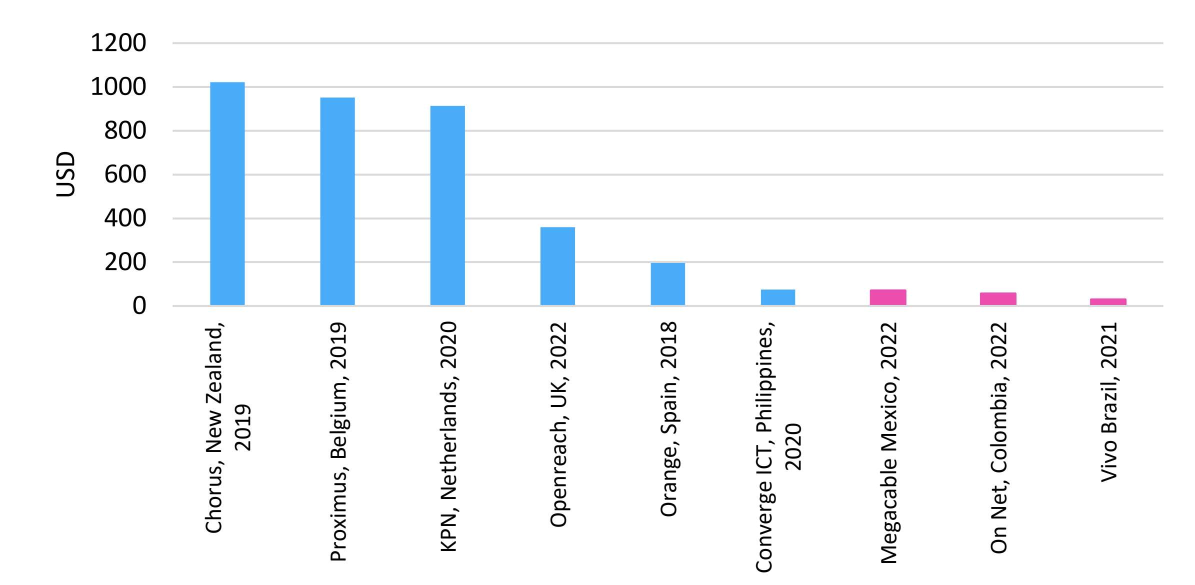
Source: http://www.cww.net.cn/article?id=568563 page 15

4.6. Low overall construction cost

FTTP costs per premises passed in Mexico and Latin America are very low compared to developed markets and can be around the USD $60 mark (see Figure 11) according to selected operators information reported by Omdia. For Mexico, Omdia estimated that Megacable had a USD $71 fiber cost per premise (2022 reported information), while On-Net Colombia had a cost of USD $57 per premise and Vivo Brazil around USD $30 in 2021. This significantly improves the business case for FTTP rollouts. There are several reasons for low FTTP costs per premises passed in Latin America:

- Lower incomes in the region help reduce labour costs which can be a large component of fiber rollout costs in Western Europe, for example.
- Latin America is a highly urbanised region which helps reduce the overall costs of deployment. According to World Bank figures in 2022, 81% of the population in Mexico lived in urban areas. This compares to just 57% for the whole world, 42% in Sub-Saharan Africa and 35% in South Asia. Population density in urban areas in Mexico and Latin America can also be high which reduces fiber rollout requirements.
- FTTP rollouts can mostly be conducted aerially in Latin America which significantly reduces the time required for deployments. In countries with very high FTTP costs per premises passed such as Belgium and Germany this often reflects the fact that there are no existing underground ducts to use for FTTP rollout since copper cables are directly buried.

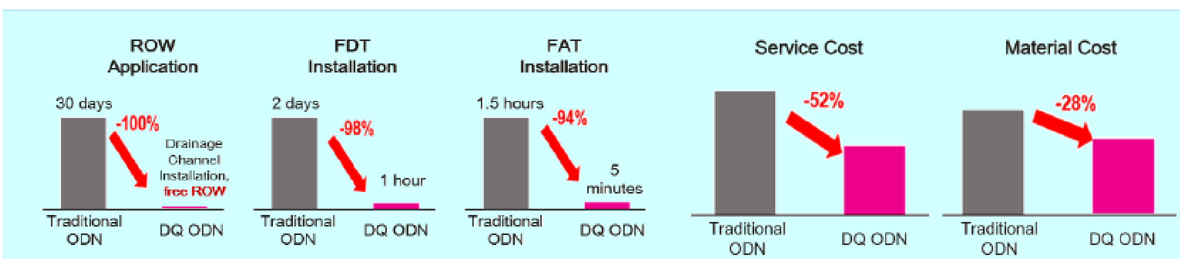
Figure 11: FTTP costs per premises passed by selected operator



Source: Operators reported and Omdia. In certain cases, for example Orange Spain and Megacable Mexico, estimated by Omdia derived from a total cost figure reported by the operator with total homes passed figure reported by the operator.

Moreover, latest fiber solution is cutting deployment costs drastically. For example, the digital-quick optical-distribution-network (DQ ODN is a full preconnectorized solution) can realize drainage installation, which exempts the approval for rights of way. Previous 30-day construction span can therefore be shortened to less than one day.

Figure 12: Cost comparison traditional ODN (a fusion solution) vs DQ ODN

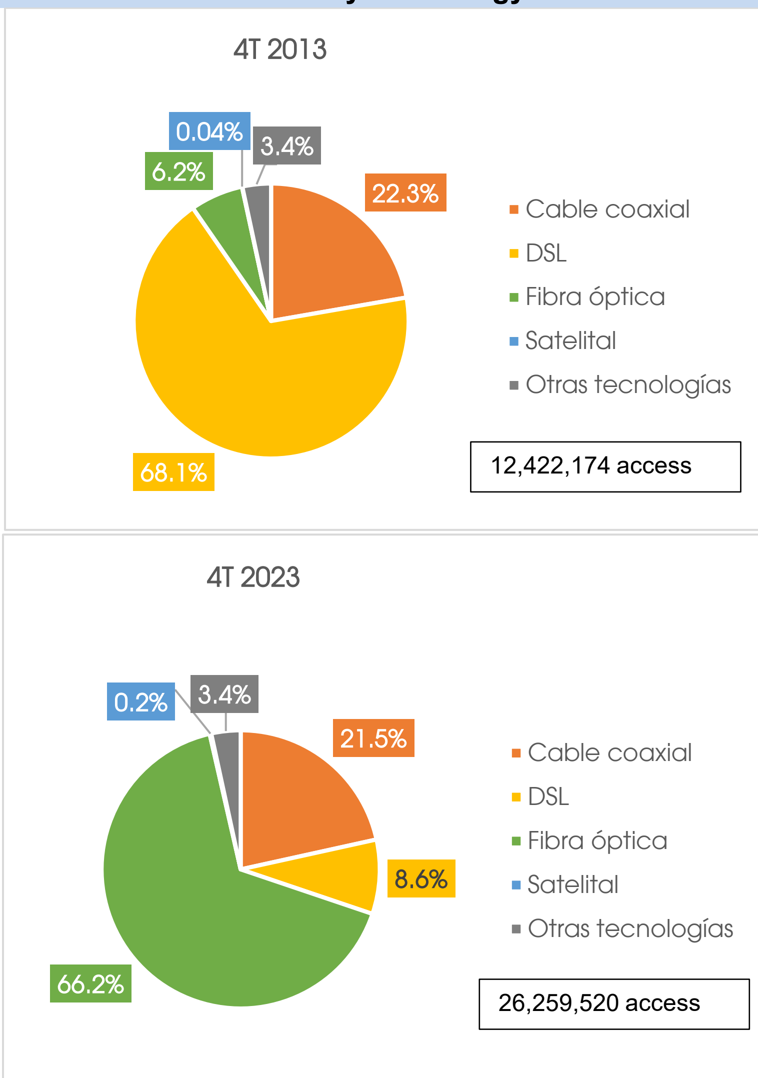


Source: From Huawei Malaysia Operator TIME Case

V. Broadband Status and Challenges in Mexico

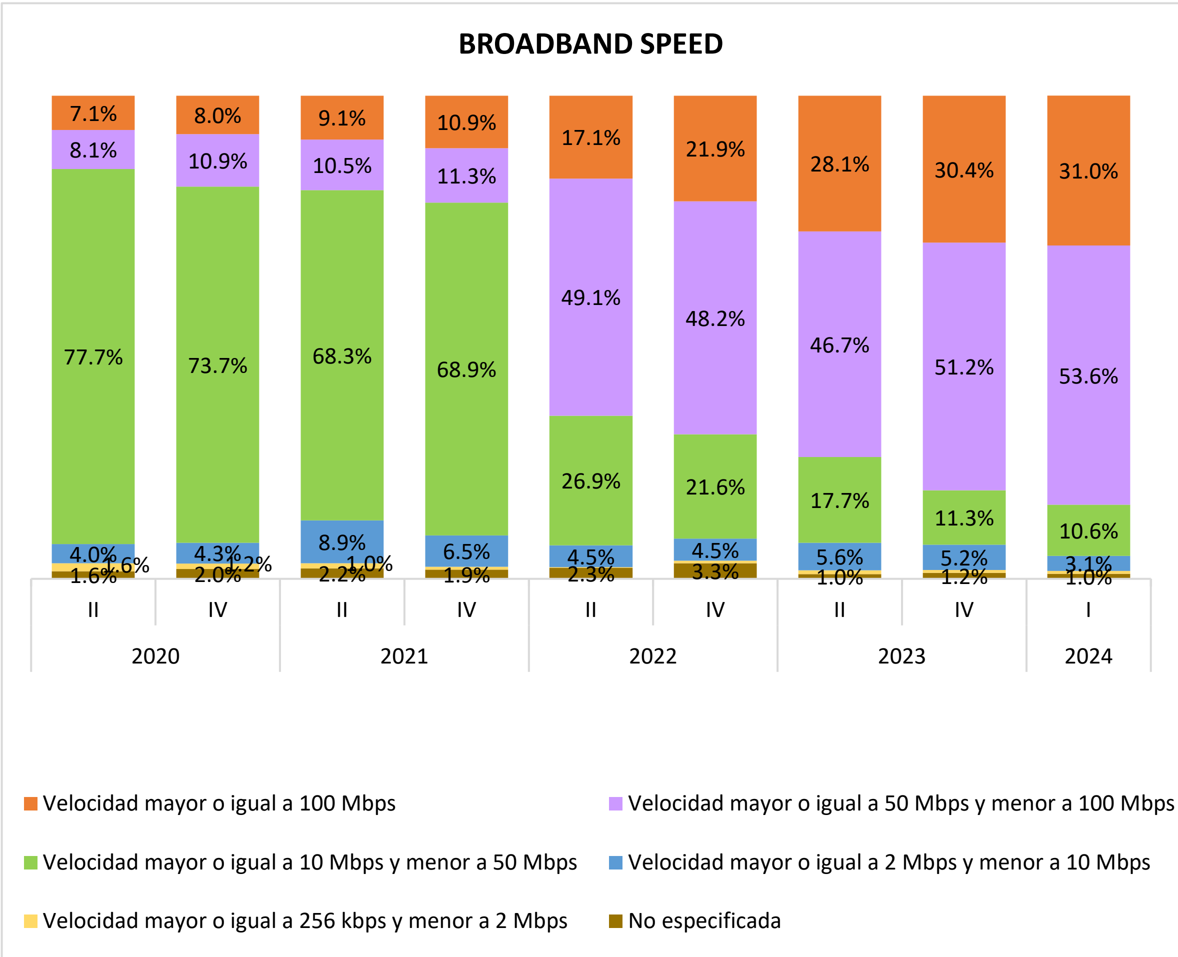
In the past few years, Mexico's fiber broadband market has developed rapidly, and both coverage and speed have been significantly improved (see Figure 13 and 14)

Figure 13: Fixed broadband evolution by technology in Mexico



Source: IFT

Figure 14: Fixed broadband evolution by download speed in Mexico

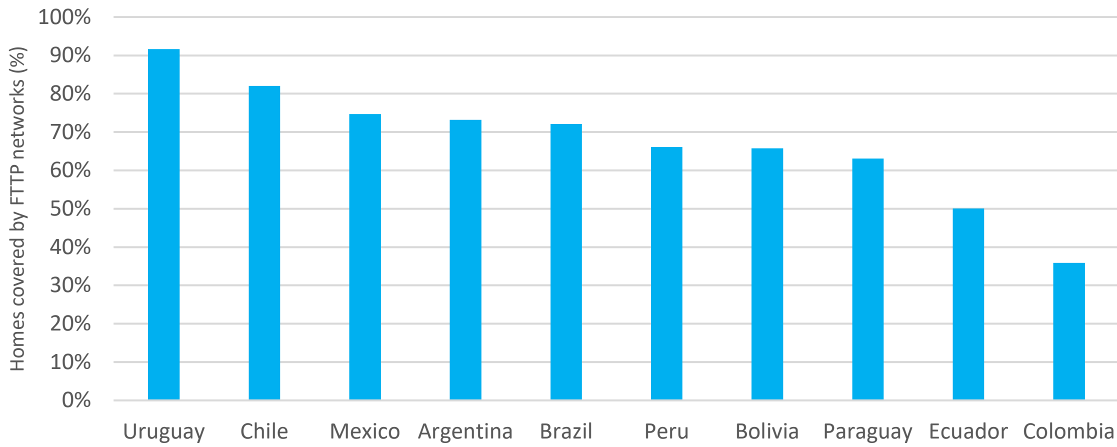


Source: IFT

5.1. Fiber broadband coverage and penetration status

To accelerate the availability of high-quality broadband networks it is essential that Mexican network operators continue with their fiber network deployment efforts. By the end of 2023, around 75% of Mexican households were passed by fiber networks, a FTTP coverage level below several peer countries in the region.

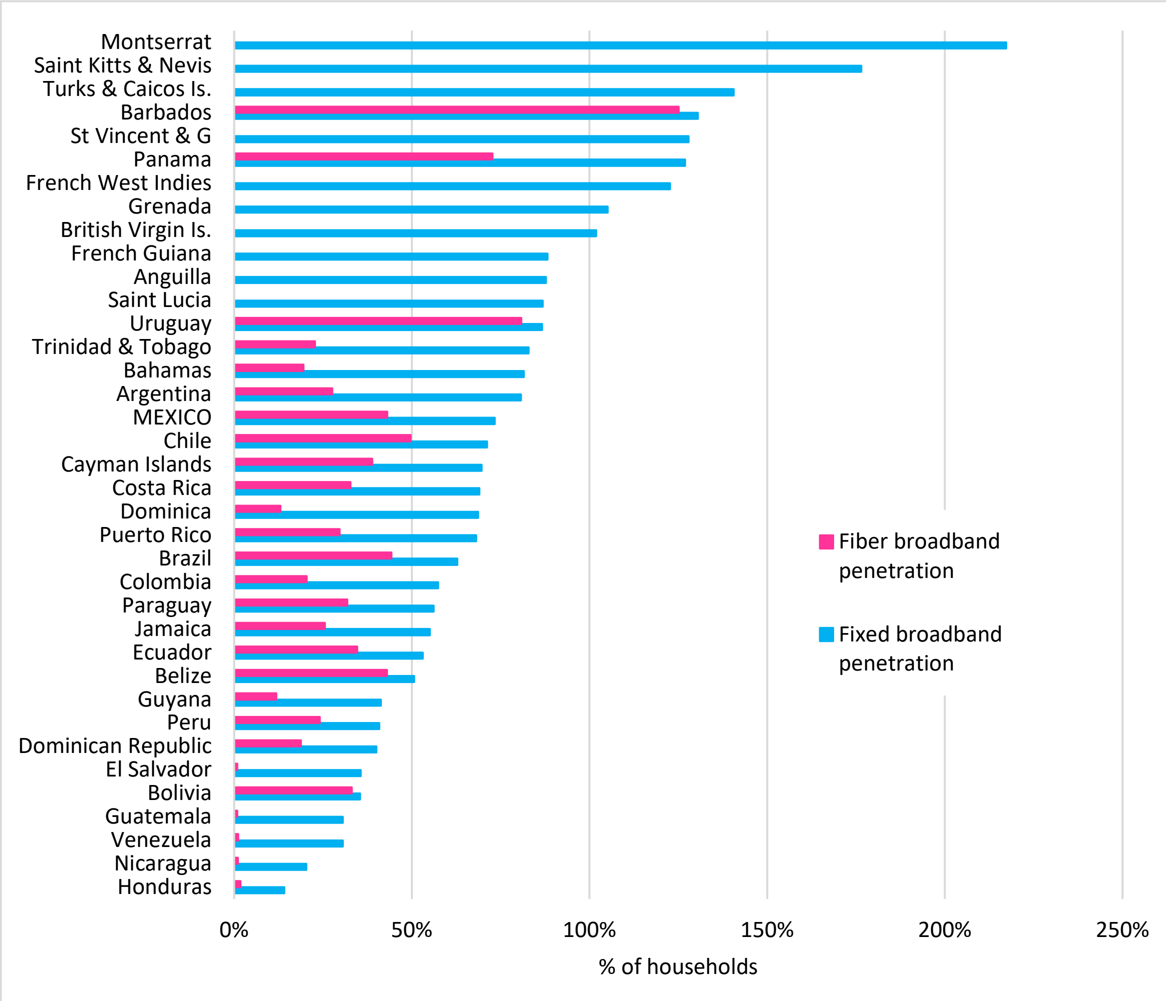
Figure 15: FTTP coverage in Latin American countries, end of 2023



Source: Omdia's Fiber Development Index 2024, information of January 2024

Mexico is above the Latin America regional average with 73% fixed broadband household penetration, but only 43% of Mexican households have a fiber broadband connection.

Figure 16: FTTP coverage in Latin American countries, 2023

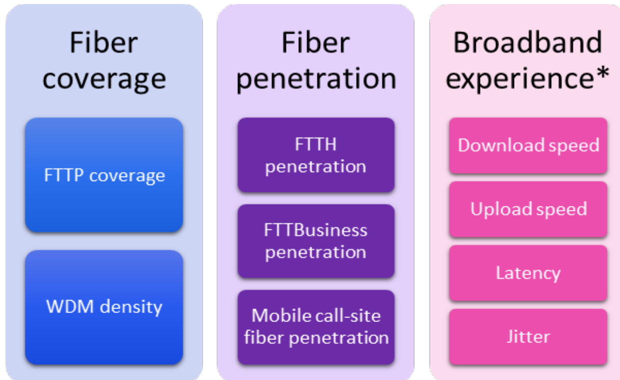


Source: Omdia

Note: Both fixed broadband and fiber broadband penetration is calculated using total broadband subscription data, which includes both enterprise and consumer broadband subscriptions

In 2020, Omdia created its Fiber Development Index (2024 is its fifth iteration), which tracks countries investment in fiber in both the access, backhaul and core networks via five key metrics. To measure the impact of this investment, Omdia then measures the overall broadband experience across 4 further metrics (Figure 17).

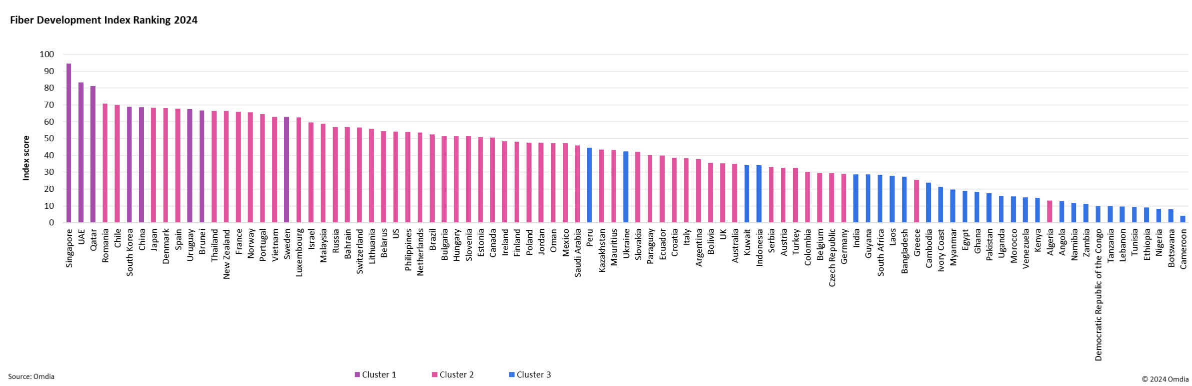
Figure 17: Omdia's Fiber Development Index



Source: Omdia's *Broadband experience measures are based on Omdia's analysis of Ookla Speedtest data

Omdia's Fiber Development Index covers 93 countries and territories of varying sizes, demographic and geographical profiles, and levels of broadband development. In Latin America, Chile and Uruguay outstand in the top fifteen countries of the ranking, while the rest of Latin American countries are still behind in fiber development and adoption. Mexico is in the 42nd position, rising 3 positions from 2023 ranking.

Figure 18: Omdia's Fiber Development Index (FDI): Chile is the leading Latin American country in the Fiber Development Index 2024



Source: Omdia FDI - https://omdia.tech.informa.com/om032629/fiber-development-index-2024

Table 2: Global broadband experience by metric for Latin American countries

Country	Median download speed	Median upload speed	Median latency	Median jitter
Chile	90	72	82	79
Uruguay	55	13	91	79
Brazil	57	38	91	79
Colombia	48	21	39	35
Peru	54	38	68	79
Paraguay	32	12	51	48
Argentina	30	15	29	35
Ecuador	32	36	91	79
Mexico	26	17	82	48
Guyana	29	13	91	35
Bolivia	13	7	35	29
Venezuela	20	21	51	29

Source: Omdia's Fiber Development Index

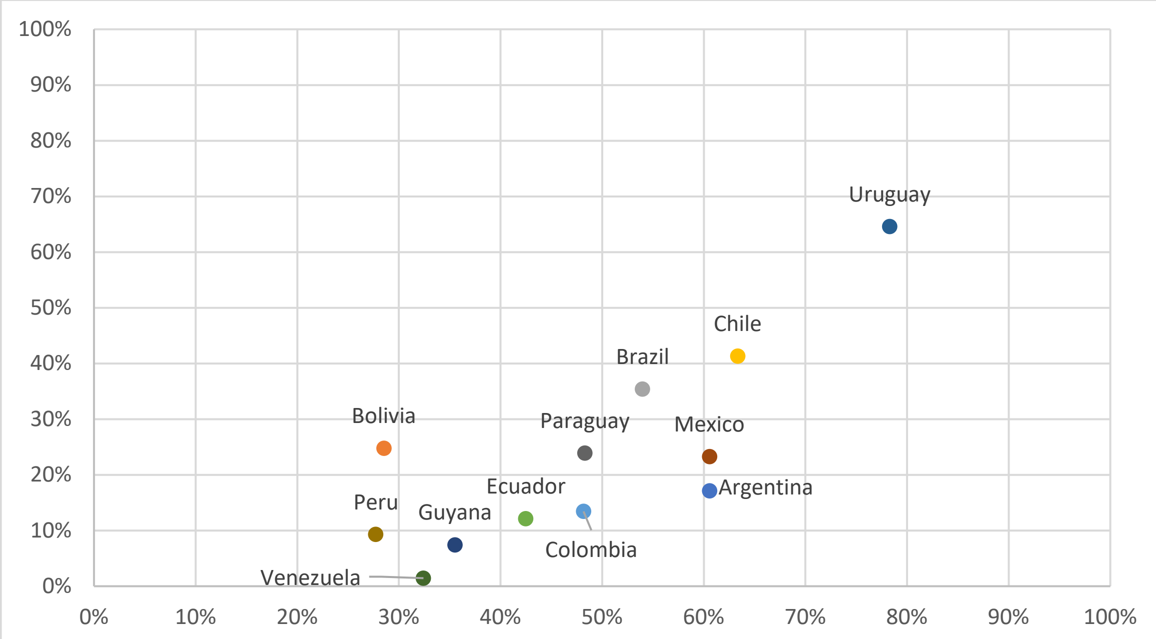
Mexico is progressing in the ranking each year, gaining positions but still below mid table of the ranking. The challenge for Mexico, like for all emerging broadband countries, will be to continue to expand FTTH networks so it can move towards becoming an advanced fiber broadband country.

Table 3: Omdia's Fiber Development Index (FDI) – Mexico

Rank	Country/ Territory	Rank change 2022–23	2020 Index Score	2021 Index Score	2022 Index Score	2023 Index Score	2024 Index Score
42	Mexico	3	23	28	34	40	47

Source: Omdia's Fiber Development Index

Figure 19: Residential broadband household penetration vs FTTH penetration, FDI 2024

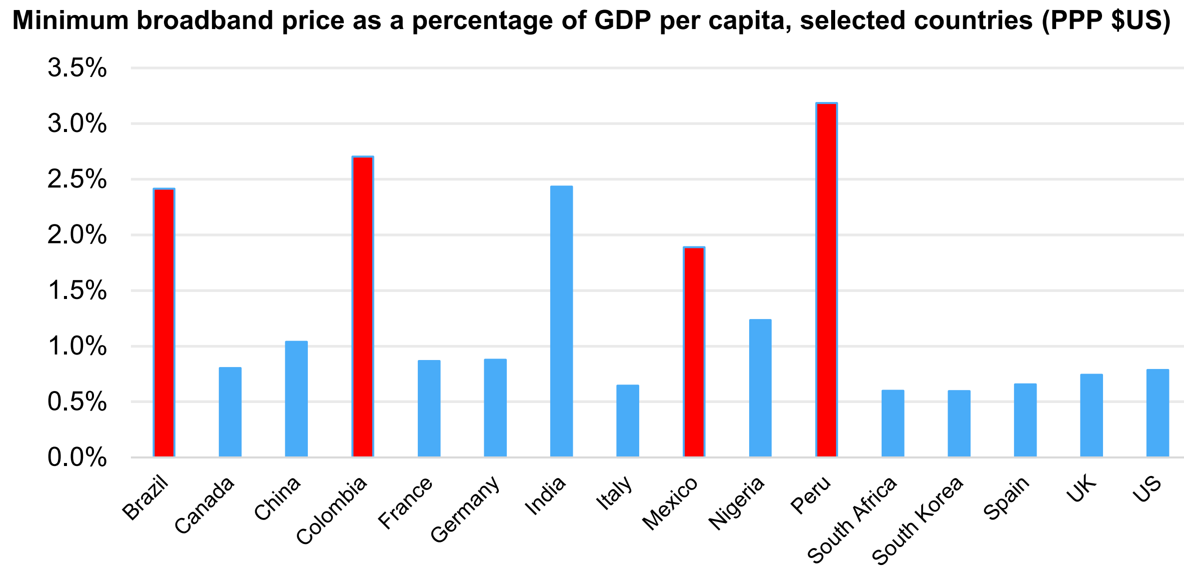


Source: Omdia

Note: In the Fiber Development Index, Omdia uses true residential penetration data, i.e. including only total broadband and fiber broadband subscriptions purchased by residential home customers, taking out all enterprise subscriptions as well as small and micro-business subscriptions of consumer broadband plans. https://omdia.tech.informa.com/om032629/fiber-development-index-2024

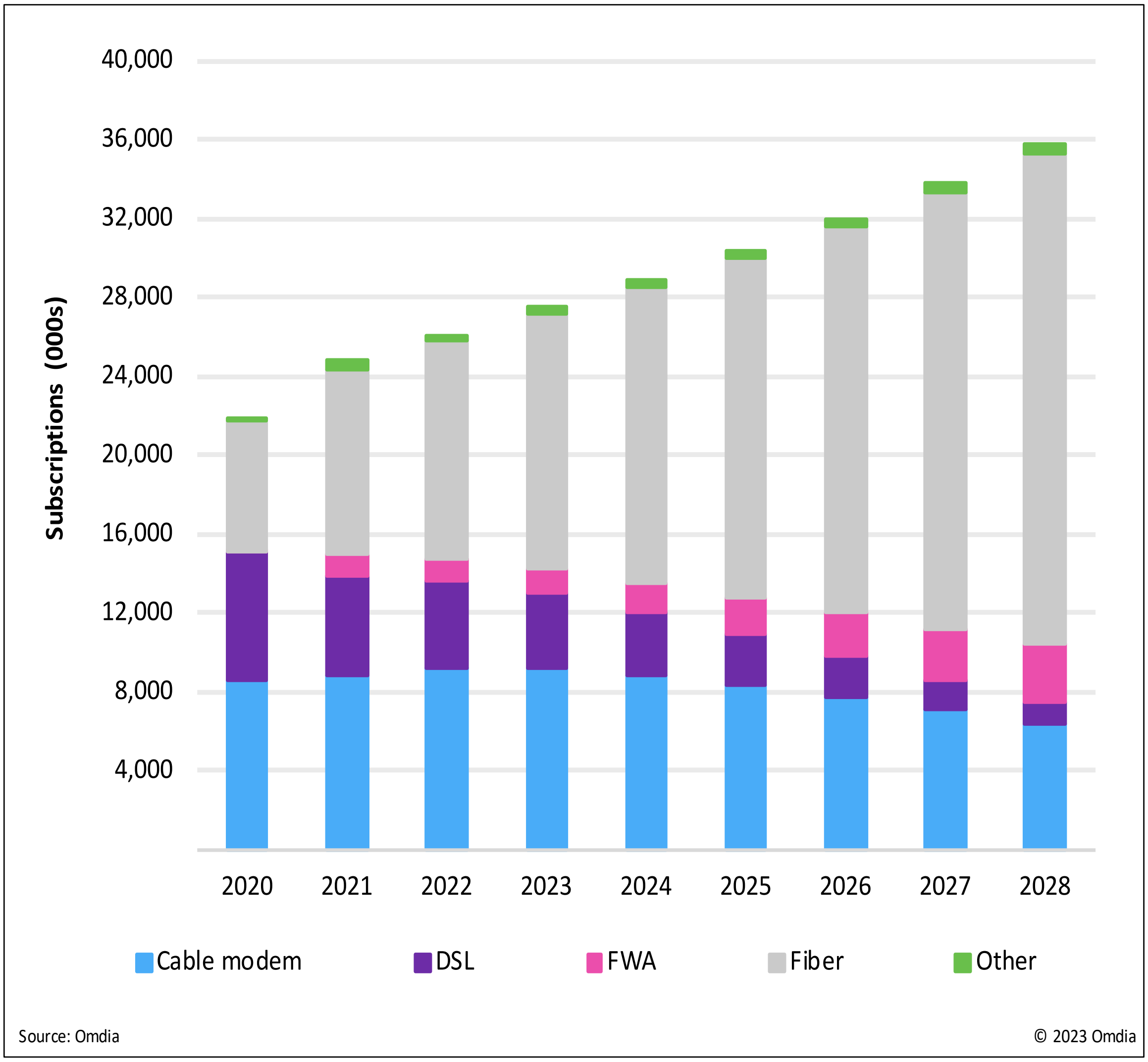
Although not a silver bullet, fixed broadband can help increase overall wealth as well as income equality through increasing population education as well as occupational mobility – two of the key drivers of income inequality. However, to do so, broadband must be available to all and thus must be made affordable to all economic classes. Figure 20 illustrates that currently broadband prices can be high as a proportion of GDP per capita in Latin American countries. Mexico minimum fixed broadband price is around 1.9%, above several developed countries, but in better position than Peru, Brazil and Colombia which are above 2.5% of GDP per capita.

Figure 20: Minimum broadband prices in Latin America are high when compared to other countries.



Source: Omdia, World Bank

Figure 21: Mexico Fixed broadband subscriptions by technology (2020-2028) Omdia Forecast

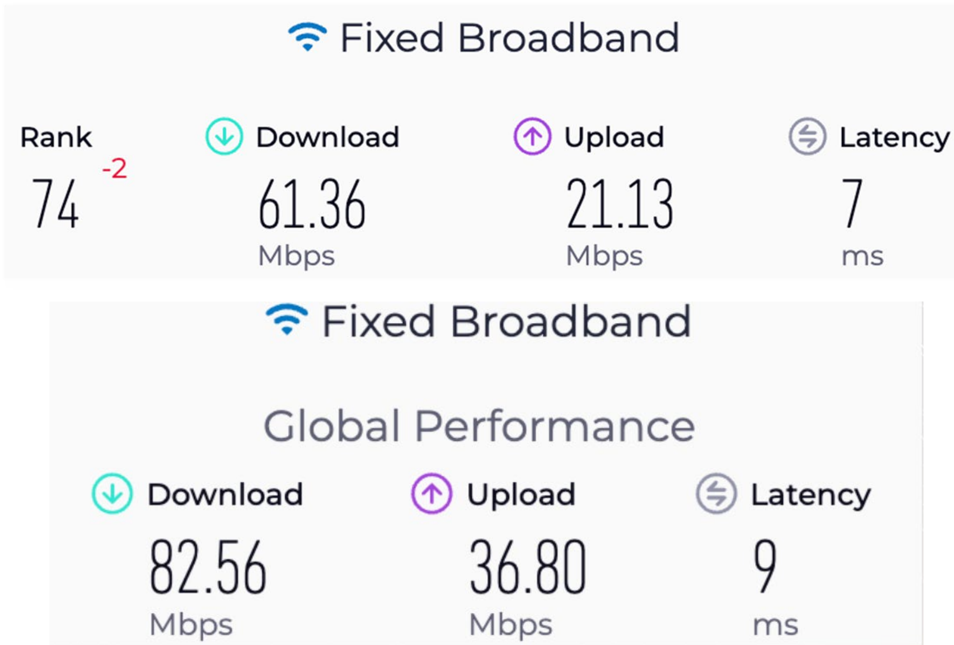


Source: Omdia

5.2. Broadband Speed Status

According to the latest Ookla's Speedtest statistics (August 2023), Mexico's median download speed rate is 61.36 Mbit/s, and the median upload speed reaches 21.13 Mbit/s. This is lower than the global median download speed rate of 82.56 Mbit/s and upload rate of 36.8 Mbit/s (Megabits per second)

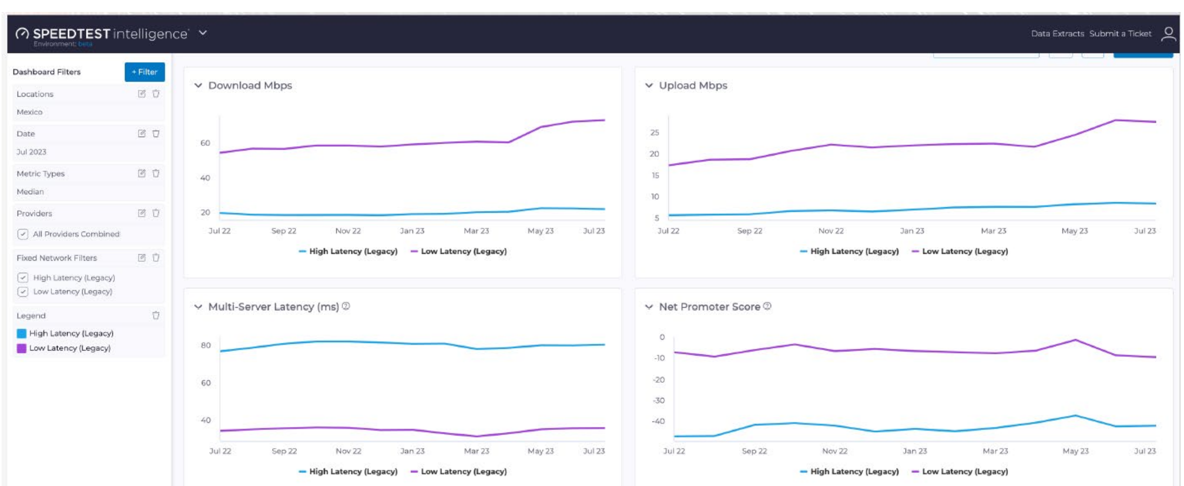
Figure 22: Ookla's Speedtest statistics - Fixed broadband performance: Mexico vs Global



Source: Ookla's Speedtest Global Index

According to technical statistics, compared with other access technologies, the download and upload speed rates of FTTH in Mexico are significantly higher than those of other access technologies (see figure 23), providing a further impetus for acceleration of fiber networks deployment in the country.

Figure 23: Ookla's Speedtest statistics - Fixed broadband performance FTTH vs other technologies Mexico



Source: Ookla's Speedtest Global Index

VI. Regulatory Context

6.1. Measures implemented/needed to promote infrastructure competition

Over the past few years, regulatory measures imposed on the preponderant operator, such as interconnection rates and infrastructure-sharing obligations, have benefited the consumers, which have witnessed a drastic decline in services prices.

Moreover, due to the need for unprecedented levels of investment in fiber and 5G networks coupled with a shrinking and highly competitive market for investment resources, there has been a realisation amongst policy-makers and industry stakeholders that infrastructure sharing, and co-investment models offer greater benefits at lower costs.

Increasingly, companies are sharing networks to lower costs, maintain profit margins and focus on innovative services to meet shifting customer demands. This dynamic requires unprecedented collaboration among operators as well as favourable regulatory environment to facilitate this process.

The increase in telecoms infrastructure sharing has allowed for a more efficient roll-out of next-generation networks. The sharing of towers and other passive equipment, including the participation of a growing range of different industry and public-sector players, also translates into the sharing of expertise and best practices. Infrastructure sharing also helps to boost competition and improve economies of scale to accelerate the development of our digital economy.

Table 4: Pros – Cons of the economic case for infrastructure sharing

Pros	Cons
Efficient use of scarce resources (avoid economic and environmental costs in network duplication)	Reduced incentives to investment
Lower industry costs (A report by the Body of European Regulators for Electronic Communications, BEREC, suggests that infrastructure sharing could reduce capital	Reduced network resilience

expenditure by up to 45% and operational expenditure by up to 33%). (BEREC, p16)[13]	
Increased network coverage	Risks of collusion
Enhanced competition	Operational challenges and costs
Lower consumer prices	

Source: Omdia based in ITU – World Bank digital regulation platform

Although there are downsides as well as benefits from infrastructure sharing, a positive overall view of infrastructure sharing is widespread amongst regulatory authorities across the world.

The challenge for regulation is to establish the conditions that maximise the benefits, minimise the downsides and create the environment for infrastructure sharing to make a positive economic impact – a situation sometimes called "co-opetition". The policy objective for infrastructure sharing is clear and straightforward: there should be as much sharing as technically feasible and economically desirable. This will minimise the overall costs of the industry, avoid unnecessary duplication and environmental disruption, and ultimately lead to improved service availability and lower prices.

Table 5: Network sharing best practices

Public Policy best practice	Country	Description
Network sharing obligations to all players	UK	OFCOM regulated in 2020 that all access seekers and access providers have an obligation to negotiate infrastructure sharing agreements, and that the terms of those agreements should be transparent, fair and non-discriminatory (there is considerable room for commercial negotiation). Regulation of the SMP (Significant Market Power) provider was required alongside wider Access to Infrastructure Regulations (UKG, 2020) that apply to all infrastructure owners.
Single shared neutral infrastructure Open Access and Co-Investment	European Union	The new EECC (in force since December 2018), considers wholesale players as key actors to enhance competition levels in emerging fiber markets (pro-

[13] BEREC, Report on infrastructure sharing BoR (18) 116, June 2018 https://www.berec.europa.eu/sites/default/files/files/document_register_store/2018/6/BoR_%2818%29_116_BEREC_Report_infrastructure_sharing.pdf

		competitive nature of independent TowerCos and infraCos). Operators with significant market power offering access to their infrastructure via co-investment can be exempted from other forms of access obligations. Almost all European countries have implemented open access fiber networks, and many of them are related to Public Initiatives Networks (with public funding). Fiber sharing is regulated in several countries, either passive or active (bitstream access). In Spain, Italy and Portugal, voluntary agreements between operators were achieved, while in other markets, such as France, co-investment regulation was implemented. In February 2023 the European Commission presented a set of actions aimed to make Gigabit connectivity available to all citizens and businesses across the EU by 2030: • Gigabit Infrastructure Act Proposal (GIA) (a regulation that will put forward new rules to enable faster, cheaper and more effective rollout of Gigabit networks) • Draft Gigabit Recommendation (conditions for access to telecom networks of operators with significant market power, in order to incentivise faster switch-off of legacy technologies and accelerated Gigabit networks deployment). Exploratory consultation on the future of connectivity and broadband infrastructure, including the Fair Share debate.
Fiber Deployment guidelines, Asymmetric regulation (i.e., sharing infrastructure reference offers, recommendations for new measures that incentivise deployment).	France	The French fiber regulation includes “asymmetric” regulation imposed by ARCEP for several markets. The rules require all operators installing FTTH/B in buildings to deploy it in such a way as to allow access to passive (dark fiber) networks at concentration points aggregating at least 1,000 lines. Offers must include the potential for co-financing (on the basis of indefeasible right of use or IRU) before the investment occurs, after the investment – or on the basis of short-term rental. The terms and conditions as well as prices were established through a series of disputes resolved by the regulator. Prices were cost-based, but with mark-ups on the WACC to account for increased risk.

One of the key challenges in the deployment of fiber networks often quoted by network operators, are legal and regulatory obstacles to obtain the necessary authorizations. These barriers are often a source of uncertainty regarding the time and conditions in which the infrastructure deployment will be carried out, affecting the ability of operators to deploy fiber networks according to planning and schedules.

In this same sense, concessionaires that already provide services need to complement their telecommunications infrastructure by leasing network elements from another operator in those areas where they do not have their own infrastructure or sufficient capillarity of their networks. Therefore, purchasing a wholesale service from another operator allows them to reach an efficient scale to install their own infrastructure in the medium term.

The IFT determined that access to the passive infrastructure of the Preponderant Economic Agent is necessary to allow other concessionaires and operators to provide competitive services without having to incur high costs of fiber rollout investment in those areas where it is not possible to reach a minimum scale of operation. In this way, the preponderant's asymmetric regulation through the use and shared access of its infrastructure under non-discriminatory conditions allows a reduction in network deployment costs, reducing the required investments, freeing up resources to finance operating costs.

6.1.1. Entry barriers imposed by local authorities

One of the main barriers faced by telecommunications operators in fiber deployments in Mexico is associated with bureaucracy and the lack of transparency in government entities regarding the diversity of permits that must be processed and the requirements that must be satisfied to obtain them.

Currently, there are 2,469 municipalities in the 32 states of the country, which makes the task of identifying and locating the permits and requirements that are needed exhausting.

Therefore, because there is no single legal instrument or any kind of guideline that regulates the requirements, authorization periods, costs, processing areas or a single permit that is exclusive to the installation, operation and/or maintenance of telecommunications network infrastructure throughout the Mexican Republic, it is very common that procedures and waiting times differ considerably from one municipality to another.

6.2. Promoting Competition

Because of the evolution and convergence of networks, it is now possible to provide a wide variety of digital services that go beyond the services traditionally offered by telecommunications operators such as broadband, voice, pay TV, messages, and data. In this sense, in addition to operators, over time new players such as Over-the-Top (OTT) video providers, cloud service providers, equipment and network infrastructure providers, and other digital services providers have been integrated into the market, forming the current digital ecosystem.

As such, telecommunications networks infrastructure is the backbone on which this digital ecosystem is based and in which optical fiber technology is the main element that provides the capacity for the transport of all the data generated by the different digital services.

For this reason, the IFT continuously reviews and updates the regulatory framework through the implementation of flexible regulatory mechanisms and policies, establishing the appropriate conditions that facilitate the deployment of optical fiber infrastructure throughout the country and favour the entry and integration of new players to the market in such a way that all players are in a position to deploy their own optical fiber networks and / or have access to the fiber infrastructure that is already deployed.

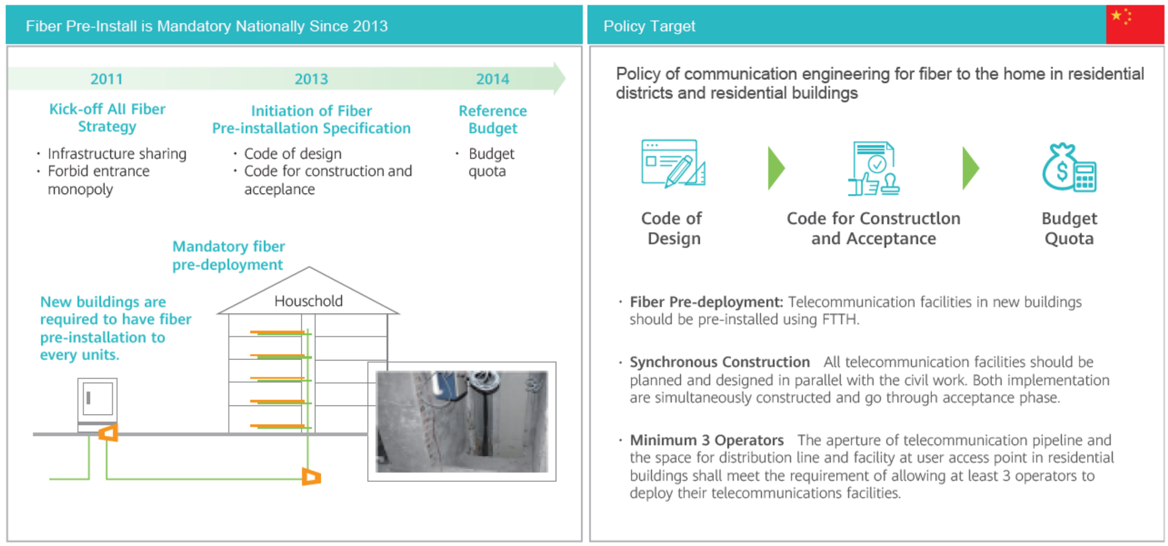
Pre-installation policy

Fiber pre-deployment policies encompass a range of measures and regulations aimed at facilitating the planning, construction, and installation of optical fiber networks before the actual deployment takes place. These policies typically focus on creating an enabling environment and addressing potential obstacles to fiber infrastructure development, such as planning and coordination frameworks that require or encourage coordination of fiber rollout plans with other infrastructure development projects (e.g. road constructions or utility installations).

Table 6: Pre-installation Best practices

Public Policy best practice	Country	Description
Pre-installation	**China**	Developed a fiber pre-deployment strategy in residential buildings in order to facilitate the development of fixed broadband services over fiber networks. Since 2013, all buildings applying for a construction permit must adhere to design codes, and construction and acceptance codes.
Infrastructure sharing	**Spain**	One of the leading countries in terms of fiber deployment. The success of the Spanish fiber roll-out can be for a large part attributed to favourable regulatory environment which supported infrastructure sharing and co-investment agreements between the incumbent, Telefónica, and its competitors. By actively promoting infrastructure and investment sharing agreements, Spanish operators were able to share costs and risks, especially in rural areas, and thus reach much higher connectivity levels than other key markets in Europe. Since 2013, operators reached an agreement on the sharing of vertical infrastructure within buildings and on the unbundling of fiber lines reaching end users and asked the regulator to set the prices for these services. In order to close the gap with Telefónica, Orange Spain and Vodafone announced ambitious plans for FTTP roll-out in Spain and signed their owns network sharing scheme in 2014. And in 2016, Orange Spain entered into joint network rollout agreement with Grupo MASMOVIL and Telefónica entered into a wholesale agreement with Vodafone Spain.

Figure 24: Fiber Pre-installation case study - China



Source: F5G lights up Giga, Brazil

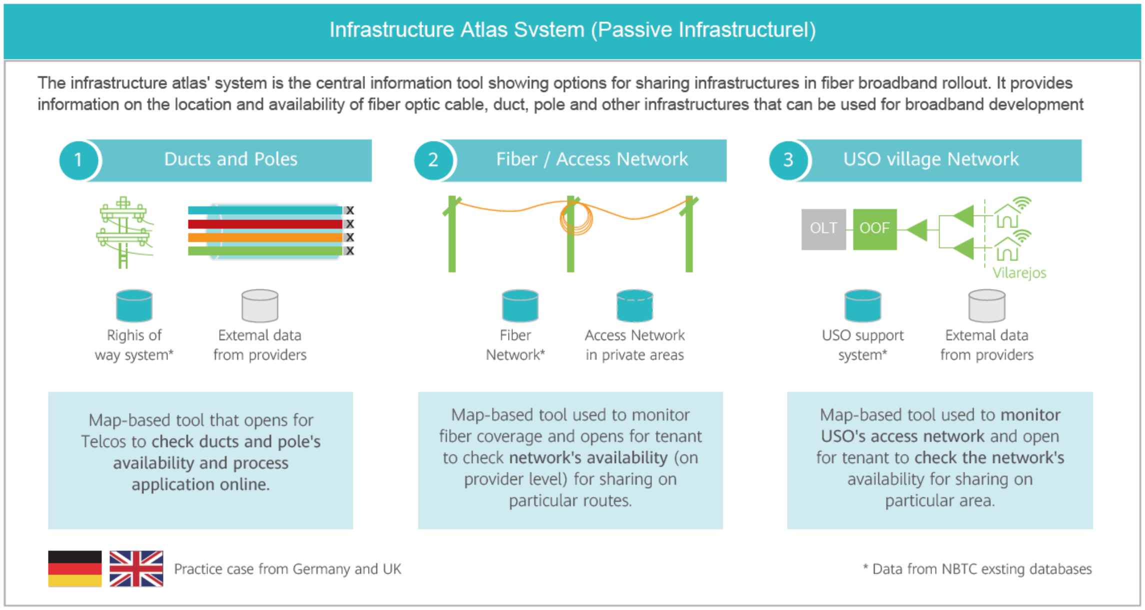
Establishing a map-based support system for infrastructure sharing by leveraging existing infrastructure, such as ducts or conduits, service providers can avoid the time-consuming process of obtaining permits and carrying out extensive construction for every deployment. Infrastructure sharing enables faster deployment of fiber networks as providers can utilize the existing infrastructure to extend their coverage and reach areas that might otherwise be economically challenging to serve. By sharing infrastructure, providers can extend their networks to underserved or remote locations.

Several countries have done efforts and continue working in having infrastructure broadband maps to facilitate infrastructure sharing and promote service competition. The infrastructure map or atlas system is a central information tool showing options for available infrastructure that could be shared in fiber broadband (and other technologies as well). It provides information on the location and availability of ducts, poles and other infrastructures that can be used for broadband deployment at a reduced and more efficient cost and time.

Table 7: Infrastructure broadband mapping best practices

Public Policy best practice	Country	Description
Infrastructure broadband mapping	**Slovenia**	An infrastructure mapping tool PROSTOR was developed in Slovenia by the Surveying and mapping Authority (Geodetska Uprava Republike Slovenije) under the Ministry of Environment and Spatial Planning. The mapping system presents graphical form of the data on ducts, cables, nodes, base stations, etc. The system gathers data on electronic communication operators' facilities, mainly location and type of networks used. Citizens can check availability of broadband provided by operators.
Infrastructure broadband mapping	**Germany**	Germany established a voluntary central infrastructure atlas in 2009, in 2018 was extended and in 2020 was relaunched with new interface and various new functions. It facilitates the use of synergies in infrastructure deployment. The atlas contains spatial data about the infrastructure of companies and institutions, such as geo-data about optical fiber lines, empty ducts, radio towers and masts as well as radio stations. More than 1,500 institutions are using it and 3,325 suppliers of information (telecoms, electricity, gas, local authorities, sewage, transport). It is a web-based geographic information system (web GIS). It also is a central information point, that shows broadband penetration and availability.

Figure 25: Infrastructure Atlas System (Passive Infrastructure) case study – Germany and UK



Source: F5G lights up Giga Brazil

6.3. Integration of new players into the digital ecosystem

As previously discussed, fiber networks provide the necessary capacity to optimally support the transport of the large amount of data generated today, as well as those generated in the future as a result of the increasing demand for data traffic derived from the growing use of bandwidth-hungry digital services and applications, such as Cloud Computing, the Internet of Things (IoT), Big Data, Artificial Intelligence (AI), Augmented Reality (AR), Virtual Reality (VR) and technologies such as 5G.

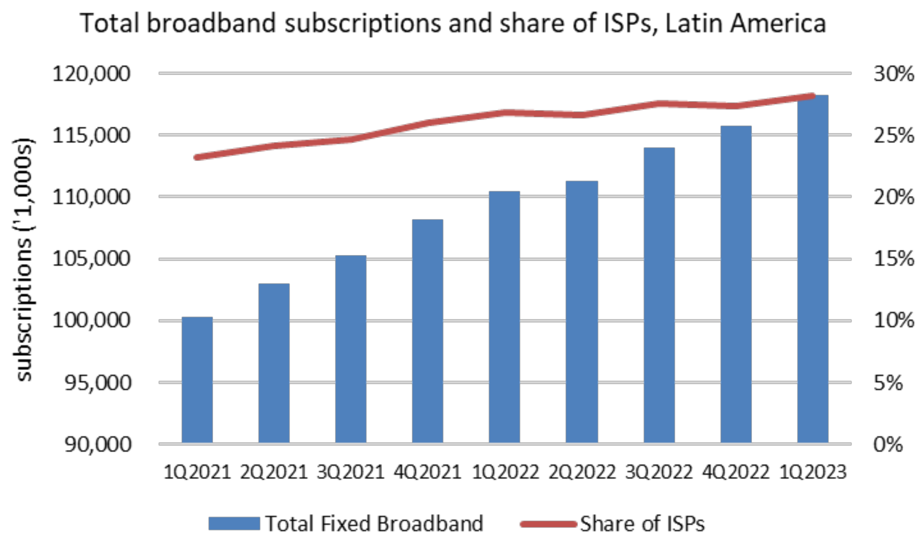
Based on the analysis carried out in the Cloud Computing Study in Mexico[14], the creation of Internet Exchange Points (IXP) can result in entry of new Internet Service Providers (ISP) into the market, creation of Content Delivery Networks and encouraging the construction of Data Centers to turn a region into a center or hub for data storage and processing, as well as for the exchange of Internet traffic. Therefore, IXPs play a key role in the evolution of the digital ecosystem.

[14] https://www.ift.org.mx/sites/default/files/contenidogeneral/politica-regulatoria/dgciestudio-cloudcomputing.pdf

To guarantee optimal performance of the networks and promote an efficient development of the digital ecosystem in Mexico, IFT has promoted a flexible regulatory framework, in such a way that barriers or obstacles that may exist are identified and eliminated where possible in order to facilitate the deployment of and / or access to optical fiber infrastructure both in the access and transport segment, as well as to encourage the construction and expansion in the country of network infrastructures such as IXPs and Data Centers, which require high data transmission capacities to interconnect with the different networks. This allows a more open and dynamic market, as well as an environment with greater competitive conditions, promoting the entry and integration of new players into the digital ecosystem, which implies more and better services available to end users.

Small and regional operators have become important players in the Latin American fixed broadband market. In many cases these operators have been responsible for bringing infrastructure to underserved areas. These operators found a market niche outside the densely populated urban areas, far from incumbent's core markets and, therefore, areas with no, or very limited, competitive pressure. These operators have grown in importance in Latin America, according to Omdia research they had 33.3 million fixed broadband connections in the first quarter of 2023. Besides, small, and regional Internet service providers (ISPs) have been growing their share in the past years, in the chart below is possible to find the evolution of their share, which grew from 23% in first quarter 2021 to 28% in the first quarter 2023 of all fixed broadband connections in the region.

Figure 26: Total broadband subscriptions and share of ISPs, Latin America



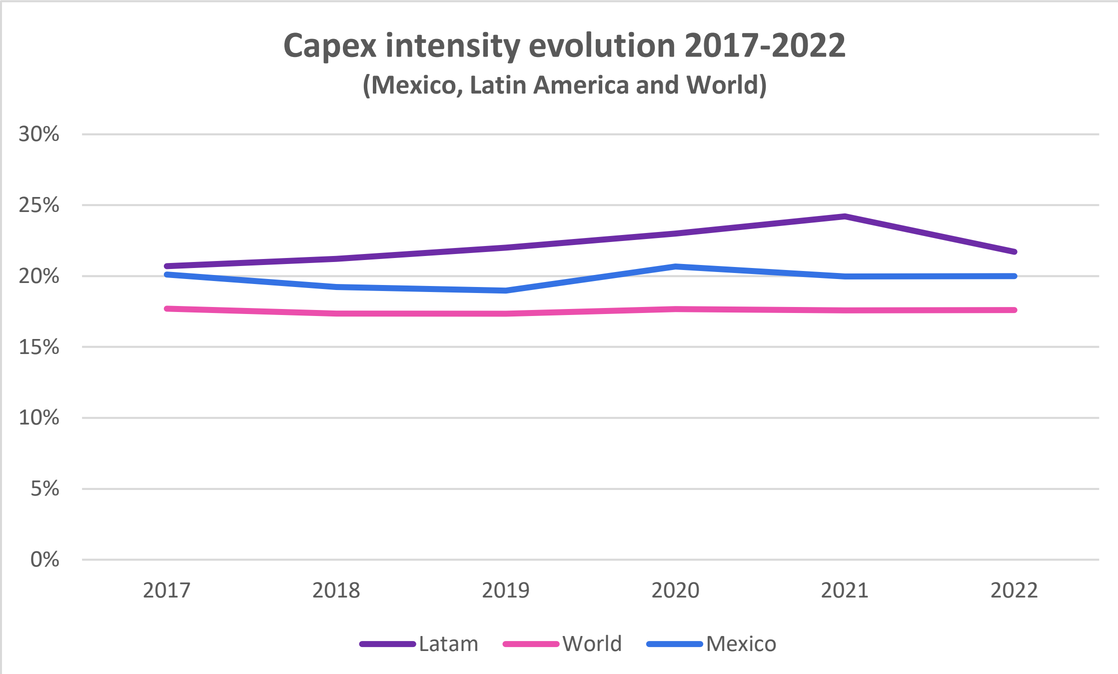
Source: Omdia
Note: ISPs refer to small and medium ISPs

Brazil is an example of this growing trend (see Appendix C) of small and medium ISPs case study.

6.4. Importance of sufficient investment and funding

Large investments in networks are required to connect Mexican citizens to the Internet, including investment in extending infrastructure in rural areas and in updating networks with fiber to match the rising demand. Capital intensity (CAPEX expenditures -CAPEX /revenues) for the communications sector in Latin America has been above the international average during the last years as shown in the following chart. While the global capital intensity average for 2017-2022 has been around 17%, in Latin America this ratio reaches 22.1% on average. This indicator shows that large investment efforts have been made in the region, even with a smaller market size and lower average revenue per user. Looking at data for Mexico, specifically, it shows a CAPEX intensity ratio above the world average.

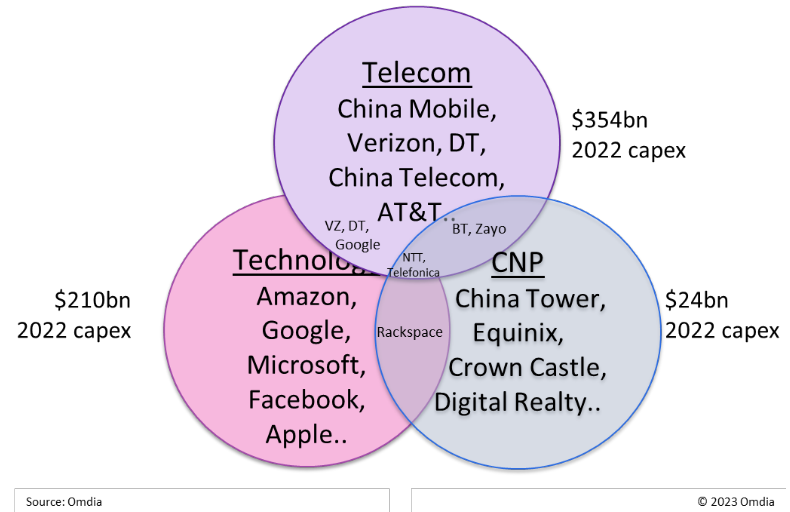
Figure 27: Capex intensity evolution 2017-2022



Source: IFT for Mexico data, 2022 Mexico data estimated. Rest of the countries Omdia – Communications Provider Revenue and CAPEX Tracker – 1Q23

Considering the broader ecosystem, telecom operators account for around 60% of global network capital investment in 2022. The global CAPEX amount was USD $354bn (60% of total), Internet technology companies CAPEX was USD $210bn (36%) and Carrier-neutral providers USD $24bn (4%).

Figure 28: Industry segments: telecom, technology, and carrier-neutral providers



Source: Omdia – Communications Provider Revenue and CAPEX Tracker – 1Q23

Note that some companies operate across segments.

Telcos have maintained global CAPEX levels during the last six years of around USD $354bn (CAGR 2017-2022: 0.2%). Technology companies have been increasing its CAPEX with a 20.6% CAGR, and increasing their contribution to networks investments from 18% to 36% of total expenditure. Neutral carriers have also increased investments with a 5.4% CAGR, but still only account for 4% of total investments. Technology companies' investments are mainly focused on Data Centers, submarine cables, cloud, computing services, CDNs and more recently on satellites, with no direct investments in local networks. This misbalance has been generating controversy and a regulatory debate on how all players should contribute to support network costs. This so called "fair share debate" is currently a high priority topic at the top of the European Union's regulatory agenda, alongside net neutrality.

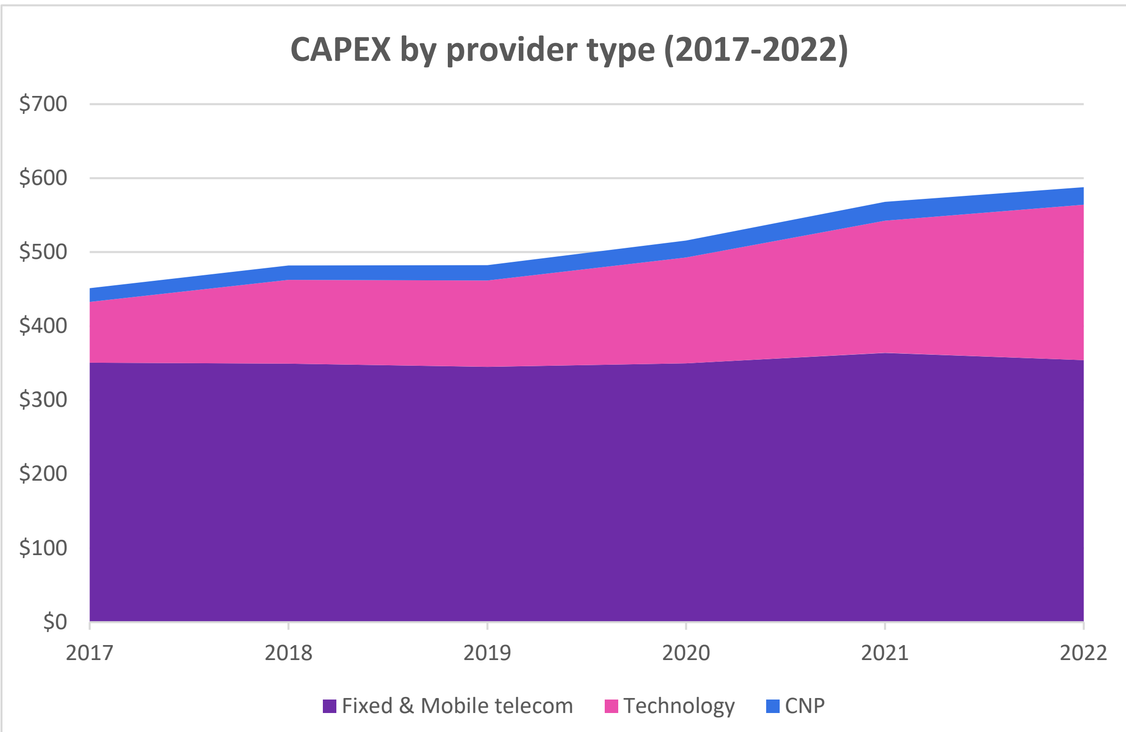
Table 8: Total CAPEX global 2017-2022

CAPEX (USD $bn)	2017	2018	2019	2020	2021	2022	2017–22 CAGR
Fixed & Mobile telecom	$351	$349	$345	$350	$364	$354	0.2%
Technology	$82	$113	$117	$143	$179	$210	20.6%
CNP	$18	$19	$21	$23	$25	$24	5.1%

Total network investment	$451	$482	$482	$516	$568	$588	5.4%
% Telecom companies	78%	72%	72%	68%	64%	60%	
% Technology companies	18%	24%	24%	28%	31%	36%	
% Carrier-neutral providers	4%	4%	4%	4%	4%	4%	

Source: Omdia – Communications Provider Revenue and CAPEX Tracker – 1Q23

Figure 29: CAPEX by provider type (2017-2022)



Source: Omdia – Communications Provider Revenue and CAPEX Tracker – 1Q23

6.5. Neutral infrastructure

The convergence of factors such as ISP growth, the need to reduce debt and the demand for fiber has changed the way in which operators understand the value of their infrastructure. If in the past they were seen as a strategic asset and a key differentiator to be kept under tight control, some of these companies have realized that they can unlock the value of these assets and attract infrastructure investors who also share investment needs. This global trend, which first originated in the U.S. and Europe, is now starting to reach Mexico and Latin America.

Latin American Communications Service Providers have been divesting not only their towers, but also their fiber infrastructure; moving away from the integrated, infrastructure end-services company model toward a purer, telco services model. This trend is generating more diverse business models that are based in infrastructure sharing. Private involvement and public-private partnership are fundamental for the success of this type of infrastructure sharing networks.

As the economics of fiber deployment are more challenging in Mexico than in other regions, particularly outside high dense city areas, creating these shared networks makes the business case more feasible and enables fiber networks deployment in less dense areas, while also avoiding over-construction in dense areas, making the most of the resources available. Additionally, the pro-competitive nature of independent infrastructure companies, brings more benefits to consumers.

Infrastructure funds and companies have different economic drivers, expecting longer return periods. This could bring additional funding resources to speed up the Mexican fiber coverage gap. Global trends show that co-investment and public-private investment models are key elements facilitating fiber deployments in a more cost-effective way and resulting in higher fiber coverage in a shorter period.

A more detailed analysis of Neutral infrastructure trends in Latin America can be found in the Appendix D.

VII. Mexico Broadband Vision

High-speed broadband is the cornerstone of economy, and although Mexico has achieved significant broadband growth in recent years, there is more that can be accomplished. In 2024, Mexico ranked 42nd in the Omdia's Fiber Development Index, placing in the middle of the 93 countries included in the FDI. The following section discusses the main ideas and concepts aimed at advancing the country's fiber connectivity and digital economy in general.

7.1. High speed broadband is the cornerstone of the economy.

As discussed in the previous sections of this paper, the constant growth of devices, applications, and services places increasing demands on broadband infrastructure, resulting in necessary upgrades to legacy broadband access networks.

High-speed broadband connectivity is the foundation of the digital infrastructure, and its socioeconomic benefits and role as a key driver of economic growth are well known and documented. The one-time investment in national fiber backbone and access infrastructure is future-proof and ready to integrate generations of future upgrades. In this context it is important to recognize the comparably low construction cost mentioned in section 4.6. (Low overall construction cost) according to Omdia reported Capex (see Figure 11), and the fact that in Mexico (similarly to the rest of the LATAM region) 81% of population is in urban areas, as well as the low labor cost, which all make fiber optic networks deployments more cost-effective compared to other countries.

Optical fiber networks play a crucial role in the context of smart manufacturing in Mexico. Smart manufacturing involves the integration of Information and Communication Technology (ICT) with next-generation manufacturing technologies, which requires a network infrastructure that connects people, machines, and objects through data-centric connectivity and an all-optical industrial network foundation. In the smart manufacturing process, it is essential to maintain low latency and jitter below one millisecond for remote monitoring and precise control in engineering, which requires optical fiber networks with wide bandwidth and low latency. Investment in optical fiber networks is critical to supporting smart manufacturing and economic growth in Mexico.

7.2. Mexico's fiber development and future trends

In line with Mexico's vision, the all-optical fiber networks are anticipated to deliver Gigabit capacity, reflecting the commitment to achieve deeper digital transformation by providing innovative products, services and applications to citizens and businesses, emphasizing the need for faster, more reliable, secure, and flexible networks to support emerging technologies and meet changing user and application demands. It is considered important to invest in fiber infrastructure as a long-term investment to ensure the viability of networks and meet the growing demands of modern communication and new immersive applications.

FTTP (Fiber to the Premises) deployment costs per location in Mexico and Latin America are considerably low compared to developed markets. This significantly improves the case for FTTP deployment in the region. Several factors contribute to these low costs in Latin America, including lower labor cost in the region, high urbanization, and population density in urban areas of Mexico and Latin America. In addition, FTTP deployments in the region can be done using primarily overhead fiber, thus significantly reducing the time required for deployments in urban areas. This efficiency in FTTP deployment is considered an advantage compared to countries where installation costs are higher due to the lack of underground conduits.

In addition, the intensity of capital investment in the communications sector in Latin America has increased in recent years, and Mexico shows substantial growth in this aspect as of 2020. In recent years, the country has experienced rapid development in the field of broadband, with notable improvements both in terms of coverage and speed. From section 6.4, in 2021 Mexico CAPEX intensity reached 20% according to IFT [15].

However, there are challenges that need to be addressed:

a. **Fiber broadband adoption:** Although Mexico has made progress in fixed broadband penetration with 73% of households connected, only 43% of households subscribe to a fiber broadband connection. This is a challenge because fiber is critical to the development of digital services and applications in various sectors, such as entertainment, education, working from home, corporate services, smart cities, and healthcare.

b. **Broadband speed:** Statistics show that the median download speed in Mexico is 61.36 Mbps, which is below the global average 82.56 Mbps. To improve the quality of the connection, it is necessary to accelerate the construction of optical fiber technologies.

[15] https://bit.ift.org.mx/

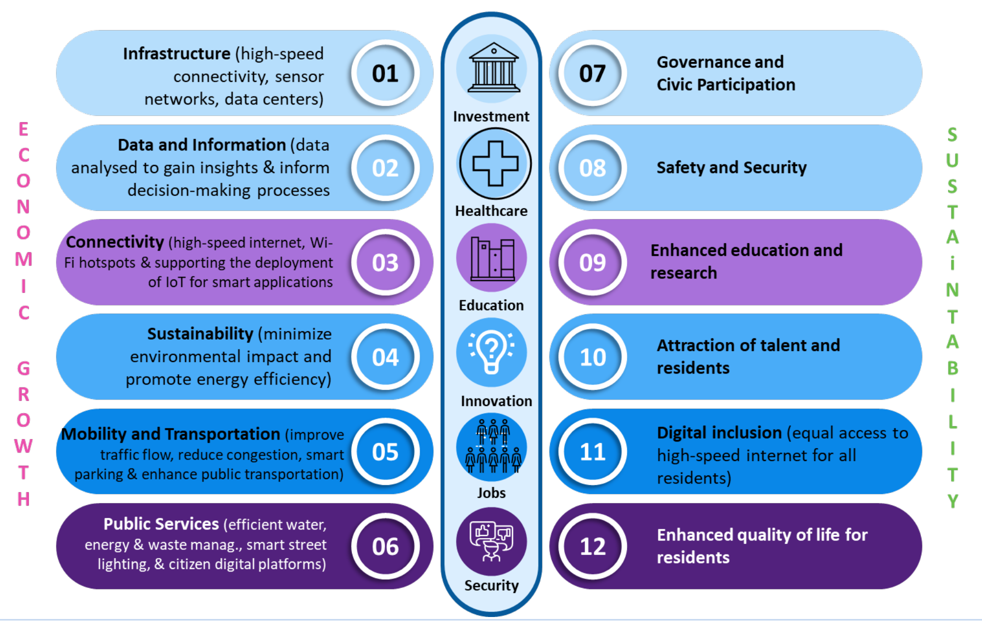
c. **Neutral and shared infrastructure:** In Mexico, infrastructure sharing is necessary. This trend would allow multiple operators to benefit from shared infrastructure, which could accelerate fiber deployment in less densely populated areas.

Mexico Gigacities vision

Mexican cities are important economy drivers and connection hubs. Therefore, the more areas reach the Gigacity vision, the more economic growth and sustainable benefits for Mexican citizens, Mexico City should lead the way towards this vision, followed by other innovative cities in the country.

The following chart illustrates the main benefits and applications of a Gigabit city:

Figure 30: the main benefits and applications of a Gigabit city



Source: Omdia

7.3. Measures to improve connectivity

1. **Establish a precise coverage map:** IFT has conducted a cost study of fixed broadband connections and optical fiber networks at the municipal level in Mexico, as well as a more reliable analysis and diagnosis of the connectivity situation in Mexico including an estimate of the resources needed to reduce the digital divide[16]. The study uses information on operator'' fixed broadband access at the municipal level and the technologies that provide these services to reflect the diversity of operators and networks deployed throughout the region. This study contributes to help eliminating inequalities in the access and use of fixed telecommunications services across the country.
2. **Promote the implementation of specific telecom infrastructure-related plans:** Pay attention to the key role of urban planning and strengthen coordination between specific plans for telecommunications infrastructure and national strategic planning, land and spatial planning, and detailed control plans.
3. **Strengthen the coordination of construction requirements**: Strengthen the coordination of construction requirements of sites, equipment rooms, and indoor distribution systems, make full use of existing resources, and share resources without new construction.
4. **Implement strict network construction standards:** The co-construction and network infrastructure sharing of facilities such as poles, pipes, equipment rooms, optical fibers, and base station access transmission lines.
5. **Promote the joint entry of optical fibers:** Promote the joint entry of optical fiber networks in key places such as urban core areas, important functional areas, scenic spots, parks, large residential areas, buildings, and public transportation.
6. **Ensure equal access to Gigabit networks:** Building property owners and other communications facilities need to facilitate access to all residents and businesses equally and make sure that user'' free choice is not restricted. Additionally, equal access to broadband networks also needs to be maintained for service providers in order to promote competition and accelerate uptake of Gigabit broadband services.
7. **Encourage cross-industry cooperation and sharing:** Access to electric power sources, such as power towers and power optical cables, as well as municipal

[16] https://desplieguеinfra.ift.org.mx/estudios.php

infrastructure, such as municipal roads, bridges, lighting poles, transportation, and communication facilities needs to be open and shared.

7.4. Open standards and neutrality compliance

Technology neutrality is one of the key principles of the regulatory framework. Technology-neutral regulations are a key pillar to drive innovation and facilitate the migration from one technology to the next without any regulatory impediments. Regulations tied to a particular technology may quickly become obsolete and require further amendment. Also, technology-specific regulations lead to dependency on specific manufacturers, developers, suppliers or distributors of technology or services. The technology-neutral principle guarantees freedom of choice by not forcing operators into using any specific technology. It also facilitates a more competitive business environment. Technology-neutral regulations bring flexibility to businesses by providing them with longer periods of regulatory certainty as well as the freedom to adopt the technology they deem best to achieve required regulatory outcomes. They can also provide potential efficiency gains, as industries are incentivized to find innovative ways to comply with the regulatory requirements without compromising health, safety, security, or environmental protections. Finally, technology-neutral regulations make it easier for businesses to adopt new technologies in the future.

Standardization organizations generally apply the principles of openness, consensus, transparency, maintenance, availability, policy, relevance, neutrality, stability, and quality.

Different technologies are defined at various standards forums to support the growing number of cloud services requiring high bandwidth and/or low latency connections, a few of them are listed below:

- IETF
- ETSI ISG F5G
- ITU-T SG15
- BBF
- IEEE
- ETSI ISG ENI ZSM
- Metro Ethernet Forum (MEF 23.1-23.2)

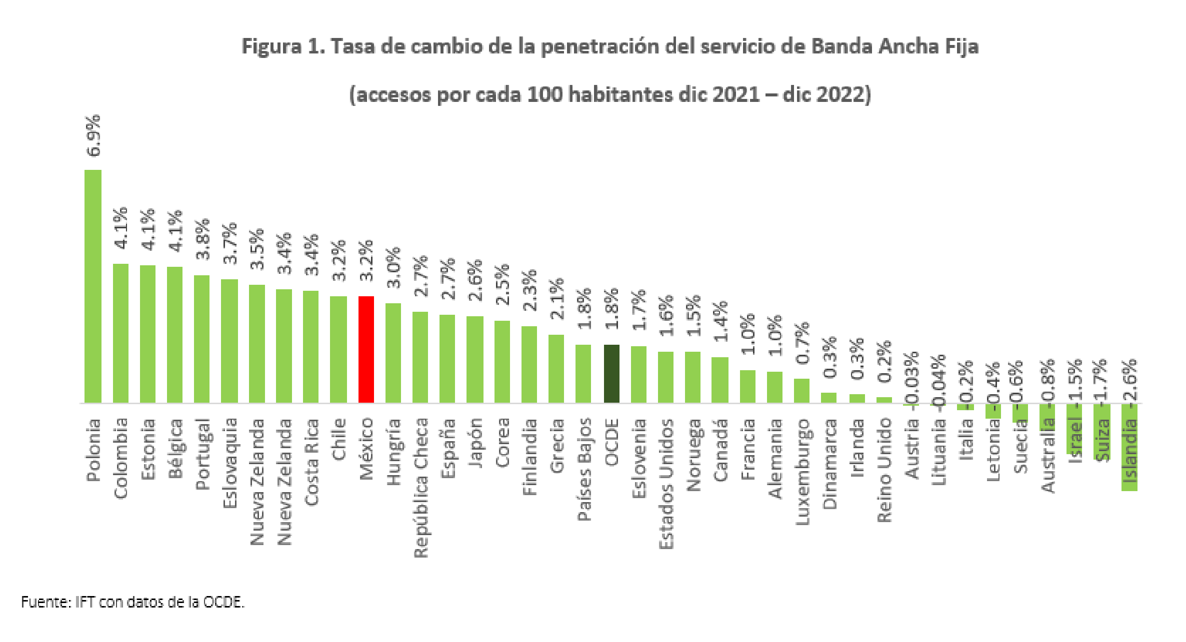
Details included in the Appendix A.

VIII. Looking into the future

From December 2013 to December 2022, Mexico experienced the third-fastest growth in fixed broadband penetration among OECD member countries, with an increase of 89%[17].

According to data from the OECD, fixed broadband service penetration in Mexico increased by 3.2% between December 2021 and December 2022, higher than the average growth rate of 1.8% in OECD countries.

Figure 31: Fixed broadband change rate of broadband service penetration 2021 vs 2022 (OECD)



Source: IFT with OECD data

High-quality and secure connectivity for everybody and everywhere in Mexico is becoming a prerequisite to deliver sustainable economic and social benefits through on modern digital services and fast Internet connections.

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[17] IFT Source：https://www.ift.org.mx/comunicacion-y-medios/comunicados-ift/es?page=2 Ciudad de México, a 13 de julio de 2023.

Broadband connectivity, especially one powered by fiber optics, allows user sites -residential or corporate - to be connected to the Internet or private network and enjoy much higher bandwidth and lower latency.

From Chapter V, it is observed that in 2022 Mexico had 21.3 million fixed broadband accesses, of which 51.48% were fiber and 27.98% were still coaxial. Based on this information, it can be expected that the growth rates of fiber networks will be maintained for the next few years.

On the other hand, at the end of 2023, Mexico had approximately 75% of homes covered with FTTP networks, but only 43% of Mexican households have fiber connection.[18]

Enhanced Fiber Broadband (eFBB)

According to the latest Ookla Speedtest data (August 2023), the median download speed in Mexico is 61.36 Mbps with median upload speed reaching 21.13 Mbps. In comparison, the global median download speed rate reaches 82.56 Mbps and the median upload speed rate is 36.8 Mbps.
According to Ookla''s data, as of March 2023, the largest proportion of fixed broadband service accesses are as follows:

- *51.46% had a download speed of 50 to 100 Mbps.*
- *22.98% had download speeds in the range of 100 Mbps to 1 Gbps.*
- *0.21% had a greater than 1 Gbps.*

It can be expected that as fiber networks' capacity continues to improve so will the speeds achieved over the coming years.

Guaranteed Reliable Experience (GRE).

The alignment between the standardization bodies MEF (Metro Ethernet Forum) and F5G fiber deployments, defined by ETSI, offers significant benefits on various fronts. Both

[18] https://www.oecd.org/sti/broadband/broadband-statistics/

organizations share a focus on interoperability, quality of service (QoS), and network management. This allows for a more effective integration of optical fiber into Ethernet networks, ensuring consistent and high-quality performance for critical applications. Furthermore, the high-speed and high-bandwidth capacity of optical fiber combines with the flexibility and scalability of Ethernet services, which is crucial in an ever-evolving environment. This alignment enhances efficiency in network management and the delivery of services in an increasingly connected world that relies on high-speed connectivity.

This Implementation Agreement MEF 23.2 uses distance as the primary means of describing **Performance Tiers** and deriving minimum delays. The distances stated for each Performance Tier can be considered as an approximate distance.

Below are the five PTs defined in this Implementation Agreement with the format:

Performance Tier Number (PT Name) –- Description (distance, derived propagation delay used in Class of Service Performance Objective constraints to establish a minimum per-Performance Tier).

- PT0.3 (City PT) – derived from distances less than Metro in extent (<75 km, 0.6 ms)
- PT1 (Metro PT) – derived from typical Metro distances (<250 km, 2 ms)
- PT2 (Regional PT) – derived from typical regional distances (<1200 km, 8 ms)
- PT3 (Continental PT) – derived from typical National/Continental distances (<7000 km,44 ms)
- PT4 (Global PT) – derived from typical Global/Intercontinental distances (<27500 km,172 ms)

Distances are not normative and are only used to provide per PT delay related Class of Service Performance Objective constraints. The intent is to provide a range of Performance Tier sets that address Carrier Ethernet Networks of different geographic coverage, design, and scope.

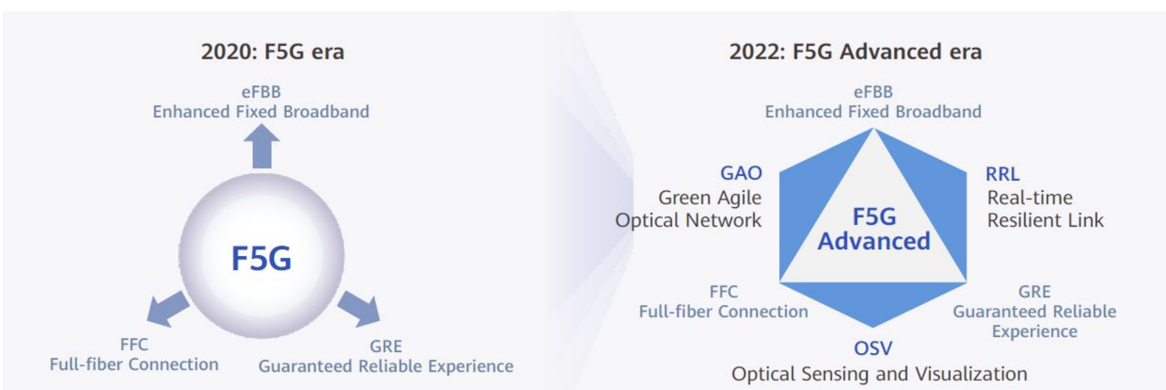
8.1. Towards F5G advanced

Optical communication is always in a state of continuous innovation and development. In the first phase, F5G standards have been put into commercial use. But F5G technologies are still developing. At the meeting on September 16, 2022, the ETSI officially named the next phase: F5G Advanced. It defines new goals and capabilities for the future development of F5G. With the wide application of F5G in various industries, new opportunities and service requirements are generated for homes, enterprises, and industries. Evolution to F5G Advanced is required to enrich applications, promote innovation, and build a sustainable fixed network industry.

Compared with the F5G, the F5G advanced has the following four core changes:

- 1 Gbps to 10 Gbps everywhere, that mean the Bandwidth can be used for the different services.
- From telecoms to industrial use, µs-level latency, 99.9999% reliability that mean better performance with high reliability.
- From communication to sensing, 1 meter positioning precision., high performance to locate issues on the network.
- From Electrical Cross-Connect (EXC) to Optical Cross-connect (OXC), that means greater energy efficiency.

Figure 32: F5G and F5G Advanced era



Source: ETSI

IX. Conclusion

With the rapid development of digital society, broadband has become an indispensable requirement of people's lives and a fundamental part of countries' infrastructure, equivalent to other utilities, such as water, electricity, and gas. Optical fiber broadband networks provide sustainable and cost-effective connectivity with high bandwidth, stability, reliability, and reduced latency, promoting long-term economic growth by enabling development of advanced digital services and applications for users, businesses, and industries.

Key messages:

- With the increasing number of home and enterprise applications and services (such as VR, AR, XR and live video), higher requirements are imposed on broadband infrastructure resulting in necessary upgrades to legacy broadband access networks.
- Fiber-optic broadband brings significant socio-economic benefits. Research shows that broadband Internet access is a key driver of economic growth and industry competitiveness, playing an increasingly transformative role in all economic sectors and society in general.
- Relevant industry standards, e.g. MEF, ETSI ISG F5G, define future networks as related to' Gigabit all-optical fiber networks.
- In Mexico, according to the analysis of the current infrastructure, the focus is on several key areas: increasing broadband coverage in remote areas, promoting technology upgrades (such as copper and cable migration to fiber), and urban fiber broadband take-up acceleration, among others.

Mexico's possible alternative is to achieve greater digital transformation by developing high-capacity networks that deliver innovative products, services and applications to all citizens and businesses.

X. Appendix

A- Standards

- IETF: The Internet Engineering Task Force. The IETF defines not only the Internet protocol suite but also management protocols and data modelling languages. Segment Routing over iPv6 and YANG data models at the service layer (e.g., L3SM (L3VPN Service Model)), network layer (e.g., L3NM (L3 VPN Network Model)) are important enabling technologies developed by IETF for network automation.

- ETSI ISG F5G: The 5th generation Fixed Network (F5G and F5G Advanced). The F5G community describes a large set of use cases for F5G (like BB5) and F5G Advanced (similar to BB5.5). Based on that use cases technology requirements and eventual gaps are shown. An overall holistic end-to-end network architecture is defined using many technologies. The group also set out to define the characteristics of the 5th generation, which is the network most operators are currently building today.

- ITU-T SG15: Various baseline technologies. SG15 has several sub-groups defining various optical communication technologies in the different end-to-end segments. Aggregation network and transmission technologies include OTN with its evolution (higher speed and sub-1G), management of transmission systems, and synchronization. In metro area network, fine-grain Metro Transport Network (G. fgMTN) is launched for carrying lower-rate premium packet service. In the access network segment, several PON generations and bidirectional Ethernet access technologies are defined. In the home/customer premises network segment, Fiber-to-the-Room and Li-Fi technologies are defined.
- BBF: Broadband Forum. The BBF defines various aspects of access networks including the home router management, PON management data models, and wireless and wireline convergence.
- IEEE: Ethernet and Wi-Fi. IEEE defines the basic Ethernet and Wi-Fi technologies (e.g., Wi-Fi 7/8) used in broadband networks. This is very important also for the data center networking aspects of broadband IEEE P802.3df Task Force is defining an 8-lane interface supporting 800 Gb/s Ethernet, and P802.3dj Task Force is working on 800 Gb/s and 1.6 Tb/s Ethernet with more advanced 200G/lane optical and electrical technology and coherent optics. IEEE802.11be Task Force (focus on Wifi7) is defining the air

interface protocol that supports the peak rate of 39.6 Mbps and uses various technologies such as 4KQAM high-order modulation and dual-link transmission. And IEEE802.11bn Task Force will define more advanced air interface protocols that operate in the 1-7.125 GHz band to improve throughput, latency, and energy consumption.

- ETSI ISG ENI &ZSM: The ETSI Industry Specification Group (ISG) on Experiential Networked Intelligence (ENI) focuses on improving the operator experience, adding closed-loop artificial intelligence mechanisms based on context-aware, metadata-driven policies to quickly recognize and incorporate new and changed knowledge, and hence, make actionable decisions. The ETSI ZSM group was formed with the goal to accelerate the definition of the end-to-end service management architecture, spanning both legacy and virtualized network infrastructure, to enable automatic execution of operational processes and tasks.
- MEF: the Metro Ethernet Forum (MEF) is a global industry organization dedicated to the promotion and development of Ethernet-related standards and services for metropolitan and wide-area networks. MEF 23.1-23.2 standards are designed to ensure a high level of reliability and performance across metropolitan and wide-area networks. This is relevant for critical applications, such as cloud services, voice, advanced data communications, and enterprise applications. By adhering to these standards, operators can provide higher quality services and minimize network disruptions.

B - Public Policy best practices

Network sharing obligations to all players – UK case study

There is a general discussion whether infrastructure sharing should be required to all network operators or just those with Significant Market Power (SMP).

A good example is the Physical Infrastructure Market Review carried out by OFCOM in the UK (OFCOM 2019). Although it considered all forms of physical infrastructure that could be deployed in the provision of electronic communication services, it found that not all infrastructure is equally valuable (there are disadvantages and complexities in using other utility infrastructure instead of specific telecommunications infrastructure) and not all infrastructure can be combined into a homogenous network (OFCOM found that communications providers have a strong preference for ubiquitous telecoms infrastructure) For reasons such as these, OFCOM concluded that even with access to all competing physical infrastructure, there would be insufficient competitive constraint on the dominant provider of telecoms infrastructure, BT Openreach. Thus, regulation of the SMP provider was required alongside wider Access to Infrastructure Regulations (UKG, 2020) that apply to all infrastructure owners.

Recommending that all access seekers and access providers have an obligation to negotiate infrastructure sharing agreements, and that the terms of those agreements should be transparent, fair and non-discriminatory is a good example of light-touch regulation as there is an inherent obligation, but it is hedged so that there is considerable room for commercial negotiation.

Single shared neutral infrastructure Open Access and Co-Investment

Many countries are moving towards a telecoms industry structure that includes a single major shared communications infrastructure provider: e.g., a national fiber backbone network (e.g. Tanzania) or a national 5G network (e.g. Malaysia) or a single integrated wholesale provider for all fixed and mobile services (e.g. Brunei Darussalam). In these circumstances regulatory obligations extend beyond “must negotiate” to include open access rules, justified either because of desired public funding or/and because of the operator’s SMP status in the market for infrastructure, whether passive or active. Open access rules should not only guarantee transparent, fair and non-discriminatory access for all interested parties; they also need to establish an appropriate pricing methodology. That means providing a commercial rate of return to the access provider, considering the risks of investment already made and incentives to continue investing in the high-capacity networks that will be required in the coming years.

The current challenges also have led to the trend towards joint ventures for Infrastructure sharing and cross-sectorial sharing agreements, leads logically to the goal of co-investment for new network infrastructure projects. Co-investment means any investment where ownership or control is shared between two or more parties.

Co-investment models allow for the concomitant risks to be shared between all the relevant stakeholders, including network operators and service providers, but potentially also businesses and government agencies.

European Union – Best practices

The regulatory framework in the European Union starts from the premise that infrastructure-based competition should be fostered wherever possible. It has recently evolved from a strict principle to a more pragmatic view of infrastructure sharing. This is due to the colossal investments required for the deployment of the latest generation networks (5G, fiber).

The new European Electronic Communications Code (EECC in force since December 2018), considers wholesale players as key actors to enhance competition levels on emerging fiber markets (previous regulations: focused on the risk for infrastructure monopolies by such players): Pro-competitive nature of independent TowerCos and infraCos.

This Code considers that operators with significant market power offering access to their infrastructure via co-investment can be exempted from other forms of access obligations.

Almost all European countries have implemented open access fiber networks, and many of them are related to Public Initiatives Networks (with public funding). Fiber sharing is regulated in several countries, either passive or active (bitstream access).

In Spain, Italy and Portugal, voluntary agreements between operators were achieved, while in other markets, such as France, co-investment regulation was implemented.

In September 2020, the EC adopted a recommendation calling for all member states to develop and agree on a common Union toolbox of best practices to foster connectivity.

In February 2023 the EU Commission presented a set of actions aimed to make Gigabit connectivity available to all citizens and businesses across the EU by 2030, this includes:

- Gigabit Infrastructure Act Proposal (GIA) (a regulation that will put forward new rules to enable faster, cheaper and more effective rollout of Gigabit networks)

- Draft Gigabit Recommendation (conditions of access to telecom networks of operators with significant market power, in order to incentivise faster switch-off of legacy technologies and accelerated Gigabit networks deployment).
- Exploratory consultation on the future of connectivity sector and its infrastructure, including the Fair Share debate.

Proposal for a 'Gigabit Infrastructure Act' (GIA) are new rules to enable faster, cheaper and more effective rollout of Gigabit networks in the EU that replaces the Broadband Cost Reduction Directive 2014/61/EU). It consists of:

- Set up a single digital point of information ("SIP") for obtaining information about existing physical infrastructure, civil works, and permits.
- Simplifies and digitalise the licensing/authorization/permitting procedures.
- Tacit approval for permit granting
- Fiber-ready connection for newly constructed sites or those undergoing major renovation (except in justified cases)
- It will reduce 'red tape' and the costs and administrative burden associated with the deployment of Gigabit networks.
- It will also enhance the coordination of civil works between network operators to deploy the underlying physical infrastructure, such as ducts and masts, and ensure that the relevant actors obtain access to it.
- Preserves the maximum four-month timeline for permit granting procedures, incentivise even shorter timelines as already seen in some Member State regions, and limit extensions for exceptional circumstances.
- Extend the principle of cost limitation beyond permits to include rights of way and other financial burden such as taxation or other charges;
- Directly provide for an exemption from any permit granting procedures for upgrades to mobile sites.
- Uphold the broad definition of physical infrastructure owned and controlled by public authorities, and the obligation for authorities to clearly identify and duly justify why certain buildings are excluded.
- Extend the one-month timeline to dispute settlement for refused access.
- Establishes a clear single information point where information can be found, applications made, and disputes resolved.

France - Best practices

The French fiber regulation includes "asymmetric" regulation imposed by ARCEP (France's Electronic Communications, Postal and Print media distribution Regulatory Authority) for several markets (Physical infrastructure; Wholesale local access provided at a fixed location; Wholesale central access provided at a fixed location for mass-market product; and High-quality dedicated active solutions for businesses).

ARCEP noted that, in 2020, Orange controlled 99.99% of copper accesses and 69% of FTTP accesses. Orange's wholesale market share (excluding self-supply) of fiber was 67%. ARCEP designated Orange as the operator with significant market power (SMP) in each of the notified markets and imposed a range of regulatory obligations, including access, non-discrimination and price controls. The other aspect to fiber access regulation is "symmetric" regulation, which sets up passive access to terminating segments of FTTP networks. The rules require all operators installing FTTH/B in buildings to deploy it in such a way as to allow access to be provided to passive (dark fiber) at concentration points aggregating at least 1,000 lines. Offers must include the potential for co-financing (on the basis of indefeasible right of use or IRU) before the investment occurs, after the investment – or on the basis of short-term rental. The terms and conditions as well as prices were established through a series of disputes resolved by the regulator. Prices were cost-based, but with mark-ups on the WACC to account for increased risk.

Right-of-way and government authorizations: Estonia - Best practices

Estonia has implemented numerous policies and practices that have facilitated fiber deployment. In 2007, Estonia was one of the first European countries to adopt a "One Dig Act", which established a legal framework for coordinated planning and the installation of conduits or empty ducts during road construction or maintenance to accommodate various utility infrastructure, including telecommunications infrastructure like fiber. The purpose of the policy is to minimize disruptions and reduce costs by enabling multiple utilities to utilize the same infrastructure.

In 2014, an e-Infrastructure Registry "Ehitisregiste") was launched providing information about existing infrastructure, including underground cables and conduits, and facilitates coordination between infrastructure operators. This registry helps avoid unnecessary excavations and promotes efficient use of the right-of-way.

Estonia also follows an open access model, meaning that network operators and ISPs are granted fair and non-discriminatory access to public rights-of-way. This encourages competition, as multiple providers can utilize the same infrastructure, reducing the need for redundant deployments.

Pre-installation best practices

China

Peopl''s Republic of China developed a fiber network growth strategy in 2011 that included infrastructure sharing and efforts to limit monopoly access. In 2013, the National Development and Reform Commission (NDRC) developed policies for fiber pre-deployment in buildings in collaboration with two primary organizations: the Ministry of Industry and Information Technology and the Ministry of Housing and Urban Rural Development, which are responsible for developing Code of design and Codes for construction and acceptance. Fiber networks are required for new buildings prior to occupancy, by adding communications infrastructure to the build acceptance standard. At least three fixed broadband operators must be supported by the cross-section of communication ducts, distribution points, and facilities for constructing fiber networks in buildings.

Subsequently, in 2014, a reference budget was created to assist real estate developers in predicting the cost of fiber network installation in building development. In summary, the Peopl''s Republic of China has developed a fiber pre-deployment strategy in residential buildings to facilitate the development of fixed broadband services over fiber networks. Since 2013, all buildings applying for a construction permit must adhere to design codes, and construction and acceptance codes.

Spain

Spain is one of the leading countries in terms of fiber deployment with 96% of households passed by fiber networks in 2023. The success of the Spanish fiber roll-out can be for a large part attributed to favourable regulatory environment which supported infrastructure sharing and co-investment agreements between the incumbent, Telefónica, and its competitors.

In July 2013, Telefónica, Orange Spain, and Vodafone Spain reached an agreement on the sharing of vertical infrastructure within buildings and on the unbundling of fiber lines reaching end users and asked the regulator to set the prices for these services. In order to close the gap with Telefónica, Orange Spain and Vodafone announced ambitious plans for FTTP roll-out in Spain and signed their owns network sharing scheme in 2014. And in 2016, Orange

Spain entered into joint network rollout agreement with Grupo MASMOVIL and Telefónica entered into a wholesale agreement with Vodafone Spain.

By actively promoting infrastructure and investment sharing agreements, Spanish operators were able to share costs and risks, especially in rural areas, and thus reach much higher connectivity levels than other key markets in Europe.

Infrastructure broadband mapping: Slovenia and UK / Germany - Best practices

An infrastructure mapping tool PROSTOR was developed in Slovenia by the Surveying and mapping Authority (Geodetska Uprava Republike Slovenije) under the Ministry of Environment and Spatial Planning. The mapping system presents graphical form of the data on ducts, cables, nodes, base stations, etc. The system gathers data on electronic communication operator'' facilities, mainly location and type of networks used. Citizens can check availability of broadband provided by operators.

Slovenia allocated financial resources from the Structural Funds for the programming period 2014-2020 to support the detailed mapping and coverage analysis, in order to support the expansion of broadband networks by implementing cost reduction methods from which all operators and the society may benefit.

C – Small and medium ISPs – Brazil case study

Brazil is one of the most discussed cases in the region when it comes to these players, ISPs are responsible for 50% of the Brazilian fixed broadband market. Lessons from this market should be taken into consideration for other countries that are planning to foster the growth of alternative broadband players.

- Fast and easy licensing procedures: Brazilian regulator, Anatel, simplified the process to request a license to provide broadband services, allowing companies to easily regularize their operations.
- Simplify taxation: Brazilian taxation system is complex and onerous, however, companies with annual revenues below US$360,000 can benefit from a simplified tax system designed to foster small companies.
- Facilitate funding: It may be challenging for new operators to secure loans, often they don't have enough guarantees to offer to banks, or even those banks don't accept the fiber network as collateral for such loans. For cases like these, governments can create funds to support the financial needs for these players, which can be simply offer guarantees to private banks loans.
- Fair interconnection costs: Usually, small and regional players invest in building the backhaul and last mile networks, few of them have the resources, or interest, in building transport networks, for these, they rely on established wholesale market, and in these cases, cost of interconnecting the network may become an important limiting factor for regional players, therefore, price regulation of the wholesale market should be considered.
- Rights of way: A key factor in enabling fiber broadband in many markets is the possibility of using aerial fiber suspended between utility poles. However, rights of way are not clearly defined in many countries, which leads to conflicting views between telecoms operators and utilities. In order to solve this issue, it is important coordination between telecoms and energy regulators to harmonize regulation.
- Municipal permits: In many countries, including Brazil, companies need municipal authorities' approval for building their networks, each city has its own set of rules, and, in many cases, there are no clear timelines for approval processes. This situation creates extra costs and delays in networks constructions. Currently is under discussion in the Brazilian Parliament a law that unifies these municipal rules and

establishes a period of time for approval of these permits, after which the project is automatically approved.

D - Neutral infrastructure trends in Latin America

The convergence of factors such as ISP growth, the need to reduce debt and the demand for fiber has changed the way in which operators understand the value of their infrastructure. If in the past they were seen as a strategic asset and a key differentiator to be kept under tight control, some of these companies have realized that they can unlock the value of these assets and attract infrastructure investors who also share investment needs. This is a global movement, initiated in the U.S. and Europe and starting to reach Mexico and Latin America. Latin America saw the launch of several new wholesale companies. Others, decided to sell and lease their fiber networks. In all these cases, the new companies opened their networks to do business with multiple operators, taking advantage of the opportunities to benefit from network multi-ownership. Several operators also created a new infra-co company, either due to regulatory decisions or business strategy.

The following table 8 presents several recent Latin American cases with different characteristics: some are limited to the last mile network, others involve everything from the last mile to submarine cables, and others are geographically limited.

Table 8: Fiber infrastructure deals in Latin America

Name Network	Country	Seller	Acquirer	Stake acquired	Date of Deal	Deal Value	Homes Passed
On Net Fibra	Chile	Telefonica	KKR	60%	July 2021	$1bn	4m (3Q23)
On Net Fibra	Colombia	Telefonica	KKR	60%	January 2022		3.4m (3Q23) (1.2m in 2022)
Telefónica	Argentina	N/A (not a sale, strictly infrastructure sharing deal)	N/A (deals with: SION, Metrotel and Iplan)	N/A	August 2021, October 2022, March 2023	-	-
Entel Fiber	Chile	Entel	On Net Fibra	100%	October 2022 (announced)	$358m	3.4m (3Q23) 1.2m in 2022
I-Systems	Brazil	TIM Brasil	IHS Towers	51%	November 2021	$295.7m	6.4m
V.tal	Brazil	Oi	BTG Pactual	Initial stake: 57.9% Current stake: 65.27%	May 2022	$2.6bn	16m (18m by 3Q22)
FiBrasil	Brazil	Telefonica	CDPQ	50%	July 2021	$306m	1.6m (3.3m by 3Q22)
Panagea Co (TEF), Telefónica, Entel	Peru	Telefónica Entel	KKR (On*Net Peru)	54% (36% TEF and 10% Entel)	July 2023	-	2.8m (3Q23) 2m (1Q23) (5.2m by 4Q26)

Source: Omdia

Latin American Communications Service Providers have been divesting not only their towers, but also the fiber infrastructure; moving away from the integrated, infrastructure end-services company model toward a purer, telco services model. This trend is generating more diverse business models that are based in infrastructure sharing. Private involvement and public-private partnership are fundamental for the success of this type of infrastructure sharing networks.

Infrastructure funds and companies have different economic drivers, expecting longer return periods. This could bring additional funding resources to speed up the Mexican fiber coverage gap. Global trends show that co-investment and public-private investment models are key allies to facilitate fiber deployments in a more cost-effective way and reaching higher fiber population coverage in a shorter time.

The market of infrastructure investment is evolving with increasing appetite for long-life network assets that underpin the operation of economies and communities. Fiber networks are now featuring in pension fund portfolios alongside toll roads, gas pipelines, ports, and wind farms. Interest in networks offering near-monopolistic long-run returns within a stable regulatory environment are attractive as investors look to match assets with their clients' long-term investment horizons.

E - Glossary

ADSL: Asymmetric Digital Subscriber Line

AI: Artificial Intelligence

APN6: Application-aware IPv6 Networking

AR: Augmented Reality

ARCEP: Electronic Communications, Postal and Print media distribution Regulatory Authority of France

BIERv6: Bit Index Explicit Replication

Bit rate: number of bits that are processed per unit of time, is expressed as "bit per second", with a prefix such as kilo (kbit/s or kbps), mega (Mbit/s or Mbps), giga (Gbit/s or Gbps) and tera (Tbit/s or Tbps).

CAGR: Compound annual growth rate

CAPEX: Capital expenditure

CAV: Connected Autonomous Vehicles

CAT5: Cable Category 5 that support Mbps/s in distances up to 100 meters.

CAT6: Cable Category 6

CNP: Carrier-neutral Providers

CPE: Consumer Premise Equipment

DOCSIS: Data Over Cable Service Interface Specifications

DQ ODN: Digitalized & Quick Optical Distribution Network

DSL: Digital Subscriber Line

EC: European Commission

ETSI: European Telecommunications Standards Institute

eFBB: Enhanced Fixed Broadband

EIB: European Investment Bank

EXC: Electrical Cross-Connect

F5G: 5th Generation of Fixed Network

FAT: Fiber Access Terminal

FDI: Fiber Development Index

FDT: Fiber Distribution Terminal

FFC: Full-Fiber Connection

FTTB: Fiber to the Building

FTTE: Fiber to the Edge

FTTH: Fiber to the Home

FTTN: Fiber to the Node

FTTP: Fiber to the Premise

FTTR: Fiber to the Room

FTTS: Fiber to the Site

FWA: Fixed Wireless Access

GDP: Gross Domestic Product

Gigabit City: refers to a city that has widespread access to high-speed Internet connections, delivering speeds of 1 Gbps or higher.

GPON: Gigabit Passive Optical Network

GRE: Guaranteed Reliable Experience

ICT: Information and Communications Technology

IETF: Internet Engineering Task Force

IFIT: In-Situ Flow Information Telemetry

IFT: Federal Telecommunications Institute

IoT: Internet of Things

IPTV: Internet Protocol Television

IPv6: Internet Protocol Version 6

ITU: International Telecommunication Union

IXP: Internet Exchange Point

ISP: Internet Service Provider

ISG: Industry Specification Group

KPI: Key Performance Indicators

MEF: Metro Ethernet Forum

ML: Machine Learning

MR: Mixed Reality

NLP: Natural Language Processing

NPS: Net Promoter Score

ODN: Optical Distribution Network

OECD: Organisation for Economic Co-operation and Development

OFCOM: Office of Communications, government-approved regulatory and competition authority for the broadcasting, telecommunications and postal industries of the United Kingdom.

OLT: Optical Line Terminal

ONT: Optical Access Terminal

ONU: Optical Network Unit

OXC: Optical Cross-connect.

PT: Performance Tiers

QoE: Quality of Experience

QoS: Quality of Service

ROW: Rights of Way

SRv6: Segment Routing over IPv6

STB: Set Top Box

VDSL: Very high bit rate digital subscriber line

VR: Virtual Reality

WACC: Weighted Average Cost of Capital

XR: Extended Reality

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