GIGACITY: UNLEASHING THE POWER OF CONNECTIVITY AND INNOVATION

WORLD BROADBAND ASSOCIATION

This report sets out a set of key characteristics developed by the WBBA to help cities benchmark their gigacity development.

FOUNDING MEMBERS

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OBSERVERS

CONTENTS

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EXECUTIVE SUMMARY

The creation of gigacities—cities where access to gigabit internet access speeds is universal—is essential to maximize a country's socioeconomic development. That is not to say that more rural areas should be excluded or ignored. However, with increasing levels of urbanization around the world, gigacity investment is an efficient way of getting gigabit broadband technology to large portions of the population and industry zones. This can especially be the case in developing markets, where current levels of overall high-speed broadband connectivity are typically lower. Government bodies must then make sure legislation is in place that encourages the expansion of gigabit broadband technology from cities into rural areas, and this will be the focus of future World Broadband Association (WBBA) papers.

KEY POINTS

- Cities and their residents, businesses, and public services can all benefit from gigabit-speed fiber connectivity. Gigabit connectivity is not only a step up from tens or hundreds of Mbps for achieving greater convenience when streaming videos or playing computer games but is a fundamental driver and enabler of broader smart city initiatives.

- Gigabit broadband infrastructure is expanding rapidly around the world, but by 2028 only 26% of households will be gigabit connected, mainly concentrated in the Oceania, Eastern & South-Eastern Asia, and North America regions. Greater investment is therefore needed if we are to ensure that 100% of the global population can take advantage of the socioeconomic benefits that high-speed broadband services bring.

- Although other infrastructure and technology such as cable broadband and 5G fixed wireless access (FWA) can deliver gigabit broadband speeds, all-optical-fiber networks are the optimal and future-proof options for gigabit broadband connectivity.

- In all smart city use cases, indoor fixed broadband gigabit connectivity is complemented by mobile 5G (and future-generation) networks outside. Fiber cell site connectivity is essential to optimize 5G mobile services.

- To support the experience of gigabit broadband speeds with low latency and high consistency, advanced home networks are also required. This will involve the rollout of new Wi-Fi standards (Wi-Fi 6 for gigacities and Wi-Fi 7 toward 10gigacities), deeper deployment of fiber through fiber-to-the-room (FTTR) architectures, and cloud artificial intelligence (AI) data analytics technology.

- By 2030, just under 60% of the world's population will live in urban areas. In some areas of the world, this proportion is already above 90%. Because of the concentration of people, urban areas naturally also contain many large industrial, educational, cultural, and other public establishments. Encouraging fiber and gigabit investment in such areas is therefore an efficient way of reaching large portions of the population and essential infrastructure.

- During the COVID-19 pandemic the importance of high-quality fixed broadband became abundantly clear. Governments around the world are therefore now increasing their investment in broadband networks and setting out wider-reaching and more ambitious broadband targets, especially around the availability of high-speed broadband. However, such strategies are often set at a national level with little consideration for the different needs and challenges of urban and rural deployment.

- To help cities benchmark their own gigacity development, the WBBA has set out a set of key characteristics, including the level of fiber to the homes passed, mobile cell site fiber connectivity, median broadband speeds, percentage of schools covered by fiber-optics, and industrial areas and other public sites covered by gigabit connectivity.

- In terms of end-to-end network architecture, the bearer network and data center network are migrating to 400Gbps or faster Ethernet (GE). The increase in traffic from individuals, homes, campuses, and enterprises will also bring higher demand on the bearer and data center networks.

- Future evolution from gigacity to 10gigacity is required to maintain future technology advancements. The evolution toward 10gigacity provides an opportunity to coordinate the efforts of government, private, and nonprofit sectors to strengthen their position as global pioneers of next-generation network technologies, enhancing the nation's competitiveness and international standing in the coming fully connected intelligent era.

RECOMMENDATIONS

GOVERNMENT AND REGULATORS

- Regulators and authorities should make policies and/or regulations that encourage greater fiber broadband deployment, including the development of gigacities, by the following methods:
  - **Set out a national, regional, and city-level plan.** Set out ambitious national broadband plans with clear targets and plans for both urban and rural areas. Targets for urban areas should include coverage of fiber infrastructure in both residential and enterprise areas, adoption of gigabit broadband services, and gigabit coverage for schools and other public buildings.
  - **Policy support.** Introduce policies to help ease the obstacles of fiber deployment including right-of-way (RoW) and fiber predeployment policies.
  - **Financial incentives.** Finance tools including vouchers and tax deductions can drive market development or support universal service obligations.

OPERATORS

- Optimize network architecture for different scenarios, including urban areas, to improve network capabilities and hence the quality of the broadband services based on the network, leading to ubiquitous infrastructure for gigacities.

VENDORS

- Vendors should consider developing customized network equipment and devices for specific deployment scenarios.

ENTERPRISE USERS

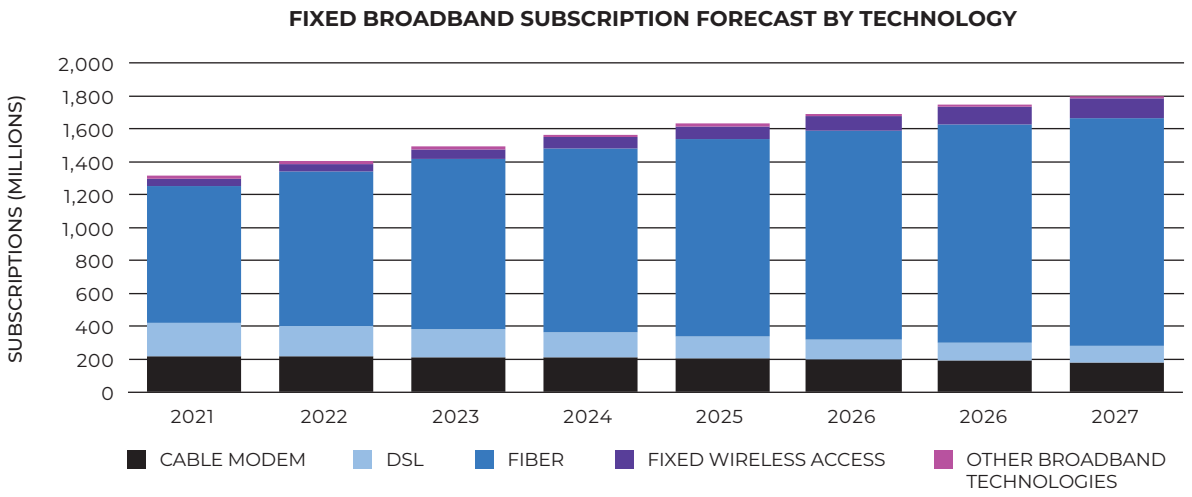
- We encourage enterprise users to actively embrace and make good use of the gigabit optical-network infrastructure in gigacities. Exploring integration with their own diversified application scenarios will lead to improved production efficiency and reduced costs and will support greater digital transformation.

INSIGHTS INTO THE GLOBAL STATUS AND TRENDS OF GIGABIT BROADBAND

THE SHIFT TOWARD GIGABIT BROADBAND

Next-generation broadband networks are rapidly being deployed. By 2028 there will be just under 1.4 billion fiber-to-the-premises (FTTP) broadband subscriptions, making up 77% of the total broadband subscription market globally. Cable broadband, which will account for another 10% of subscriptions, is also evolving to more advanced DOCSIS standards that enable gigabit speeds, and FWA (7% of subscriptions) is transitioning to 5G technology.

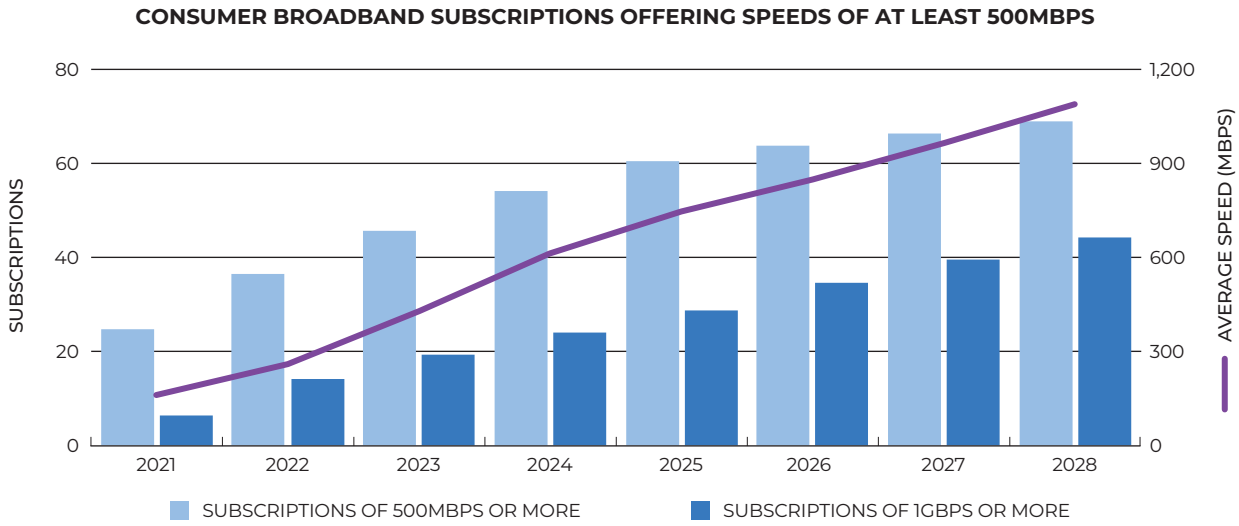
FIGURE 1: FTTP WILL MAKE UP 77% OF BROADBAND CONNECTIONS BY 2028



SOURCE: OMDIA: TOTAL FIXED BROADBAND FORECASTS, 2023

Omdia expects that by 2028, therefore, most broadband connections will be using next-generation broadband access technology capable of delivering high broadband speeds. Indeed, 69% of all consumer-grade broadband subscriptions by that time will be on tariffs offering speeds of 500Mbps or more, 44% will be gigabit services, and the overall average subscription speed will be 1Gbps (see **Figure 2**).

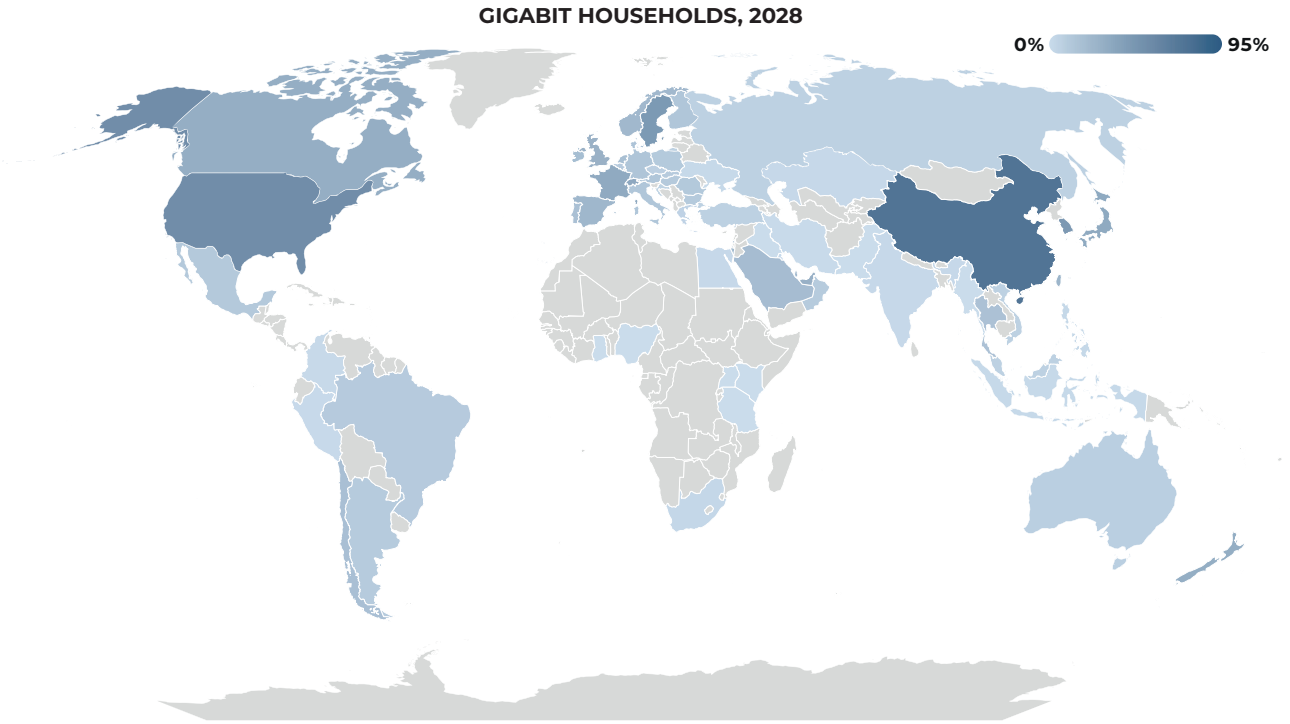
FIGURE 2: AVERAGE BROADBAND SUBSCRIPTION SPEEDS CONTINUE TO INCREASE ON A GLOBAL BASIS



SOURCE: OMDIA: CONSUMER BROADBAND SUBSCRIPTION AND REVENUE FORECAST, 2023

However, after small businesses that take consumer-grade broadband services are removed, this still equates to only 26% of global households by 2028 receiving gigabit broadband speeds, with a heavy focus on penetration around Oceania, Eastern & South-Eastern Asia, and North America (see **Figure 3**). If we are to ensure that 100% of the global population can take advantage of the socioeconomic benefits that high-speed broadband brings, there is still much to do to close this growing gigabit digital divide.

FIGURE 3: BY 2028, GIGABIT PENETRATION WILL RANGE FROM 95% TO LESS THAN 1%



SOURCE: OMDIA: TOTAL INTERNET USERS FORECAST, 2023

GLOBAL DIGITAL INFRASTRUCTURE DEVELOPMENT TREND

Besides the trend toward FTTP, Wi-Fi and IPv6 also play an important role in internet connections. Wi-Fi 7 is expected to pass 80% adoption in business and campus applications in 2030. While 5G is mostly for individual users, and fiber to the home (FTTH) is for home users, Wi-Fi is the most widely used technology in business scenarios such as offices, parks, technology campuses, and public areas. Currently, Wi-Fi 5 and Wi-Fi 6 have maximum theoretical rates of 3.5Gbps and 9.6Gbps respectively. The latest standard, Wi-Fi 7, is expected to be able to deliver peak rates of at least 30Gbps. The requirements on the fixed infrastructure will increase accordingly.

The global adoption of IPv6 as the protocol interconnecting all the networks mentioned above (5G, FTTH, Wi-Fi) is forecast to be beyond 80% in 2030. IP (Internet Protocol) is the fundamental protocol of the internet, and IPv6 is the only sustainable path of internet evolution. According to Google IPv6 statistics, global IPv6 adoption is close to 45% in 2023. However, the development is unbalanced among different countries and regions. Adoption rates are high in the leading countries in ICT such as France (74%), the US (48%), Germany (73%), and India (71%), whereas many countries in Africa have not started the migration process. With the exhaustion of IPv4 addresses, IPv6 adoption will accelerate and is expected to pass 80% in 2030, relieving limits on service and user growth.

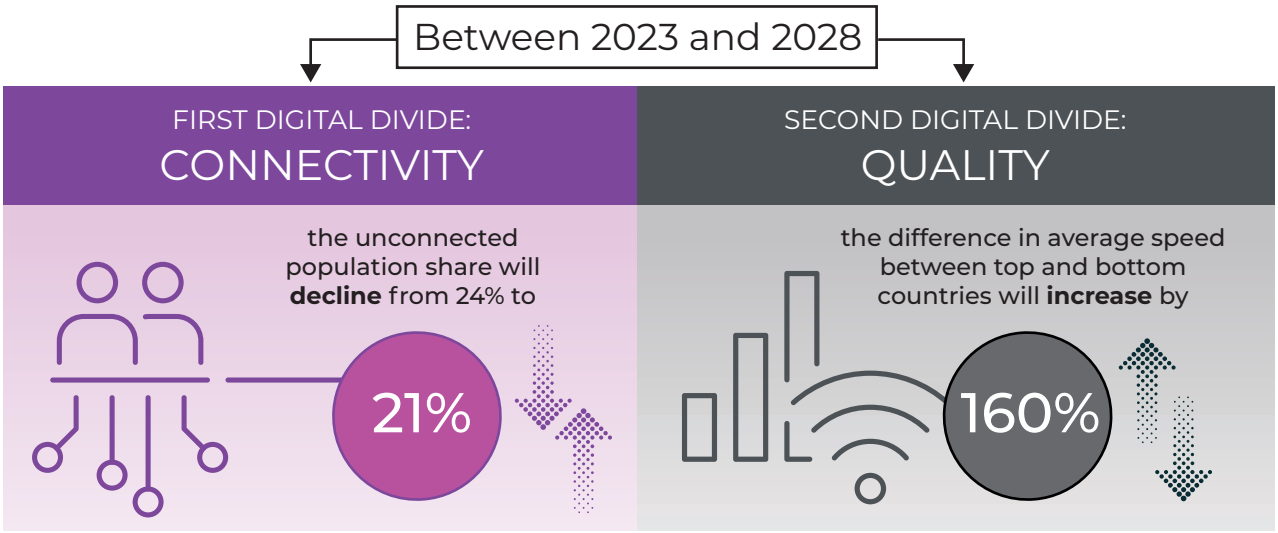
Moreover, in terms of the end-to-end network architecture, the bearer network and data center network are migrating to 400 Ethernet (400 GE) because of the increase in traffic from individuals, homes, and enterprises. The major technology used in bearer and data center networks in 2023 is 100 GE or 200 GE, but 400 GE ports are forecast to reach 30% of shipments in 2027 and expected to pass 60% in 2030.

MOVING TO FIBER NETWORKS TO CLOSE THE GIGABIT DIGITAL DIVIDE

AS ONE DIVIDE CLOSES, ANOTHER OPENS

As a society we have been relatively successful in gradually closing the first digital divide, which was focused largely on basic connectivity. Today, 76% of the world's population has personal access to the internet in some form, and this is set to increase to 79% by 2028. If we discount the population under four years of age, it will be as high as 87%. However, how people are connected is far from equal. By 2028, 41% of the connected population will only be connected via a mobile device, and of those that have fixed broadband at home, 7% will still be limited to speeds of less than 30Mbps. Indeed, even by 2028 the average broadband speed in some countries is expected to still be lower than 20Mbps, whereas the most developed countries will see average speeds of more than 1.5Gbps. As one digital divide closes therefore, another, related to the quality of the internet connection, opens (**Figure 4**). As more innovative applications—requiring a high-speed and high-quality internet connection to function—enter the market, citizens in countries that have limited broadband access could therefore find themselves at a distinct disadvantage.

FIGURE 4: AS ONE DIVIDE SHRINKS, ANOTHER GROWS



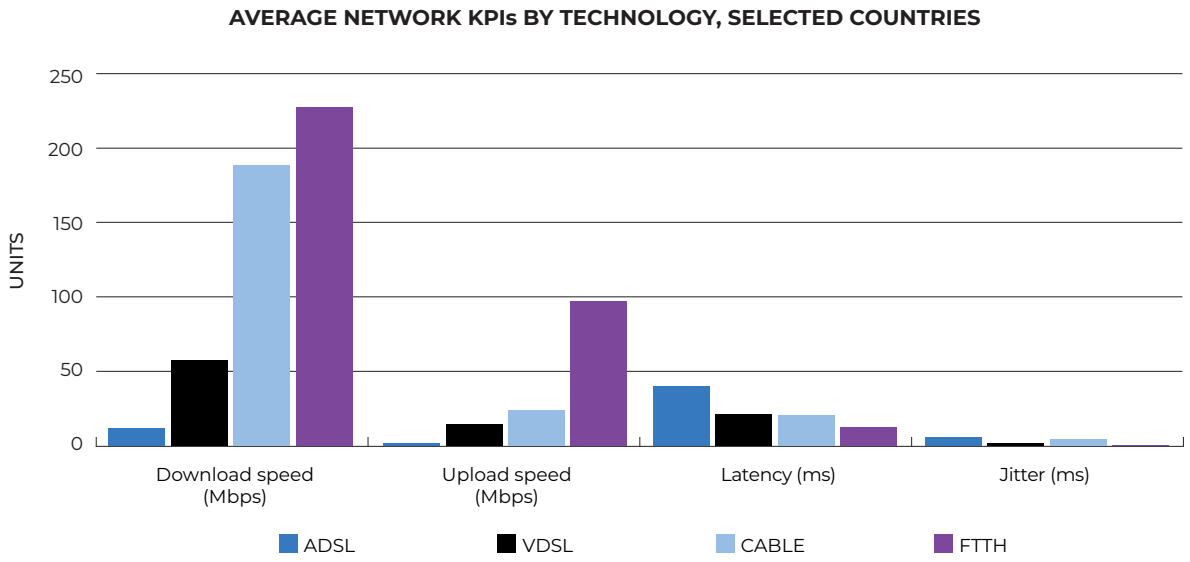
SOURCE: OMDIA

THE SHIFT TO ALL-FIBER NETWORKS WILL HELP CLOSE THE SECOND DIVIDE

If we are to close both the first and the second digital divide, greater deployment of optical-fiber broadband networks is essential. Fiber-based networks are recognized as providing the most sustainable and future-proof communications networks of them all with greater bandwidth, stability, and reliability and reduced latency.

Based on real network data from Medux's report "Residential fixed broadband in Europe," **Figure 5** illustrates how fiber outperforms other technologies in all areas. Such key performance indicators (KPIs), related to quality of service (QoS), have a significant impact on the quality of experience (QoE) of an application. Web browsing, video streaming, gaming, and cloud services experiences may all be heavily affected depending on actual or average/median values but, most importantly, on the stability of those KPIs over time, especially during peak hours. Because an all-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.

FIGURE 5: FTTH NETWORKS PROVIDE A TRULY HIGH-END EXPERIENCE

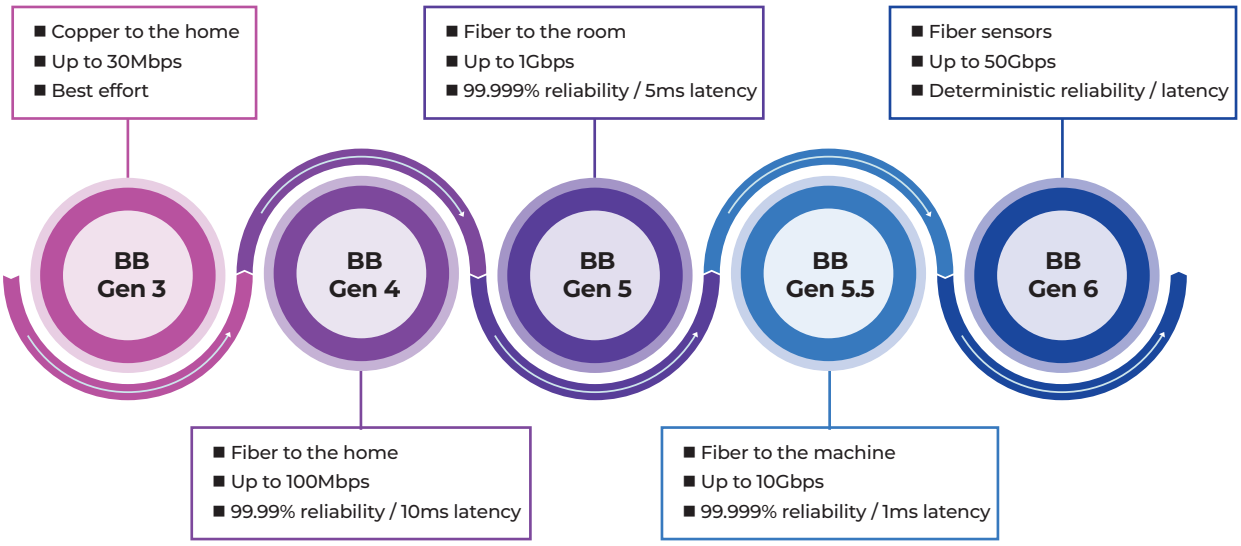


SOURCE: MEDUX, OMDIA

xDSL IS QUICKLY TRANSITIONING TO FIBER

As outlined in the WBBA report "Next-Generation Broadband Roadmap 2023 to 2030," FTTH is a natural evolution of copper-based DSL broadband networks. DSL was an innovative and cost-effective early broadband technology because it utilized the existing copper access network that telcos around the world had deployed extensively, primarily for the delivery of public switched telephone network (PSTN) services. However, although it went through several generational upgrades itself, DSL technology was always going to be limited when it came to delivering ultrafast broadband speeds. Fiber, therefore, has gradually replaced the copper loops, initially partially through what is known as fiber-to-the-cabinet/curb architectures (FTTC), and more recently fully with FTTH/FTTP. Within the WBBA's generational roadmap, this is referred to as the transition from broadband Generation 3 to broadband Generation 4 (**Figure 6**).

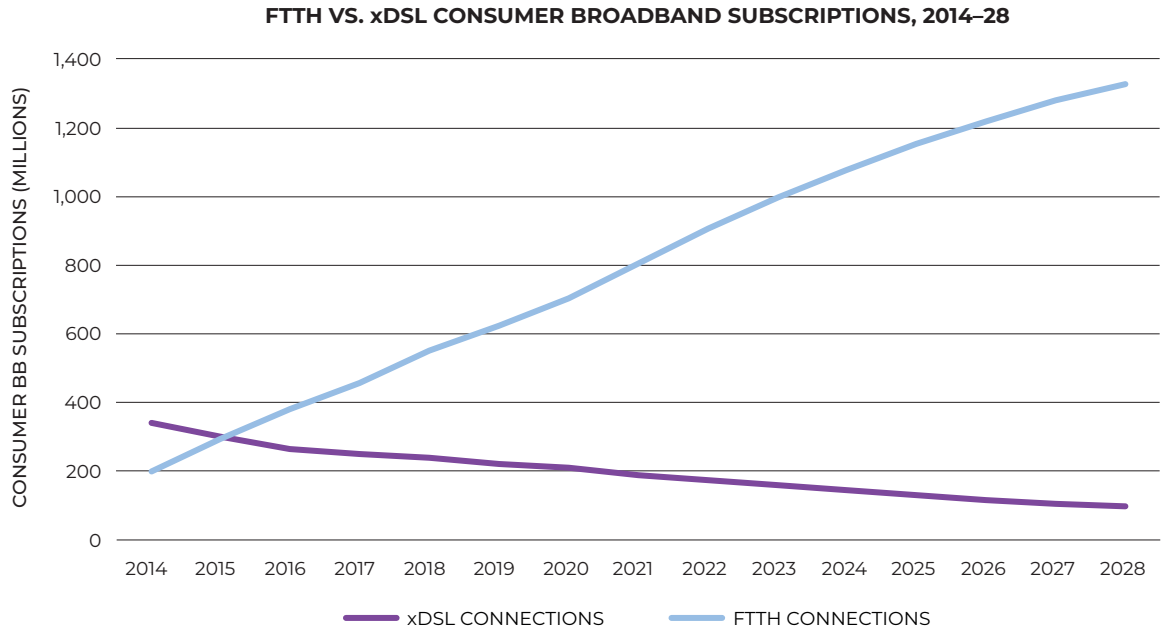
FIGURE 6: FTTH IS A NATURAL GENERATIONAL UPGRADE OF xDSL TECHNOLOGY



SOURCE: WBBA: NEXT-GENERATION BROADBAND ROADMAP 2023 TO 2030, 2023

At its peak, DSL was the most popular broadband technology by some margin. However, as telcos started to replace their copper networks with fiber, and FTTH rose in popularity, DSL subscriptions naturally declined: the inflection point between the two at a global level came in 2015 (**Figure 7**). Today there are more than 900 million consumer FTTH broadband subscriptions. This number will rise to more than 1.3 billion by 2028, accounting for 77% of all consumer broadband subscriptions.

FIGURE 7: THE INFLECTION POINT BETWEEN xDSL AND FTTH SUBSCRIPTIONS CAME IN 2015



SOURCE: OMDIA: CONSUMER BROADBAND SUBSCRIPTION AND REVENUE FORECAST, 2023

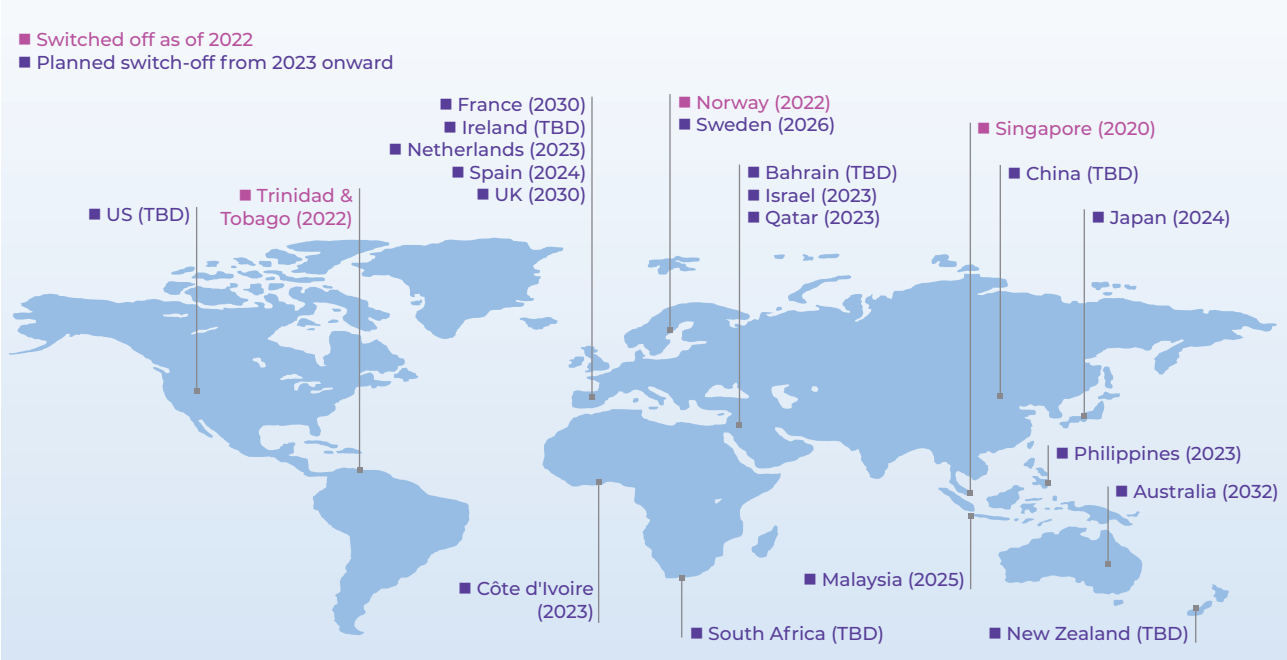
THE MOVE TO COPPER SWITCH-OFF

As legacy copper networks become harder and more expensive to maintain and are increasingly unable to support the growing consumer demand for bandwidth, operators around the world are starting to consider phasing them out. Maintaining legacy networks becomes expensive and inefficient as maintenance costs rise and the number of connected customers dwindles. It is important for network owners to retire their legacy copper networks to reduce operating costs and free up investment for further, more future-proof fiber deployment. It is vital, therefore, that government legislation and regulations are put in place to aid operators in this transition.

Furthermore, the primary motivations for decommissioning legacy copper networks are to free up funds and resources that can be redistributed to focus on providing gigabit broadband using the most effective future-proof technologies and to reduce the operating expenses associated with an expensive, energy-hungry, and operationally inefficient legacy technology.

Many European countries are showing steady progress toward fiber deployment, but the pace of decommissioning copper networks is still relatively slow and rather fragmented. Regulators and policymakers in countries including France, the Netherlands, and the UK have set out an implementation plan, but the situation can be quite different in other countries. The German regulator, for example, has not imposed any obligations as to when the copper network must be phased out. The global picture is also varied. In the Middle East, Qatar and the UAE have implemented effective migration programs, moving more than 85% of customers to fiber so their copper networks can be retired. In Asia, Singapore turned off its copper network back in 2018. In Latin America, however, countries are still a long way off starting copper retirement plans. A summary of countries that have either switched off or are expected to switch off their copper networks in the next few years is shown in **Figure 8**.

FIGURE 8: COUNTRIES THAT HAVE EITHER SWITCHED OFF OR ARE EXPECTED TO SWITCH OFF COPPER NETWORKS

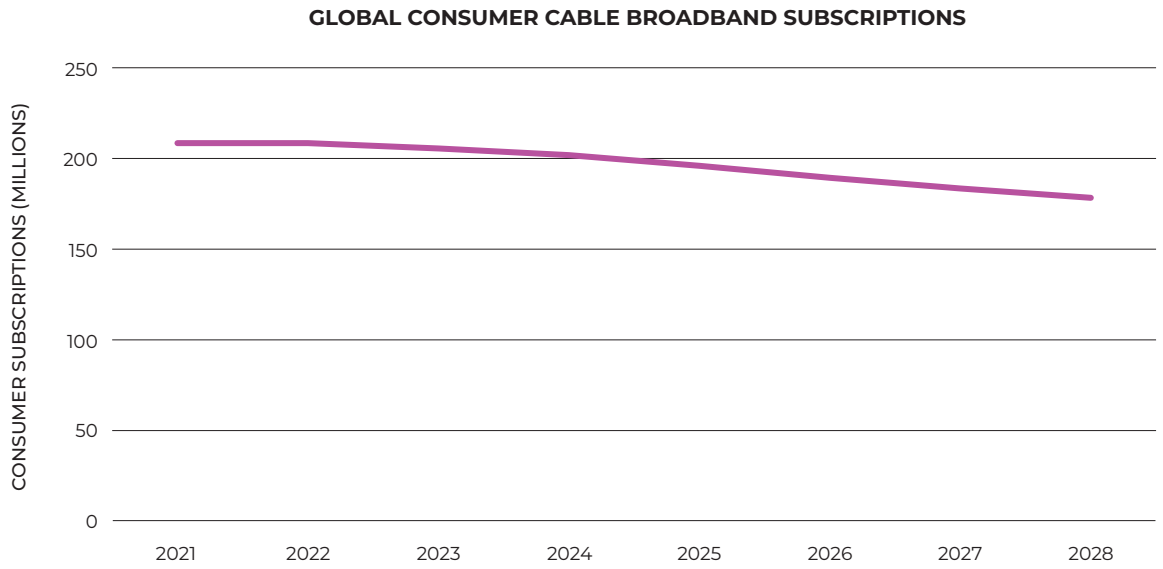


SOURCE: OMDIA: COPPER SWITCH-OFF REGULATIONS AND POLICIES

CABLE OPERATORS ARE ALSO GRADUALLY MOVING TO FIBER

Cable will have a longer tail than DSL-based networks, because if it is upgraded to new DOCSIS standards, speeds can remain comparable to those of today's FTTH offerings. However, with the increasing momentum behind fiber Passive Optical Network (PON) upgrades, it will become more and more difficult for cable networks to remain competitive. Omdia predicts that on a global level cable subscriptions will start to slowly decline from 2022 onward as cable operators gradually upgrade to fiber (**Figure 9**). DOCSIS 4.0 can deliver shared downstream capacities of up to 10Gbps and shared upstream capacity of 6Gbps. However, this is still below the symmetrical 10Gbps capacity that XGS-PON can deliver.

FIGURE 9: GLOBAL CABLE MODEM SUBSCRIPTIONS ARE NOW IN STEADY DECLINE



SOURCE: OMDIA: CONSUMER BROADBAND SUBSCRIPTION AND REVENUE FORECAST, 2023

THE HIGH COST OF CABLE DOCSIS 4.0 UPGRADE TIPS THE SCALE TOWARD FTTH INVESTMENT

XGS-PON upgrades can be completed quickly and efficiently, but DOCSIS 4.0 upgrades can be time consuming and relatively expensive because they are likely to require the swapping out of amplifiers and of numerous passive components in the cable network.

An internal study by Virgin Media O2 in the UK, for example, found that upgrading its entire cable network (15.5 million homes) to full-fiber technology would only cost 40% more per household than upgrading to DOCSIS 4.0 (an estimated £100 per home passed compared with approximately £60). Although in the short term it would be more expensive, Virgin Media O2 therefore decided to make the decision to upgrade to full fiber because it would provide a future-proof solution that can be easily upgraded in future with new generations of PON technology.

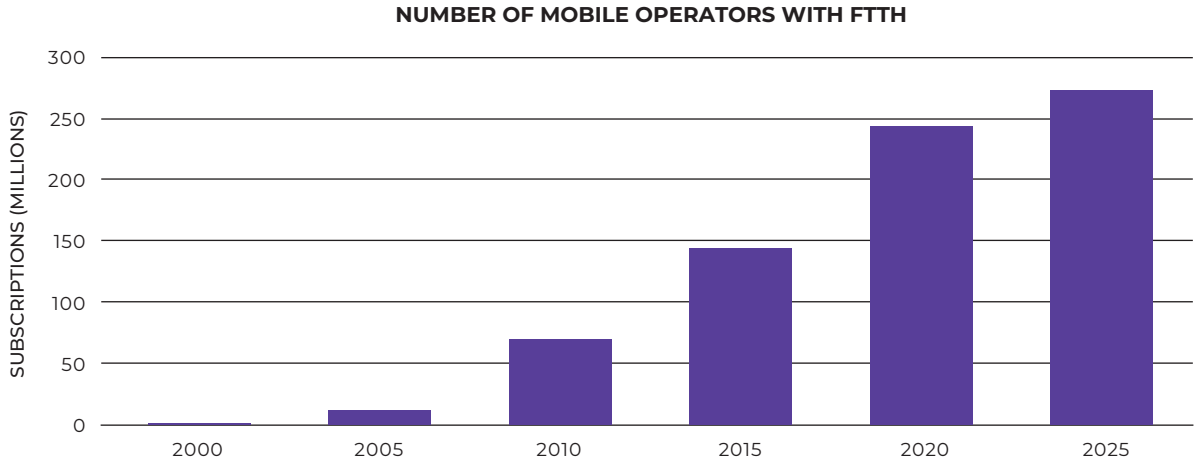
Moreover, there is no clear roadmap for DOCSIS cable upgrades beyond DOCSIS 4.0. It will become increasingly challenging to use higher frequencies on the co-axial cable plant because of physical limitations of the cabling. Vendor support for future DOCSIS upgrades is also questionable, and the vendor ecosystem for the technology is significantly less diverse than for FTTP.

MOBILE AND FIBER CONVERGENCE IS A GROWING TREND

According to Omdia's figures, as of the end of 1H23, 60% of telecom operators worldwide (540) are now converged (an increase of 1% year on year) as consolidation in the telecom industry continues despite turbulent times. Unconverged operators have distinct disadvantages in comparison with their converged competitors because they have fewer opportunities for growth and innovation and are unable to deliver the same value proposition to their customers as their multiservice counterparts. Unconverged operators are therefore pushed into mergers as they aim to create value and increase profitability in the postmerger integration process.

As regulators are becoming more lenient to further market consolidation the number of fixed-only or mobile-only operators will continue to decline in the outlook. For example, in July 2023, Bulgarian telecom regulator CRC approved Vivacom's acquisition of seven fixed-line operators, further reducing the share of small internet service providers (ISPs) in the fixed-line market and strengthening Vivacom's position as a converged operator. The number of mobile operators with fixed-line FTTH assets will therefore continue to grow, as shown in **Figure 10**. Although this chart does not tell the full story (the analysis only includes operators that publish both mobile and FTTH subscriptions data), the trend is still clear.

FIGURE 10: AS CONVERGENCE GROWS, SO DOES THE NUMBER OF MOBILE OPERATORS WITH FTTH ASSETS



SOURCE: OMDIA

THE HOME NETWORK IS ESSENTIAL FOR OVERALL QOE

The home network has become a critical part of the overall broadband supply chain. The number of devices in the home is not just accelerating but is also rapidly developing to include more screens and more advanced solutions such as extended reality (XR) and glasses-free 3D technology, all of which will put greater demands on the broadband network. As already discussed, network operators are meeting this challenge by moving to all-fiber-optical networks capable of delivering multiple gigabits of bandwidth into the home. However, all this investment is fruitless if the end user and their devices cannot effectively access that capability. The home network is the key element that links the user to the broadband network, and if it does not keep up with both the wider capability of the broadband access network and the demands of new applications, it will quickly become the new bottleneck in broadband QoE delivery.

Wi-Fi has become the most dominant home-networking technology. It has developed significantly over the years and today is capable of theoretical maximum speeds of multigigabits per second. The latest Wi-Fi 7 standard, for example, is capable of theoretical speeds of 11.5Gbps and expected typical real-world speeds of 4Gbps.

However, Wi-Fi remains an imperfect technology, and the QoS provided can be disrupted or limited because of physical obstructions, distance between router and end device, electromagnetic interference from other items, and congestion from other Wi-Fi devices on the network. In addition, because of the way internet protocols work, traffic queues can form over the Wi-Fi portion of the network even on multigigabit networks. These factors can affect not only the final network speed received by the device but also other metrics such as latency and jitter.

To minimize the impact of the Wi-Fi network, many operators have turned to Wi-Fi extenders and Wi-Fi Mesh access points with the aim of increasing the strength of the Wi-Fi signal received by reducing the distance between end point and device. Some operators, especially in Asia & Oceania but also in the Middle East and to some extent Latin America, have also started to deploy FTTR.

However, although such strategies can solve some Wi-Fi issues (mainly the physical obstruction and distance issues) they do not by themselves resolve issues such as interference and congestion. By deploying an independent centralized smart Wi-Fi management platform that can manage all customer premises equipment (CPE) devices regardless of hardware vendor or chipset, service providers can gain full visibility and management capability across the entire customer footprint. With the use of AI data analytics and other techniques such as latency management, such platforms can dynamically monitor and flex the home Wi-Fi network to optimize its performance.

GIGACITY TRENDS

In the gigacity proposition, there are several key indicators for broadband quality, for example, the expected data speeds of at least 100Mbps to 85% of households and at least 20Mbps to 95% of households, which indicates the speed and coverage requirements.

More and more users choose 5G-capable smartphones: the 5G user penetration rate in the gigacity is expected to be more than 25%, the first layer alignment of the 5G spectrum should be more than 80%, and the 5G indoor coverage of key public places should be more than 80%. In enterprise business scenarios, Wi-Fi will remain the predominant access technology.

The requirement for network connection quantity and quality will keep increasing, and the traditional protocols based on IPv4 cannot provide enough IP addresses and new features for the network. Full deployment of IPv6 will facilitate the application of segment routing, network slicing, and network digital map in the end-to-end networks.

GIGABIT SPEEDS FOR ENTERPRISES

Enterprises are the major components driving the digital economy, and in comparison with individuals and homes, enterprises have higher connectivity demands in terms of bandwidth, quality of service, and security. Gigabit connection is not just a technological upgrade: it is a strategic imperative for enterprises looking to fully capitalize on the transformative capabilities of AI and cloud computing. It underpins the efficiency, scalability, and competitiveness of businesses as they navigate the intricacies of the digital age.

To accelerate the gigabit network and service development for enterprises, the following planning and actions should be considered:

- **Accelerate the commercialization of new technologies.** The upgrading and evolution of government, enterprise, and public networks to technologies such as Wi-Fi 7 and enterprise private lines for gigabit enterprise is encouraged. New campuses, industry parks, public buildings, and transport centers should have large-scale deployment of Wi-Fi 7.
- **Establish benchmark projects.** Governments should help the setting up of model applications in domains such as e-government, finance, scientific research, higher education, and manufacturing. In line with the demands of Industry 4.0, factories will need to implement a wide range of IoT sensors and devices to enable data analytics, AI, and machine learning applications. Another possible action is to build several innovative and high-quality gigabit campus infrastructure models to effectively support technological innovation, system tests, and industry promotion.
- **Strengthen standard support and leadership.** Research institutes and universities are encouraged to establish and improve the national enterprise network standard to build a highly efficient, standardized, and open ecosystem. Active participation in international standards and industry organizations is also recommended to make international contributions and increase global impacts.

BEARER AND DATA CENTER NETWORKS EVOLUTION

The construction of a gigacity involves delivering gigabit speeds to individuals, homes, and enterprises. Having gigabit speeds only at the access network level is not enough to unleash the full potential of gigabit because the eventual goal is to bring the traffic from access networks to the data centers and cloud. Therefore, readiness of the end-to-end architecture requires the bearer and data center networks to provide ultra-low latency.

400 GE BEARER NETWORK

The bearer network will be expected to not only support simple traffic flows as in the past but to support fixed-mobile convergence (FMC) that enables ultra-reliable low-latency communications. According to “Next-Generation Broadband Roadmap 2023 to 2030,” released by WBBA, the IP bearer network needs to be gradually upgraded to 400 GE technologies. The shift to the gigacity will also require adoption of IPv6 to support billions of connected devices. Full deployment of IPv6 will facilitate the application of the latest IPv6 Enhanced innovations such as segment routing (SRv6), network slicing, and network digital map in the bearer networks.

400 GE DATA CENTER NETWORK

AI will become a dominant factor from the perspective of the data center computing force. To meet the requirements of these AI computing cases, the following key features are necessary: ultra-large bandwidth, supporting 400 GE; high throughput, supporting 98% utilization of GPU computing power; and a lossless Ethernet network with zero packet loss.

The following actions should be considered in order to build the bearer and data center networks for the gigacity to support the digital hub and AI strategy:

- **Accelerate IPv6 adoption.** To further accelerate IPv6 deployment, require newly built networks to have IPv6 capability and encourage SRv6 deployment, network slicing, and digital map. Launch an IPv6 innovation challenge to encourage key operators and enterprises to set up models and to stimulate deployments.
- **Improve the capability of bearer networks for digital hub.** Further development of internet exchange points across each nation is a consolidated trend. For metro and backbone networks, it is recommended to accelerate the deployment of 400+ GE technologies.

- **Optimize the capability of data center interconnections for the AI infrastructure.** The enhancement of the data center interconnection and the connection to enterprises through high-bandwidth 400 GE backbone for the regional digital hub should be planned, and the acceleration of 400 GE technologies deployment for data centers is very important.

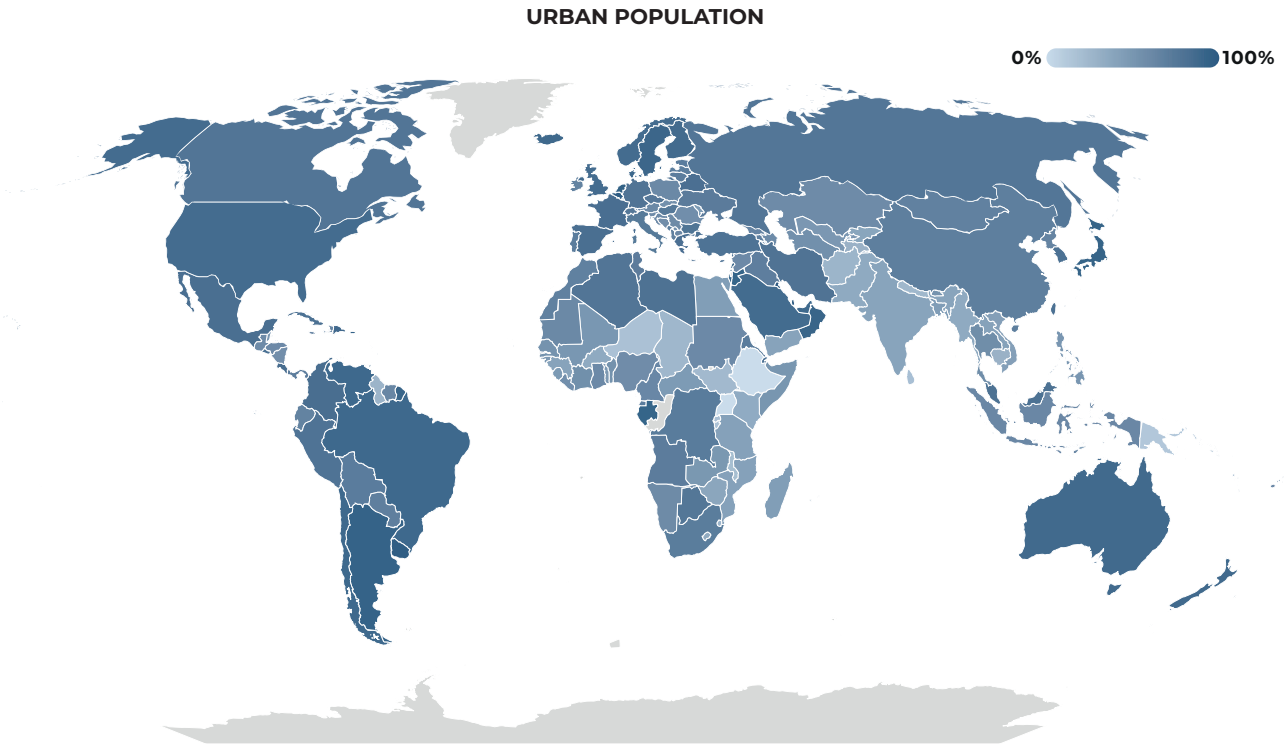
INTRODUCTION TO GIGACITY INITIATIVES

GIGACITIES CAN ACT AS A CATALYST FOR MORE NEXT-GENERATION BROADBAND DEPLOYMENT

If next-generation broadband access is to be one of the catalysts in leveling up all communities in a society, it is vital that over time equal access is deployed to all citizens in all areas of a country. However, because of a combination of longer loop lengths, more difficult terrain, and lower population density, the business case for deploying wireline fixed broadband networks in some areas of most countries can be challenging. Although equal access should be the long-term plan, it can often make more economic sense to initially focus optical-fiber investment on urban areas:

- Because of economies of scale, the cost per connected customer is lower.
- Typically, a higher portion of the population lives in the area, so more people can be reached more quickly (see **Figure 11**).
- Important financial and/or industrial centers that are significant drivers of national GDP tend to be located in areas of greater population.
- Additionally, many large government institutions, hospitals, education facilities, and so on are also located in these areas.

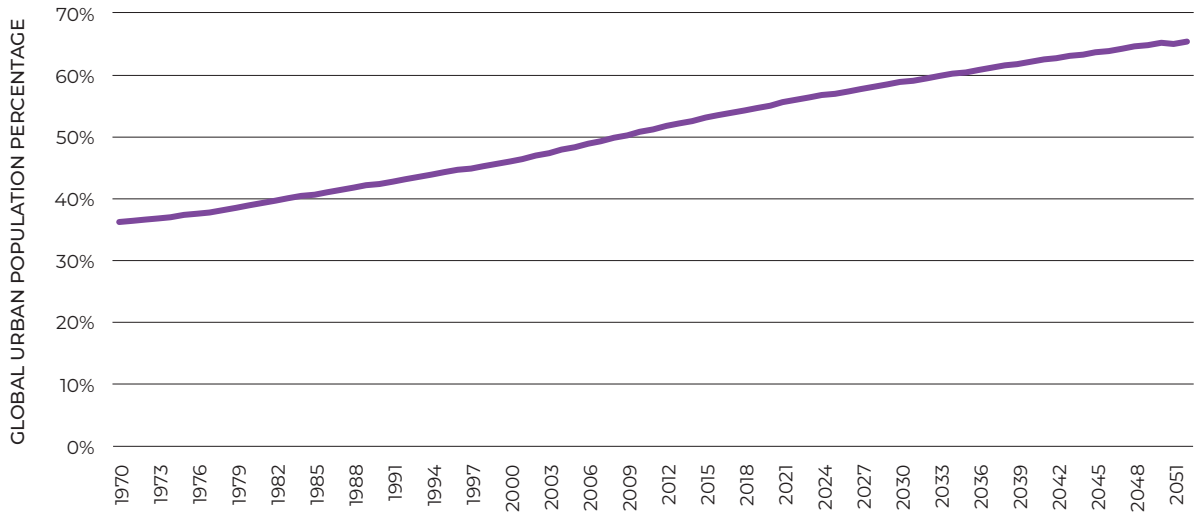
FIGURE 11: ON AVERAGE, 58% OF THE WORLD'S POPULATION LIVES IN URBAN AREAS



SOURCE: OMDIA

The importance of urban areas is only going to increase over time as the world's population becomes more urbanized. In 1970 only 36% of the world's population lived in urban areas. By the turn of the century this had increased to 55%; by 2030 it will be 59% and by 2050 over 65% (see **Figure 12**).

FIGURE 12: THE PERCENTAGE OF PEOPLE LIVING IN URBAN AREAS IS SET TO CONTINUE TO INCREASE

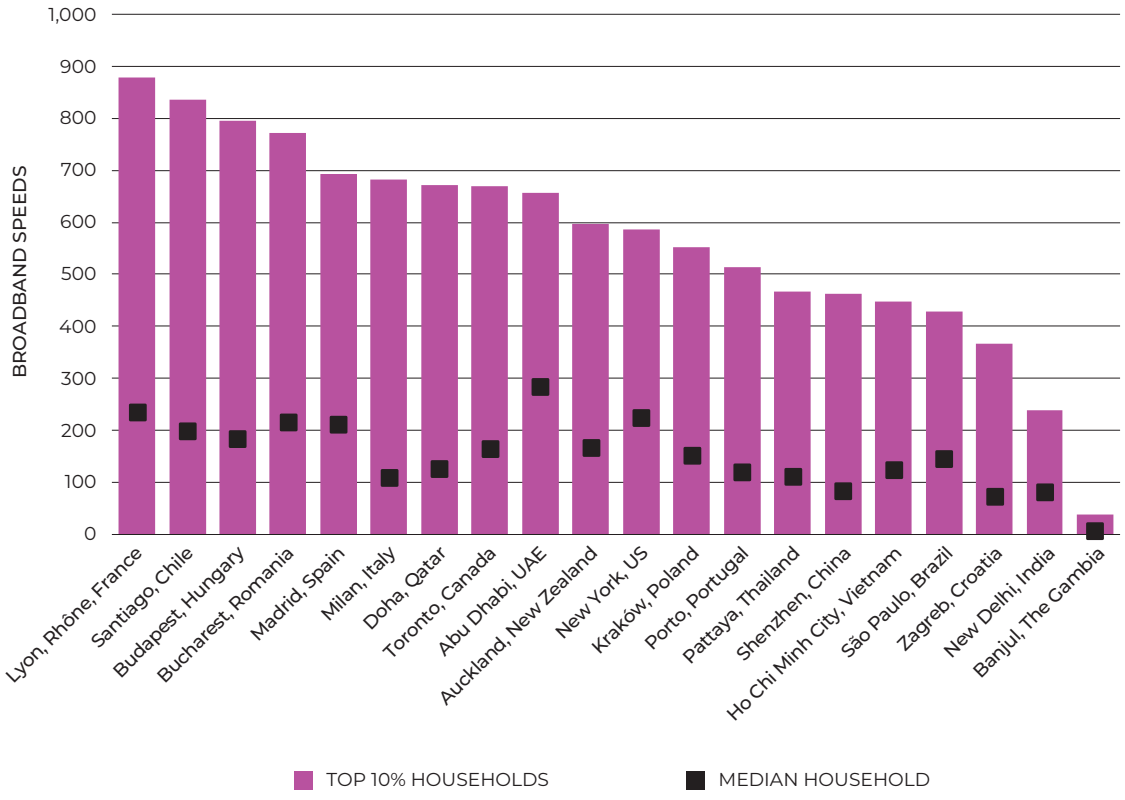


SOURCE: OMDIA

CITY SPEEDS ACCELERATE FASTER THAN THE NATIONAL AVERAGE

Having larger populations and lower deployment costs per household than other parts of the country, urban areas typically receive broadband service of higher speed and better quality than that available elsewhere. With multiple broadband tiers still on offer and often based on speed, it is not the case of course that all customers in urban areas receive ultrafast services yet, but it is common, as shown in **Figure 13**, for the top 10% of households in leading broadband cities around the world to be rapidly moving toward becoming gigabit broadband households.

FIGURE 13: TOP HOUSEHOLDS IN LEADING CITIES ARE APPROACHING GIGABIT SPEEDS



SOURCE: OOKLA

EXPERIENCE DRIVERS OF GIGABIT BROADBAND

CONSUMER BROADBAND DEMANDS WILL GROW EXPONENTIALLY

Networks are quickly expanding from connecting individuals and homes to connecting things including everyday objects (inside and outside our homes) and items that we wear and even integrate with our bodies. By 2030, there will be 13.7 million new consumer devices connected daily, with a total of more than 9 billion consumer mobile connections and 33 billion consumer Internet of Things (IoT) devices. The majority of these devices will rely, at least for part of the time, on home broadband connectivity.

This level of connectivity will create a world where digital information and content are ever present and instantly accessible. Additionally, the way we are experiencing the internet is changing: from largely 2D experiences we will move to ones in which digital and physical worlds merge through the use of augmented reality (AR) or to fully immersive 3D through a mix of AR and virtual reality (VR) known as mixed reality (MR).

This combination of an exponentially increasing number of devices and the move to more advanced, bandwidth-hungry applications will drive the need for faster and faster broadband. Using compression techniques, today's video-streaming services can offer HD video using less than 5Mbps, but high-quality 4K video streams can require speeds of up to 50Mbps, and 8K video streams need up to 300Mbps. XR technologies will see a further step change in terms of network demand. Advanced applications could require speeds of 1–2Gbps and a maximum, and consistent, latency of less than 3ms.

INDUSTRY TECHNOLOGICAL DRIVERS FOR GIGABIT BROADBAND

CAMPUS / COMMERCIAL CENTER DIGITALIZATION

The aim of the campus network is to achieve an all-in-one network for office work, security, and production with simplified passive optical LAN (POL) network architecture, accelerating the wide application of cloud services and improving the office efficiency of enterprises.

Office buildings are increasingly fitted with gigabit switches, Cat6A Ethernet, and optical-fiber connectivity as the cost of these upgrades becomes more affordable.

University campuses can form gigabit clusters for high-speed connectivity across premises (e.g., University of Cambridge in the UK). Gigabit districts and regions are emerging in various locations globally, ranging in coverage from certain business districts and urban regeneration zones to entire cities, metropolitan areas, and wider regions (e.g., Singapore, Seoul, Kansas City).

E-GOVERNMENT

E-government technology and tools enable a more efficient way for governments and businesses to function and to achieve increased transparency and greater participation by citizens in political life. The use of information and communication technologies (ICT) within government bodies is, of course, not new, but e-government goes beyond just technology adoption, enabling a rethink of processes and how bodies are organized and behave with the aim of dramatically increasing the efficiency of the way public services are delivered, saving money for governments and businesses alike.

The potential cost savings from e-government are significant. According to The European Commission (EC), for example, in Denmark electronic invoicing saves taxpayers €150m ($164m) a year and businesses €50m ($55m) a year. If this was to be rolled out across the EU, it is estimated the annual savings could exceed €50bn ($55bn).

SMART FINANCE

Smart financial technology will enable comprehensive intelligence in business processes, business development, and customer service to improve the efficiency and security of financial transactions.

Banking is shifting to a digital-first approach including an omnichannel customer experience and AI-driven applications and processes. Generative AI will play a key role in serving not only customers but also staff members to help them make better decisions in real time. Since these processes are data heavy and require ultra-low latency, gigabit connectivity is becoming a necessity. Similarly, in the insurance sector data volumes are expected to rise exponentially as IoT-based real-time monitoring takes off. Gigabit connectivity will be needed across wider areas (i.e., beyond major cities) as people, vehicles, and devices move around.

INDUSTRY 4.0 AND THE FUTURE

Industry 4.0 aims to accelerate industry digitalization, realizing the concepts of the smart factory, intelligent production, and logistics and fully releasing the potential of the manufacturing industry.

Industry 4.0 (and 5.0 as a more value-focused model featuring humans working alongside AI), are highly data driven, requiring fast and uninterrupted connectivity for operating automated production lines, autonomous vehicles, and robotics and various IoT-based analytics for operational efficiency, quality control, and worker safety, which requires action to be taken within milliseconds. Compatibility with legacy systems is important in addition to gigabit networks to support new workloads, and systems need to support the convergence of IT and operational technology (OT), meaning that data traffic needs to be routed as efficiently as possible instead of just with high bandwidth.

SMART MOBILITY/HOSPITAL

Key healthcare use cases enabled by gigabit networks include remote patient monitoring, remote care, real-time professional consultations with specialists via HD-quality videoconferencing, and faster access to health records (e.g., digital X-rays). For example, Karolinska University Hospital in Sweden uses gigabit connectivity to provide a home-based treatment program for patients with Parkinsons with specific exercises monitored by neurologists via videoconferencing. Another example is Shandong Provincial Hospital in China, which has established a gigabit Ethernet campus network focusing on high security and reliability with the capacity to handle large data volumes for its medical imaging systems, further enabling robotic and video-assisted surgery.

RETAIL

Gigabit connectivity is important for transforming the retail experience across in-store and VR shopping, supply chain efficiency, and real-time insights to support sales assistants. In-store systems such as cloud-based point-of-sale applications need fast and robust connectivity, as do any IoT devices used in smart fitting rooms, and connectivity for customer mobile devices via Wi-Fi offers an uninterrupted omnichannel experience.

POLICY AND REGULATION DRIVERS

Most countries have a national broadband plan in place. However, as connectivity has become increasingly ubiquitous in developed markets, the focus has shifted away from basic coverage and competitive pricing toward QoE, including much more ambitious targets with regard to broadband speeds, service reliability, and content bundling. In developing markets, although increasing coverage and equal access are still important factors, there is also a growing desire to leapfrog in terms of development and move directly to high-speed broadband technologies as they are developed.

In both cases, many such initiatives and legislation are focused entirely on the national level. Examples include the following:

- In the UK, the Building etc. (Amendment) (England) (No. 2) Regulations 2022 came into force on December 26, 2022 and introduced gigabit broadband infrastructure and connectivity requirements for the construction of all new homes. The UK also launched its Project Gigabit, which is investing £5bn ($6.3bn) into connecting hard-to-reach communities with gigabit broadband.

- In the US, the government has launched the Broadband Equity, Access, and Deployment (BEAD) Program, which provides $42.45bn to expand high-speed internet access by funding planning, infrastructure deployment, and adoption programs in all 50 states. Some states have also introduced regulations aimed at encouraging gigabit broadband rollouts. For example, Utah's Gigabit Opportunity Act of June 2023 would amend the Internal Revenue Code of 1986 to provide tax benefits for investments in gigabit opportunity zones.
- In the EU, the EC's Digital Decade 2030 strategy aims to extend gigabit connectivity to every household in every member country by 2030.

However, within these national plans some regulatory bodies, especially in emerging markets but also, for example, in China, have specific city / urban area targets that specifically encourage faster deployment in these important areas. Three examples of such policies are in China, Thailand, and Malaysia:

- In China, the Ministry of Industry and Information Technology (MIIT) adopted the "Dual Gigabit Network Coordinated Development Action Plan," in March 2021, setting gigabit fiber-optic and 5G network expansion targets for 2021 and 2023. By the end of 2023, the target is to cover 400 million households with a fiber network, connect more than 30 million users with gigabit speed, expand the 5G network beyond the township and village levels, and build more than 100 gigabit cities.
- Under new policies as set out by the Thailand Digital Economy and Society Development Plan from MDES (MDES Action Plan 2018–2022, and ONDE Action Plan 2022–2027), the Thai government developed five key targets related to the development of fixed broadband networks. One of the targets was specifically aimed at urban areas, stating that by 2027, speeds of at least 1Gbps will be available in the municipality, economic zone, public utility, and learning centers. Currently the mean average download speed of fixed broadband connections in urban areas is just under 2Gbps, but there are still many households on copper and co-axial cables. To meet the speed requirement, therefore, the Thai government is recommending that all infrastructure in urban areas be upgraded to fiber-optic networks.
- In 2018 the Malaysian Communications and Multimedia Commission (MCMC) carried out a review of its national broadband strategy and found a number of performance challenges that were holding back the country's broadband development. Although at that time broadband services were available to 92% of the population in populated areas, rural areas were still less well served. It also found that even where it was available, the quality of the broadband infrastructure could also be low, while prices were still relatively high, even in its urban areas. The organization therefore set out its "National Fiberisation and Connectivity Plan (NFCP) 2019–2023" with the following targets:
    - Set entry-level broadband packages equivalent to 1% of gross national income (GNI) by 2020
    - Gigabit broadband services available in industrial areas by 2020 and all state capitals by 2023
    - A minimum speed of 500Mbps available to 100% of premises in state capitals and selected high-impact areas and to 20% of premises in suburban and rural areas by 2022
    - The fiber network to pass 70% of schools, hospitals, libraries, police stations, and post offices by 2022
    - An average speed of 30Mbps in 98% of populated areas by 2023
- In 2022, Brazil's National Telecommunications Agency (Anatel) approved its "Strategic Plan 2023–2027," setting out its targets for the next four years. Two of these were focused on urban areas:
    - Expand fiber-optic backhaul connectivity from 83.97% of municipalities to 100% by 2027.
    - Expand fiber-optic backhaul connectivity in locations with more than 600 inhabitants from 13.63% to 50% by 2027.

Although the WBBA firmly believes that rural areas should not be forgotten in broadband plans and regulations, given the importance of urban areas it recognizes that setting out specific targets that speed up development in such areas, especially in developing nations, is practical. It therefore recommends that all regulators should explore the production of more detailed national plans with targets and recommendations that take into account the opportunities and challenges of broadband deployments in both urban and rural areas.

GIGACITY CASE STUDIES

SHENZHEN, CHINA

Shenzhen is an important city within the Greater Bay Area of China, representing an information exchange hub for the area as well as being a local and national source of social, economic, talent, and capital development and investment.

In this light, the city continues to invest in developments supporting manufacturing, finance, and science and technology. As part of this aim it is deploying a "double gigabit" network to not only enrich personal and family life but also support enterprise applications in fields such as urban operation and management, digital rural construction, digital transformation of industries, digital upgrade of traditional infrastructure, and public services. The new network must therefore be capable of supporting the requirements of typical scenarios such as cloud VR, smart home, cloud desktop, safe city, enterprise cloudification, online education, telemedicine, and smart manufacturing.

Environmental topics also play a part in Shenzhen's plans. As one of the first low-carbon pilot cities in China, Shenzhen has accumulated many successful experiences in low-carbon urban development. The energy consumption and carbon emission per unit of GDP are currently one-third and one-fifth respectively of the national average. As part of its ongoing development therefore, Shenzhen wishes to try and take the lead in promoting a green, low-carbon, and high-quality development of information infrastructure.

THE LAUNCH OF A "DUAL GIGABIT" NETWORK

The dual gigabit network is made up of mobile 5G technology and gigabit optical networks, providing gigabit broadband speeds to both fixed and mobile end devices. The concept is part of the Chinese government and the MIIT's efforts to construct a gigabit network capability and promote it to the population of China. It is planned that by the end of 2023, the capacity of gigabit optical fiber will cover 400 million households, 30 million gigabit broadband users, and 10 million 10G-PON or higher ports. On the mobile side it is expected that 5G networks will cover all township-level areas and key administrative villages, and 100 gigabit cities will be built.

On this basis, the Shenzhen municipal government is planning a pioneer city providing fast broadband in 2024. According to the overall layout of "city + campus + edge," Shenzhen has promoted

- Data center planning and construction: approved 30,000 new standard racks, planned to deploy 10 campus-supporting data centers, and built 15 edge computing centers
- Construction of the Pengcheng Cloud Brain Phase and the second phase of the National Supercomputing Shenzhen Center
- Construction of market-led intelligent computing infrastructure
- Construction of a full-stack, self-controllable 400 GE hyperconverged data center network and the deployment of key technologies such as network-level load balancing and digital maps
- Planning of the "transport artery" of urban computing power: support the application of new technologies, and accelerate the deployment of 400 GE ultra-broadband routers, optical transport networks (OTNs), and all-optical cross-connect (OXC) devices
- Construction of 400 GE converged bearer networks and the deployment of key technologies such as SRv6, network slicing, and digital maps
- Total OTN/SPN/IPRAN network coverage in key application places such as party and government organs, financial institutions, medical institutions, institutions of higher learning, science institutes, and regulated enterprises
- Construction of high-quality 10GE campus networks for enterprises and the implementation of technologies such as Wi-Fi 7 and Ethernet switches

In addition, Shenzhen will focus on the interconnection needs of scientific research platforms such as large scientific installations, supercomputing centers, scientific research universities, and key laboratories. It will promote ultrafast fiber connections in scientific and technological innovation corridors such as the Hetao Shenzhen-Hong Kong Science and Technology Innovation Cooperation Zone, Xili Lake International Science and Education City, and Guangming Science City.

MSHEIREB DOWNTOWN DOHA, QATAR

Msheireb Downtown Doha is the world's first fully built smart and sustainable city district, located in the heart of Doha, Qatar. It is fully sustainable with all buildings either Gold or Platinum LEED certified and adheres to high standards in green building services. The district was designed to be a smart city from conception, adopting the latest advanced technology features in its infrastructure and with services to cope with the next generation's needs. It has a range of mixed-use and commercial buildings that offer a wide array of retail and business services as well as cultural buildings. It is also the home to Msheireb Museums, Mandarin Oriental Hotel, Al Wadi Hotel, MGallery by AccorHotels, Park Hyatt Hotel, Msheireb Galleria, and Barahat Msheireb—the biggest open-air covered pedestrian square in the region.

In April 2023, it was announced that Msheireb would become the first gigacity in the Middle East, thanks to a fiber technology project run by Vodafone Qatar in collaboration with Nokia. The project will deliver speeds of up to 25Gbps and will extend the collaboration to demonstrate speeds of up to 100Gbps in the near future. Vodafone Qatar GigaHome Fibre customers will receive an upgrade to 1Gbps on their existing plans.

In terms of smart city infrastructure, the network supports

- As much as 430km of fiber-optic cables, 100% FTTH ready with telecoms, internet, IPTV, and satellite media services
- Full-coverage public Wi-Fi internet across the campus with 5,000-plus Wi-Fi access points
- More than 650,000 IoT devices for controlling and proactive monitoring of the operations of a smart city community campus, smart buildings, and smart homes
- Campus security and safety monitoring via 10,000 cameras from a centralized command-and-control room
- Basement car parking with 10,000 spaces, automation of entry and exit, and parking guidance with utilized and vacant positions status
- Integrated command-and-control center with ICCC platform and data analytics
- Three secondary control rooms for monitoring security and facility operations
- Smart access infrastructure for all buildings, parking, and homes with centralized control and support
- Four electric-vehicle (EV) charging stations for electric cars
- Eight thousand smart meters for electricity, water, gas, and cold water (air conditioning) utility consumption
- A Tier 2 on-premises data center for keeping the data safe and secured with 100% redundancy

ZAGREB, CROATIA

The vision for the City of Zagreb is to create by 2030 a European metropolis that can measure up to any other large European city. The digitalization of businesses and public services is key to this strategy, ensuring a high level of quality of life and cost savings in addition to driving new business and economic growth.

To meet this vision, the City of Zagreb has set out a Smart City Framework (**Figure 14**) with digital infrastructure being a central pillar.

FIGURE 14: ZAGREB SMART CITY FRAMEWORK

DIGITAL INFRASTRUCTURE	SMART PUBLIC ADMINISTRATION AND CITIZEN INCLUSION	SMART ENERGY AND UTILITY SERVICES MANAGEMENT	EDUCATION	ECONOMY	SUSTAINABLE URBAN MOBILITY
■ Integrative smart city platform ■ Cadastre of ducts and infrastructure ■ Broadband access infrastructure ■ Sensory narrowband infrastructure	■ Digital public services and citizen inclusion ■ Interoperability ■ Business processes and organizational structure ■ Referent architecture and standardization ■ Encouraging innovation culture ■ Development of local infrastructure and spatial data ■ Continuous improvement of service quality	■ Smart electricity network management ■ Smart CHS management ■ Smart water supply and drainage management ■ Smart gas network management ■ Smart public lighting management ■ Integration of smart buildings and infrastructure	■ Introduction of modern ICT in schools ■ Organization of student competitions ■ Organization of courses and lectures for primary and secondary school teachers and educational, informative, and promotional activities for all citizens	■ Developing entrepreneurial skills ■ Financial instruments for early stages of enterpreneurial development ■ Platform for testing innovative solutions	■ Increasing the appeal of public transport ■ Improving the traffic management system ■ Improvement of bicycle and pedestrian traffic ■ Innovative mobility systems (electromobility)

SOURCE: ZAGREB SMART CITY FRAMEWORK STRATEGY, 2023

Within "Broadband access infrastructure," it is Zagreb's aim to encourage the rapid implementation of advanced fixed (FTTH, G.Fast, DOCSIS 3.1) and mobile 5G technologies, especially via ultrafast fiber-optic access networks. Based on this strategy, in 2021 Zagreb became the first 10G city in Europe.

Local operator Telemach Hrvatska is building one of the fastest fiber-optic networks in Europe as part of an investment of more than $248m. The existing infrastructure allows the operator to initially achieve internet speeds of up to 10Gbps in 12,000 households in Zagreb with the aim of expanding its reach to the entire city.

Internet speed is a clear differentiator for Telemach, which offers its customers speeds up to 20× higher than the Croatian average. Various smart city initiatives benefit from the gigabit fiber network, including Zagreb's drive for a more efficient and transparent city administration, smart energy and utility services management, and sustainable urban mobility. Across all areas, real-time data collection and analysis will also enable better decision-making.

AUCKLAND, NEW ZEALAND

Tāmaki Makaurau / Auckland is New Zealand's largest and fastest-growing city with a population of over 1.5 million. In August 2016, Auckland Council launched its smart city strategy with a people-centric vision of making it the world's most livable city. A smart city with smart citizens needs smart infrastructure, and fiber is at the heart of that.

Chorus, New Zealand's largest digital infrastructure provider, started building Auckland's fiber network back in 2011, initially prioritizing schools, hospitals, and businesses. By 2014 all 556 schools were connected to gigabit-capable fiber. By 2019 all 663,000 residential and business premises also had access to gigabit fiber, giving the city 100% gigabit fiber coverage.

Today 502,000 homes and businesses in Auckland are connected to the fiber network, which represents an uptake of 76%. Ninety percent of customers are on fiber speeds of 300Mbps or more, and the average household data usage is 632GB per month: 17% are power-user households, using more than 1 terabyte (TB) of data per month.

The ubiquitous fiber network is also being leveraged by utilities and transport operators for connecting smart locations. EV charging stations, digital signage, CCTV cameras, and public Wi-Fi hotspots are just some of the use cases.

On November 18, 2019, the capability of the Auckland fiber network took another major step with the launch of Hyperfibre. Hyperfibre is Chorus's multigigabit product built with XGS-PON technology, offering symmetrical speed plans of 2Gbps, 4Gbps, and 8Gbps. Hyperfibre capability is available across the entire Auckland fiber footprint, and uptake is strong in the small business, education, and early-adopter residential segments.

The ubiquitous availability of fiber for cell site connectivity has been a key enabler for improved mobility services. In December 2019, 5G mobile services were launched in Auckland, and in March 2021 the America's Cup sailing regatta showcased the capability of 5G technology with a range of innovative use cases.

In November 2023, Auckland Council adopted a new growth strategy with its population expected to hit 2 million by 2040. Sustainability and infrastructure resilience were at the heart of the strategy, which includes a commitment to grow in a way that reduces emissions and adapts to climate change. Scalability, resilience, and sustainability are hallmarks of fiber, so Auckland's smart city infrastructure is well positioned for the future.

THE GAMBIA'S FIRST SMART CITY

Gamtel, in collaboration with TAF Africa Global, is working on creating The Gambia's first smart sustainable city, enabling the use of ICT and other tools to improve quality of life, competitiveness, and the efficiency of urban operations and services while guaranteeing that it meets the social, economic, and environmental needs of present and future generations.

To date Gamtel has deployed 72 pairs of fiber cable infrastructure for the provision of FTTP across the city, which includes 5,000 residents and hospitals, schools, and entertainment centers.

The project's goal is to provide affordable and dependable broadband connectivity to the entire city in alignment with the government's goal of transforming Gambia into an information-rich, knowledge-based economy and society by 2028 and beyond by leveraging broadband technology and digital transformation.

The fiber distribution terminal (FDT) and fiber access terminal (FAT) have been installed and commissioned successfully for the first estate of 64 homes, and internet connectivity is now available to residents. As the other estates are developed, this deployment will be expanded across the city.

GIGACITY CRITERIA

As is evident from the case studies discussed above, cities and their residents, businesses, and public services can benefit from gigabit-speed fiber connectivity to improve citizens' lives, achieve cost efficiencies, and support enterprises of all sizes. Gigabit connectivity is usually not just a step up from tens or hundreds of Mbps for achieving greater convenience when streaming videos or playing computer games but a fundamental driver and enabler of broader smart city initiatives.

Cities (and wider regions/countries) are increasingly competing as preferred business and residential locations by aiming to provide public services in a more efficient and easily accessible way. Many smart city initiatives also focus on environmental impacts such as reducing emissions through better traffic flow and often include the creation of entirely new smart neighborhoods as test beds for new concepts, such as all amenities being reachable by residents within a 5–10 minute radius, autonomous transport schemes, and AR/VR-based entertainment.

As can be seen from the variety of use cases, a smart city built around gigabit connectivity may include intelligent road/traffic management, AI-based production automation for Industry 4.0, remote patient care and surgery in hospitals and care homes, large campuses with private networks for offices and universities, generative AI for financial firms requiring ultra-low latency, smart retail with true omnichannel enablement, and smart grids for energy monitoring and usage efficiency.

Fiber connectivity is the main enabler for gigacities. In most cases, this is further enhanced by mobile 5G networks and private networks for large campus sites. Network connectivity needs to be tightly integrated with a hybrid/multicloud environment, edge computing for lower latency and data compliance, and tight cybersecurity across the entire ICT environment.

CHARACTERISTICS OF A GIGACITY

To meet the above gigacity aims, the WBBA has set out a list of metrics that characterize a gigacity (see **Table 1**).

TABLE 1: SUMMARY OF THE CHARACTERISTICS THAT DEFINE A GIGACITY

CHARACTERISTIC	DESCRIPTION	IMPORTANCE
FTTH HOMES PASSED	The percentage of households in the city covered (i.e., households that are connected or could be connected in a short time) by the optical-fiber network	Represents the current potential of the fiber access network. A limited coverage will mean that only a small selection of households and businesses can gain access to the full benefits of a fiber network.
MOBILE CELL SITE FIBER CONNECTIVITY	The percentage of total mobile cell sites in the city that are fiber connected	Mobile cell sites need high-speed and high-quality backhaul capabilities to optimize mobile-access performance, maximizing the potential for smart city use cases.
MEDIAN BROADBAND SPEED	The median household download speed in Mbps	Advanced fiber networks can deliver very-high-speed broadband services. Although not the only important network metric, speed is essential for delivering bandwidth-hungry applications such as 8K video in a quality fashion. The median broadband speed will indicate what level of service and therefore the range of advanced applications the average household in the city can receive.
MEDIAN BROADBAND SPEED (TOP 10% HOUSEHOLDS)	The median household download speed in Mbps of the top 10% of households in the city	The median broadband speed of the top 10% of households in the city will indicate what level of service and therefore what range of advanced applications the most bandwidth-hungry household in the city can receive.
PERCENTAGE OF SCHOOLS CONNECTED BY FIBER	The percentage of schools and education facilities in the city that are fiber connected	Broadband services provide access to a range of educational material and tools. Because they potentially serve thousands of students per premises, it is critical that schools are equipped with high-speed and quality broadband networks to optimize functionality and teaching facilities.
INDUSTRIAL/ ENTERPRISE ZONES GIGABIT COVERAGE	The percentage of Industrial/ enterprise zones that have widespread gigabit coverage	Successful industrial and enterprise zones are crucial for the economic development of both the immediate city area and the nation as a whole. The availability of gigabit broadband in such areas will enhance business efficiency and innovation, helping to make local businesses more successful and to attract new ones into the area.
HOSPITALS AND OTHER GOVERNMENT PREMISES CONNECTED BY GIGABIT BROADBAND SERVICES	The percentage of hospitals and other government premises in the city that are connected to gigabit broadband services	Gigabit broadband services are an essential tool for improving the efficiency and level of service that institutions such as hospitals and government offices can provide.

SOURCE: WBBA

HOW TO ACHIEVE THE GIGACITY

Achieving the gigacity is an ambitious goal that requires a comprehensive approach.

First, it is crucial to invest in the necessary infrastructure. This includes deploying or expanding fiber networks, upgrading existing infrastructure to all-optical, and deploying advanced fiber access technologies such as XG(S)-PON and 50G-PON. These network investments must also take care of the infrastructure to mobile sites, industrial parks, schools, hospitals, and other governmental institutions. Such investments will ensure that high-speed internet is accessible to a larger population. City governments can implement policies that facilitate fair competition and incentivize ISPs to invest in high-speed networks.

In terms of the end-to-end network architecture, the bearer network and data center network will need to be migrated toward 400 GE, to accommodate the expected increase in traffic from individuals, homes, campuses, and enterprises. Full deployment of IPv6 will also facilitate the application of segment routing, network slicing, and network digital map in the end-to-end networks.

Second, the infrastructure needs to be used for the benefit of the economy and the people. Specifically, access to the education and government institutions of the gigacity enables a lot of innovation. But in addition, digital literacy and education play a vital role in the achievement of widespread gigabit usage for all types of applications. Providing training programs and resources to help individuals understand, utilize, and innovate effectively based on high-speed internet is crucial. This will empower people to take advantage of the opportunities that come with faster internet, such as remote work, online education, and access to the digital services of the city.

MEASURING GIGACITY DEVELOPMENT

The WBBA recognizes that all cities are at different stages of their broadband development and has therefore split these characteristics into three bands—Bronze, Silver, and Gold—so that cities can benchmark themselves against these criteria and understand where they are in their development in comparison with their global peers. The definitions of the three levels of gigacity development are as follows:

- **Bronze**: The city is well underway with its fiber deployment and has a good level of gigabit coverage but still needs to encourage greater penetration.
- **Silver**: The city has a high level of fiber coverage and a good level of gigabit take-up across residential, enterprise, and public sites.
- **Gold**: There is a high level of both fiber coverage and gigabit penetration across all use cases.

TABLE 2: GIGABIT CITY CHARACTERISTIC METRICS

CHARACTERISTIC	BRONZE	SILVER	GOLD
FTTH HOMES PASSED	20–59%	60–89%	90% plus
MOBILE CELL SITE FIBER CONNECTIVITY	At least 20%	At least 50%	80% plus
MEDIAN BROADBAND SPEED	At least 50Mbps	At least 150Mbps	200Mbps plus
MEDIAN BROADBAND SPEED (TOP 10% HOUSEHOLDS)	At least 100Mbps	At least 500Mbps	800Mbps plus
PERCENTAGE OF SCHOOLS COVERED BY FIBER		At least 50%	90% plus
INDUSTRIAL/ENTERPRISE AREA GIGABIT COVERAGE		At least 50%	90% plus
HOSPITALS AND OTHER GOVERNMENT PREMISES GIGABIT COVERAGE		At least 50%	90% plus

SOURCE: WBBA

EVOLUTION TOWARD 10GIGACITY

INTRODUCTION

At present, the world is experiencing an unprecedented pace of technological advancement, with digital technologies such as 5G, cloud, and AI rapidly evolving across many disciplines and industries. The evolution toward the 10gigacity provides an opportunity to coordinate the efforts of government, private, and nonprofit sectors to strengthen a city's position as a global pioneer of next-generation network technologies, enhancing the nation's competitiveness and international standing in the fully connected intelligent era.

The 10gigacity is a key element of infrastructure that is critical to pursue national digital strategies and to boost the digital economy. The development of the "10Gbps society" means the delivery of 10Gbps speeds for home, campus, mobile broadband, and enterprise network. It also involves converged bearer networks and AI data center networks. Moreover, the establishment of 10Gbps technologies could directly boost the contribution of ICT to GDP growth. The adoption of 10Gbps aligns with green best practices because it means embracing next-generation high-speed networks that have significantly lower carbon emissions than legacy networks.

THE VALUE OF THE 10GBPS SOCIETY

The 10Gbps society has significant economic, social, and environmental value and will directly contribute to economic growth and job creation, enhancing competitiveness.

SOCIAL VALUE

In the internet era, digital technologies are critical enablers of city development. A citizen today uses digital devices to interact with the environment for daily living, work, and entertainment. Correspondingly, evolved cities now have tech-integrated public environments and workspaces, integrated multimodal transportation systems, and platform-driven visitor experiences.

The 10gigacity brings new services and benefits across society. Fast broadband enables smart home applications, 8K streaming, XR gaming, and seamless remote working, reducing commuting time and therefore energy consumption and pollution. E-health services such as remote procedures, diagnoses, examinations, monitoring, and telemedicine; unmanned industry; and smart ambulances are all enabled by 10Gbps broadband, reducing healthcare costs and saving lives. Additionally, 10Gbps broadband and fiber infrastructure enable fully autonomous vehicles, promoting efficient traffic systems, decreased congestion, and fewer accidents for a safe transport experience. The spread of 10Gbps broadband to rural areas enables such advanced services to be provided remotely, enabling people to learn, work, and live in the area of their choice, thus closing the digital divide in rural areas.

ECONOMIC VALUE

The 10gigacity has a positive impact on the economy in a range of ways, whether directly through increased investment and consumption of ICT services or indirectly through the creation of new industries and services. It also induces impact through the increase in productivity of all sectors from the application of technology. The 10Gbps network is expected to significantly boost GDP through new services, investments, and job creation.

ENVIRONMENTAL VALUE

The adoption of 10Gbps supports aims to reach energy-neutral, zero-carbon, and zero-waste governance processes. The 10gigacity technology prioritizes environmental sustainability, promoting energy savings and reduced carbon emissions. The optical-fiber network is notably ecofriendly, using 60–75% less energy than copper. The 10Gbps network employs AI intelligence and 5G Advanced to optimize energy usage, while green data centers utilizing renewable energy sources reduce carbon emissions. Furthermore, the 10Gbps society will change the way people live and work, with an impact on the average individual's carbon footprint. The pervasive application of remote working in the 10Gbps society will further decrease carbon emissions in commuting.

BUSINESS VALUE

Advanced services enable remote operations in healthcare and education. Enhanced mobile and fixed broadband networks facilitate hyperconnected communities and digital societies, offering new opportunities for operators and promoting smart lifestyle experiences. This supports various applications, enhances user loyalty, and boosts revenue. New use cases such as smart manufacturing and smart city applications are emerging, improving enterprise efficiency and productivity through real-time communication and accelerating the monetization of digital infrastructure. Unmanned industries for companies operating in dangerous sectors reduce social costs and improve worker efficiency. There is also the possibility of using remote experts to improve work quality and reduce costs.

IMPLEMENTATION OF 10GIGACITY

As demand for 10gigacity implementation accelerates, next-generation technology for both mobile and fixed networks must be introduced. For mobile broadband, 5G carrier aggregation and mmWave are expected to support the necessary speed upgrade. By 2030, 5G/6G will become the dominant technology with 5G/6G user penetration potentially reaching 90% in large cities, and mmWave could be deployed for hotspots in dense urban areas. The fixed network must properly underpin this additional demand for bandwidth.

For fixed broadband, FTTH offering gigabit or faster speeds will be highly universalized.

To enhance the backhaul network of mobile infrastructure and provide a solid ultrafast speed infrastructure for the 10Gbps network, 100% OTN reachability for 5G base stations and central office hubs must be in place.

Regarding wireless LAN (WLAN), early deployments of Wi-Fi 7 started in 2023 and Wi-Fi 8 standardization is expected by 2028. As a key infrastructure for business and consumer internet access, Wi-Fi 7/8 is expected to achieve penetration higher than 80% in 2030.

Because of the end-to-end network capability required to enable the 10gigacity, the backbone and data center networks also need to be upgraded. The large-scale deployment of 400G Ethernet will start in 2024, and together with future higher-rate Ethernet it is expected to reach an 80% deployment rate by 2030.

The backbone network will be expected to not only support simple traffic flows as in the past but to be FMC capable with the ability to support ultra-reliable low-latency communications. According to WBBA's "Next-Generation Broadband Roadmap 2023 to 2030," the IP bearer network needs to be gradually upgraded to 400GE and future higher-rate technologies. The shift to the 10Gbps society will also require adoption of IPv6 to support billions of connected devices. Full deployment of IPv6 will facilitate the application of the latest IPv6 Enhanced innovations such as segment routing (SRv6), network slicing, and network digital map in a converged bearer network.

AI will become a dominant factor from the perspective of the data center network computing workforce. To meet the requirements of these AI computing cases, the following key features are required:

- Ultra-large access bandwidth
- High throughput supporting 98% utilization of graphics processing unit (GPU) computing power
- Lossless Ethernet network

In conclusion, the key features of the 10gigacity include 5G and FTTH network coverage and high user take-up rates. Furthermore, Wi-Fi 7/8 will strengthen user access speeds for both residential and enterprise users. Enough bandwidth must be made available by the backhaul/campus/backbone network, and full IPv6 adoption is needed to improve overall network efficiency.

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