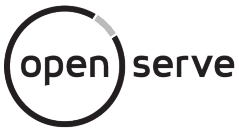
NEXT-GENERATION BROADBAND ROADMAP

WORLD BROADBAND ASSOCIATION

This report sets out the World Broadband Association's (WBBA) roadmap for the future broadband network of 2030 and beyond.



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EXECUTIVE SUMMARY

Even though fixed broadband services have been available for more than 20 years, and there is now broad understanding of and consensus on the importance of broadband to a country's wealth and social development, the levels of progress in fixed broadband technology between countries still varies wildly, from markets with 100% full-fiber connectivity to countries that have less than 1% fixed broadband penetration of any type.

Emerging broadband markets, however, have an opportunity to not follow the same path as their more developed neighbors that started off on copper technologies such as ADSL but to "leapfrog" these older generations of broadband technology and jump straight to fiber-first broadband. All countries, regardless of their broadband legacy, should therefore aim to develop broadband networks that provide

- Ultra-high-speed connectivity for all
- A converged network to deliver all services, create synergies, and accelerate monetization
- An agile network that enables the creation of efficient new use cases and business models
- Full automation to maximize network and service operations optimization
- Minimal impact on the environment

KEY MESSAGES AND RECOMMENDATIONS

- Deploying new advanced broadband networks is an expensive business. To maximize such investment, it is imperative that the same infrastructure is used for multiple use cases, thus maximizing the revenue potential while also reducing the total cost of ownership (TCO) on a per customer basis.
- Future consumer and enterprise applications will require not only ultra-high bandwidths but also other network characteristics such as ultra-low latency and jitter and high levels of service consistency and reliability.
- On top of the application demands, there will be new business demands on the network, such as being extremely energy efficient and having high levels of intelligence, automation, and security in addition to new capabilities such as network sensing.
- If service providers are to build such networks, it is critical that they are able to generate a fair return on that investment. In the past, generating greater broadband access ARPU or alternative broadband business models has been difficult. However, new models are starting to be developed thanks to new technology capabilities around prioritization and customer data. Current regulations will need to be reviewed, however, if all these new models are to be maximized.
- To set out a roadmap for the future broadband network of 2030 and beyond, the World Broadband Association (WBBA) has created a broadband framework around six key characteristics:
    - Ultra-enhanced speeds
    - Ultra-reliability and consistency
    - Enhanced connectivity
    - Greater intelligence
    - Sensing capabilities
    - Trustworthy and green
- Today, leading broadband operators are building broadband networks that
    - Are moving beyond fiber to the home, pushing fiber closer to the user for "fiber for everything"
    - Offer residential speeds of up to 1Gbps, and enterprise services of 100Gbps
    - Offer L3 conditional autonomous capability
    - Are 99.999% reliable and offer latency of less than 5ms
    - Are more energy efficient than old copper networks by a factor of five
- To take into account future network demands, the WBBA recommends that as the industry approaches 2030 and beyond, leading operators should be working toward networks that will be capable of
    - Residential speeds of up to 50Gbps and enterprise speeds of up to 3.2Tbps
    - Providing fiber connectivity to individual sensors
    - Being fully autonomous

- Having deterministic reliability with less than 1ms latency guaranteed
- More energy efficiency per bit
- Very fast security breach detection and response (seconds)

MARKET DRIVERS

VISION FOR THE FUTURE BROADBAND NETWORK

The vision for the broadband network of 2030 is one that provides

- Connectivity for all
- Fiber for everything (converged networks)
- An agile network that enables efficient new use cases and business models to be created
- Full automation to maximize network and service operations optimization
- Minimal impact on the environment

The WBBA recognizes that different broadband network operators play different roles in the broadband supply chain and are currently at different starting points in terms of their legacy networks and the overall stage of development in the markets where they operate. Regardless of this, all operators should create network roadmaps that work toward the above future vision.

CONNECTIVITY FOR ALL

Broadband's socioeconomic benefits are well known and documented. The global broadband subscription market alone was worth more than $356bn at the end of 2021 and supports a wider information and communication technologies (ICT) industry that typically accounts for between 2% and 7% of a country's overall GDP. A study by the World Bank calculated that an increase of only 1% in the use of fixed communications infrastructure increases a country's GDP by 0.08% and, in addition, that the chance of an educated population finding a job increases by 7–13% when it has access to fiber-optic infrastructure. Such measures are purely economic ones, however. Although more difficult to quantify, the benefits of broadband networks to society include better health and educational facilities and other more social aspects such as well-being and social equality. Making sure 100% of the world's population can access such benefits must therefore be one of humanity's top priorities.

NETWORK AGILITY

In previous generations of the broadband network, network demands changed slowly and in a relatively predictable way. Add to this myriad, complex legacy operational and support platforms that need to be navigated with every service change, and the telco broadband operation would move slowly, making innovation difficult to manage. In the new world, customer demand changes quickly, and if telcos are to keep up and innovate in the same way as so-called "over-the-top" (OTT) players, the network must be capable of meeting such demand.

NETWORK AUTOMATION

In meeting this demand, the network must also be efficient. Manual intervention to manage unpredictable changes would be both unworkable and expensive. Full network automation will allow the networks to flex and meet such unpredictable demand while also resolving recurring network incidents to improve service reliability.

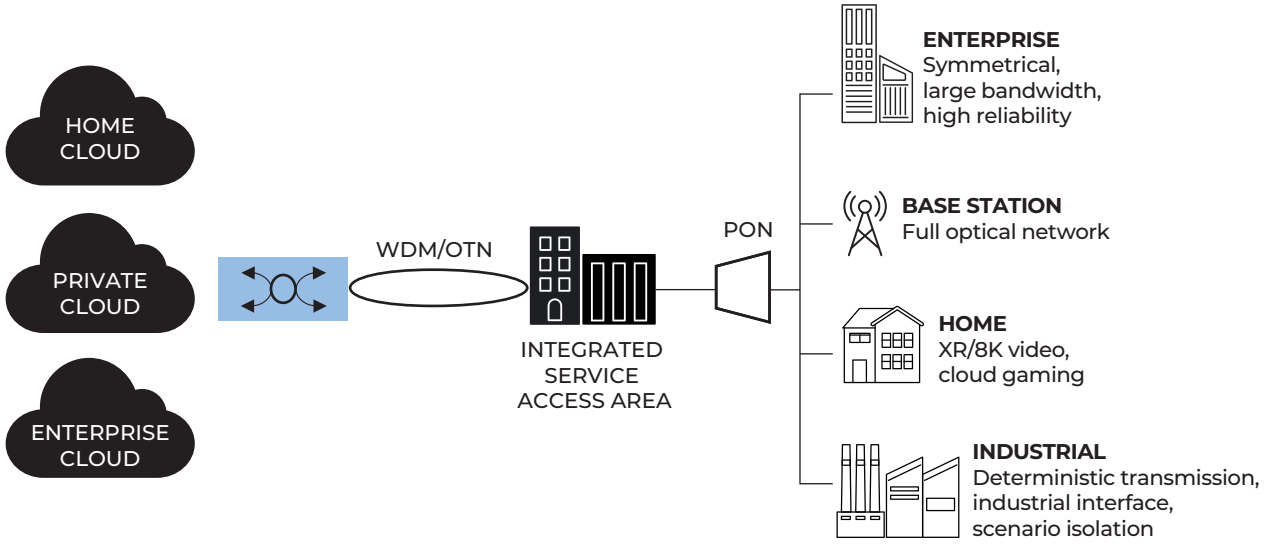
MINIMIZING ENVIRONMENTAL IMPACT

Many broadband service providers have already added environmental elements to their list of corporate values. Advanced broadband network technologies can help with such initiatives by reducing the amount of space and power required to run them. Minimizing the impact on the environment should be baked into every future network design decision.

ONE NETWORK, MULTISERVICE

Once deployed the physical fiber-optical network infrastructure will be in the ground for decades to come. It is therefore imperative that the investment in it is maximized. One way to do this is to reuse the same infrastructure for multiple use cases, thus maximizing the revenue potential while also reducing the TCO on a per customer basis.

FIGURE 1: INVEST ONCE, MONETIZE MANY TIMES



SOURCE: OMDIA

Access networks based on Passive Optical Network (PON) are already supporting residential and nonresidential customers and applications today. Next-generation PON variants, such as 10G PON, are optimized to support future FMC (fixed-mobile convergence) needs because transport traffic (e.g., wireless backhaul) can be supported over the same PON infrastructure as end-user services. This approach saves fiber assets and operational costs, thereby achieving faster return on investment (ROI). In addition, next-generation PON access networks will be future-proofed to support all enterprise services and smart city applications.

It is important to note that this future transport network will not be a dumb pipe that is fully dependent on IP capabilities but will rely on end-to-end optical networking to ensure guaranteed user experiences. This has led to a major industry mind shift in flattening the metro from the traditional five hops to a one-hop optical access. An underlying optical network (WDM and OTN) that flattens the metro and backbone network with all-optical ensures guaranteed bandwidth, higher network resiliencies and reliability, and service-level agreement assurance for vertical business services and home users.

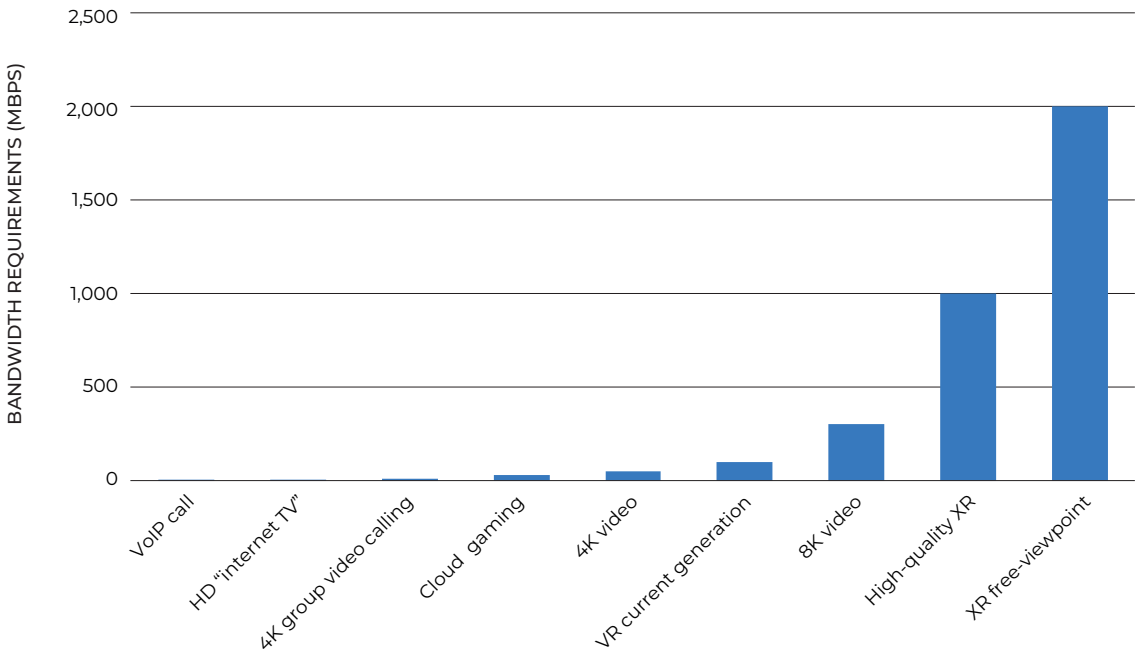
End-to-end IP-based packet networking is the basis for true FMC network construction and provides fast service routing and switching capabilities. Network operators use IP ports to connect 5G RAN eNodeBs (base stations) with 10G or 25G interfaces to support 50G or 100G per ring and direct traffic to superfast heavy-duty core routers via cloud metro aggregations. For edge computing and latency-sensitive applications, many use-case service centers will be near the edge and used in cloud metro for quick response time. An excellent example of such a service is an edge-distributed content delivery network (CDN). Segment routing removes the need for resource reservation protocol - traffic engineering. Moreover, the hardware and software of existing brownfield deployment routers require updates to support soft and hard slicing for many digital time-sensitive services. An all-optical network with smart protocols is a requirement for the gigabit society.

APPLICATION AND SERVICE DRIVERS

THE CONSUMER DEMAND FOR SUCH A NETWORK

Digital consumer applications are developing rapidly and will increasingly rely on high-bandwidth, highly consistent, and low-latency networks to function at the required quality. Some applications, such as cloud gaming, will not require such high bandwidth but will rely on ultra-low latency; XR applications on the other hand will need both high bandwidths and low latency.

FIGURE 2: DEMANDS ON THE NETWORK OF FUTURE APPLICATIONS WILL GROW EXPONENTIALLY



SOURCE: OMDIA

THE RISE OF XR

One of the most exciting developments in both consumer and enterprise internet applications is the development of augmented (AR) and virtual reality (VR). Today it is most common to use AR and VR independently, with AR mainly being used (certainly in the consumer space) in mobile applications and VR, via VR headsets, in applications such as VR gaming. However, the blurring of the line between AR and VR is inevitable, and research by Omdia suggests that we will see more tangible examples of mixed reality (MR) emerge in 2022.

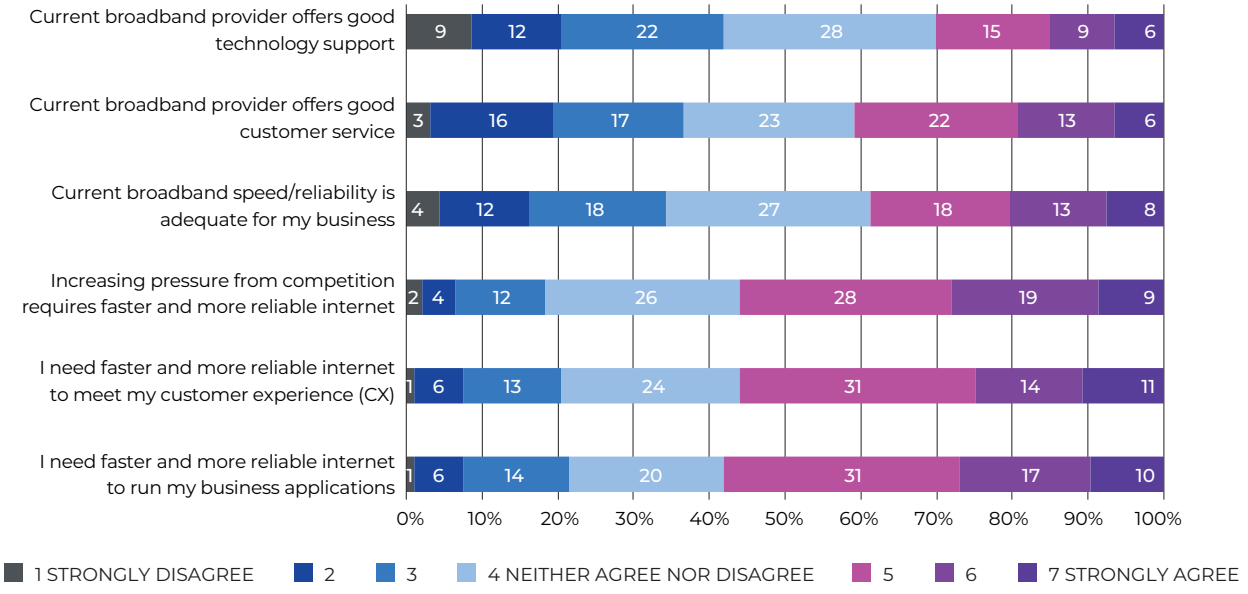
One of the most interesting aspects of MR development is the potential creation of the metaverse, a virtual world facilitated by the use of high-quality video mixed with augmented and virtual reality. Although the term *metaverse* originated in 1990s science fiction, the concept has gained traction in recent years, and some see it as the future default way of interacting with the internet.

Today, AR glasses and MR headsets are almost entirely used for enterprise applications. VR headsets are more common in the consumer market but even so are still relatively niche, with only 2.3% household penetration on a global basis according to Omdia's research. However, VR is now taking steps toward becoming a mass-market proposition, largely driven by increased investment from Meta (Facebook), and AR glasses are expected to go mainstream from 2025 onward.

TRANSFORMING ENTERPRISE OPERATIONS THROUGH CONNECTIVITY

As businesses look to rapidly digitize, the demand for broadband connectivity within the enterprise sector has increased significantly and is only expected to continue rising. In the WBBA's 2021 Thought Leadership Enterprise Survey, 56% of business respondents stated that they needed faster and more reliable internet to run their business applications. The ability to create meaningful customer experiences will hinge largely on connectivity, and 56% of respondents also indicated that they need faster and more reliable internet to meet their customer experience requirements and to stay competitive (see **Figure 3**).

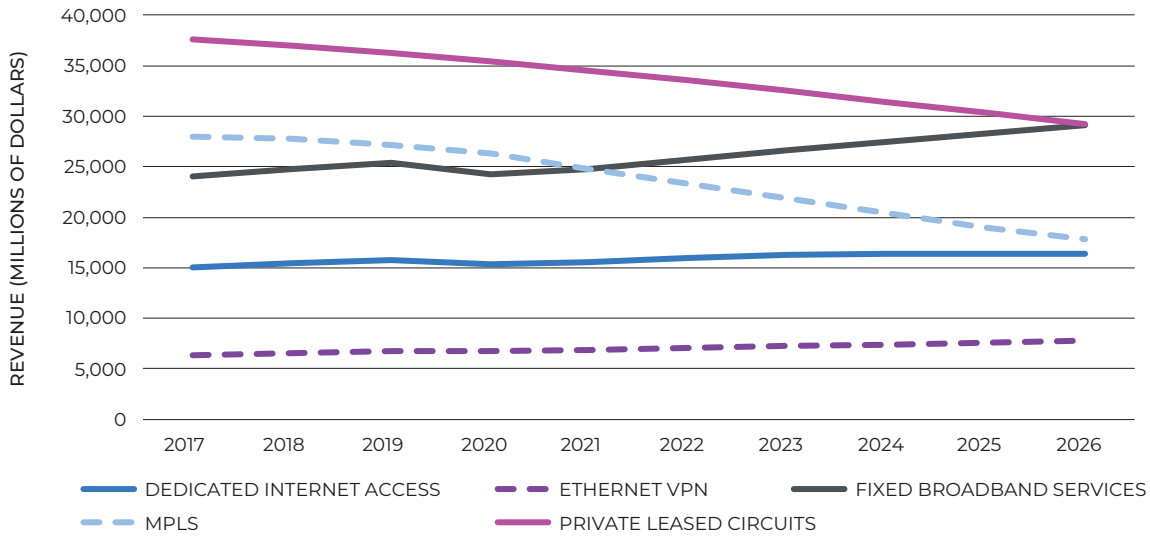
FIGURE 3: ENTERPRISE'S ACCESS TO CURRENT BUSINESS BROADBAND



SOURCE: WBBA THOUGHT LEADERSHIP ENTERPRISE SURVEY; N=75

The importance of broadband is reflected in enterprises' reported spending intentions. Omdia forecasts that fixed broadband will have the strongest revenue growth of the five core network services (see **Figure 4**), driven by trends in software-defined wide area networking (SD-WAN) and hybrid networking. In addition, enterprises are increasingly using broadband as the primary connectivity for smaller branches.

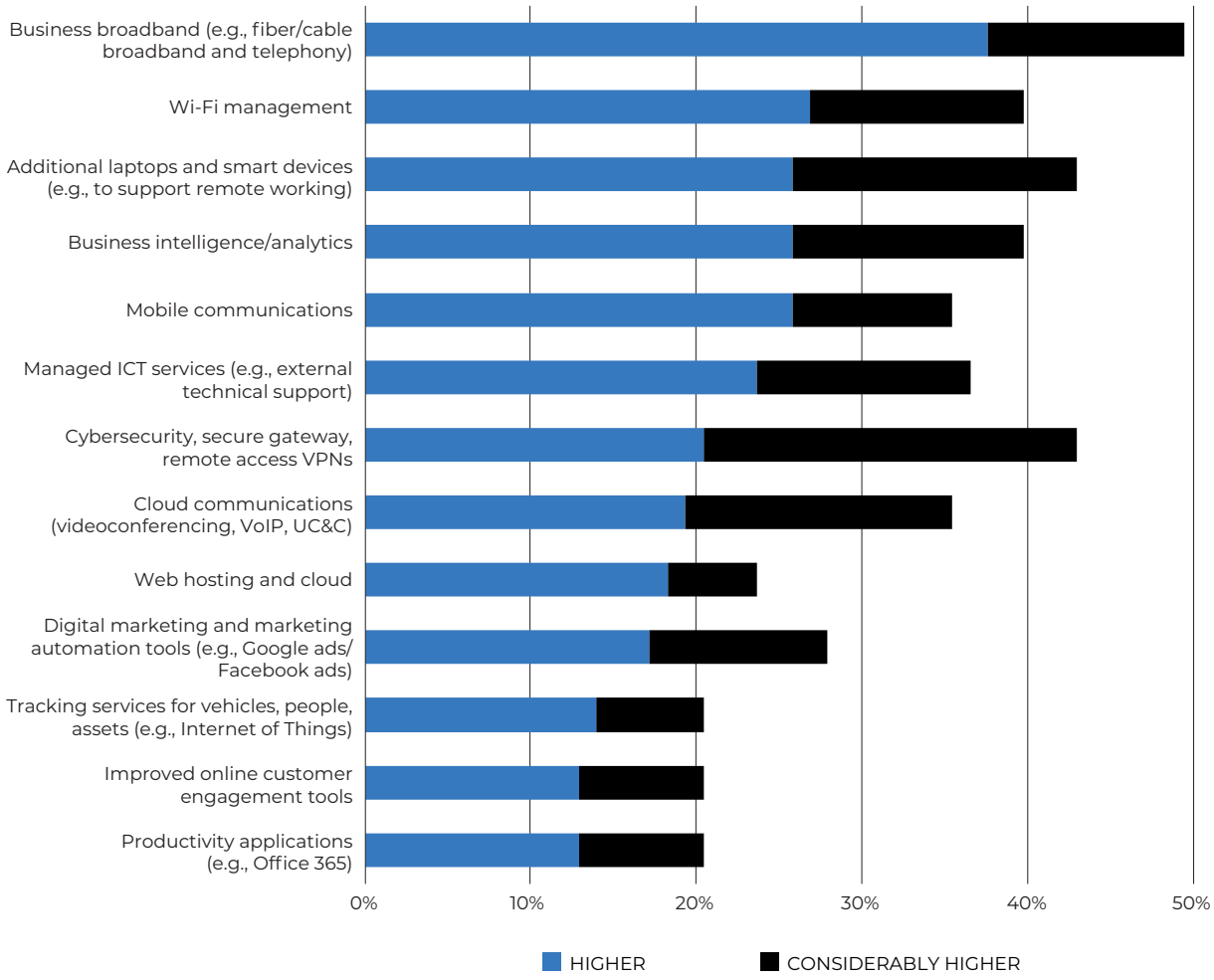
FIGURE 4: BROADBAND WILL SEE THE STRONGEST GROWTH OF THE MAIN ENTERPRISE NETWORK SERVICES



SOURCE: OMDIA

This forecast is validated by WBBA's Thought Leadership Enterprise Survey, which surveyed businesses of all sizes and found that planned business broadband expenditure will grow higher this year than last year, irrespective of industry.

FIGURE 5: HOW DO YOU EXPECT YOUR ORGANIZATION'S EXPENDITURE ON COMMUNICATIONS AND DIGITAL SERVICES TO CHANGE THIS YEAR COMPARED WITH LAST YEAR?



SOURCE: WBBA THOUGHT LEADERSHIP ENTERPRISE SURVEY; N=75

VERTICAL INDUSTRIES NEED BROADBAND FOR INDUSTRY TRANSFORMATION

Under normal conditions, broadband connectivity usually translates into productivity improvements by facilitating the adoption of more efficient business processes (e.g., marketing, inventory optimization, and streamlining of supply chains); into accelerated innovation by introducing new business applications and services; and into more efficient functional deployment of enterprises by maximizing their reach to employees (using videoconferencing and collaboration tools), raw materials, and customers.

Looking further ahead, industries are moving toward more fundamental digital transformation provided by better connectivity:

- **Manufacturers will use Internet of Things (IoT) and artificial intelligence (AI) to automate their operations.** Manufacturing and supply networks worldwide are undergoing digital transformation under the umbrella of smart manufacturing and Industry 4.0. AI-enabled digital transformation provides an opportunity to address product lifecycle issues, including design, manufacturing, sustainability, and resilience. The adoption of AI-enabled technology results in increased connectivity, transparency, and visibility across digital supply networks.

- **The changing face of retailing.** The retail industry is undergoing a rapid and dynamic digital transformation process. This rapid growth of technologies such as AI, mobile technologies, AR, VR, and the IoT is essentially changing the interplay between customers and retailers, thus altering the retail landscape.
- **Digital education will continue to grow.** The broadband industry is in the lead in the race to deliver the new immersive digital experience.
- **The rise in e-health adoption.** Health and social care organizations around the world are under pressure as populations age. E-health technology and services will play a key role in providing future healthcare solutions.
- **High-quality e-finance industry.** The financial industry needs a higher-quality and lower-latency private network with more security requirements.

CLOUD AND COMPUTING CONNECTION

The multicloud transformation trend of global enterprises is increasing significantly. The proportion of multicloud utilization is forecast to reach over 80% by the end of 2023. The computing power used by a typical enterprise is diversified in several categories, and AI computing power will expand to reach 46% of the total capacity by 2025.

The network plays a crucial role in this computing power. It is estimated that by 2030, a single data center will have 1 million computing nodes. A rate of 1 in 1,000 network packet loss would result in 50% computing power loss. Congestion caused by unbalanced workloads can cause up to 70% loss of AI computing power. In addition, computing power will be more distributed in the future, and high-quality requirements will be extended not only to data centers but to the entire WAN. The future network, therefore, must be capable of application and computing awareness, with deterministic latency and higher reliability.

The computing power of a single data center cannot grow indefinitely. Therefore, computing power coordination among multiple data centers is required in the short term with high throughput extended to each. Model parameters are used for collaborative computing between data centers, collaborative computing between clouds, and single sign-on across multiple clouds, making end-to-end data exchange work as a forwarding bus enabling high-performance computing. For example, the target of real-time settlement of cross-bank digital currency transactions in China is 1 million transactions per second. We believe that bandwidth will grow at a CAGR of 30% in the next few years, reaching terabit speeds in 2030.

HYBRID WORKPLACE SCENARIOS FOR ENTERPRISE

Driven by the impact of the COVID-19 pandemic, the hybrid workplace, combining onsite and remote working, will become common. In a survey by PwC of more than 52,000 workers across 44 countries and territories (PwC's 2022 Global Workforce Hopes and Fears Survey), 26% of respondents stated that they would prefer to continue to work from home full-time, though only 18% said this is how their employer would likely expect them to work in the long term. On the flip side, only 11% of workers stated that they would prefer to work full-time in the office, fewer than the 18% who said this is likely how their employer would prefer them to work. On the whole therefore, hybrid working is likely to be the compromise made by many employers, making home-working IT solutions a key growth segment moving forward. Upwork and Inavero predict that 78% of teams will have remote employees by 2028.

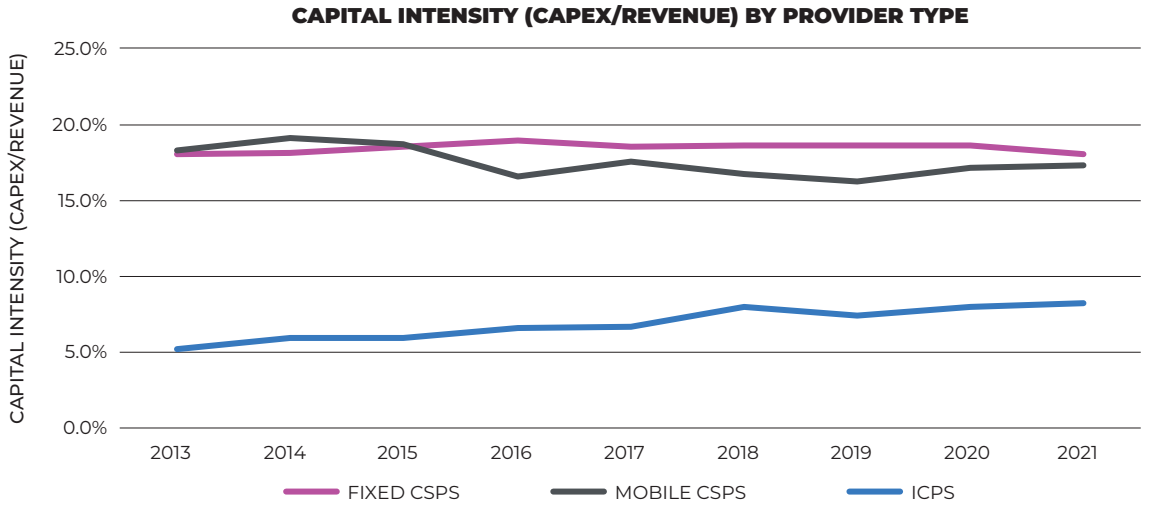
Currently, the communication efficiency of remote work is lower than that of onsite work. The future network and next-generation human-machine terminals will provide a real-life onsite experience for remote working by using XR, 3D, digital touch and smell, digital twin, and digital body technologies. It must connect customers and enterprises through future networks and digital technologies that integrate software, virtual and physical integration, and multisensory interaction, deployed on global multi-vendor clouds to create the best experience online and offline.

Future broadband networks and multisensory interactive digital technologies will enable employees to communicate and work more effectively anywhere and anytime, improving office and R&D efficiency and shortening the time to market.

ENSURING A FAIR TELCO ROI

Telco investment in advanced broadband networks (both fixed and mobile) is significant. Fixed capital intensity in particular is expected to remain higher than that for mobile over the next few years as communication service providers build out robust wired optical access, backhaul, and fronthaul infrastructure. On the flip side, internet content providers (ICPs), are able to retain a lower capital intensity because although their level of capex is increasing because of increases in capex in cloud, data center interconnection (DCI), content, and automation, it is offset by much higher revenue growth over the same period (See **Figure 6**).

FIGURE 6: COMMUNICATION SERVICE PROVIDERS RETAIN A HIGH CAPITAL INTENSITY



SOURCE: OMDIA

If broadband service providers are to continue to invest in advanced broadband networks in the long term, it is vital that they can continue to find ways to generate a reasonable return on that investment. As we head toward 2030, the average cost per home passed to deploy advanced broadband networks is likely to increase as operators approach more rural areas. As one example of this, in a recent statement from the UK's BT Openreach on its fiber-to-the-home (FTTH) deployment strategy, the company stated that the first 50% of households in the UK typically cost £300–400 per home passed; the final 10% cost approximately £4,000. The cost per home depends on several variables that can change significantly from one country to another and from one operator to another, so the costs will be different for different operators in different countries, but in general the rule of thumb that hard-to-reach households cost more remains true whatever the country or operator situation.

It is critical, therefore, that if telcos are to keep their capital intensity at least level or, preferably, even reduce it, then ways to either keep costs under control or push revenue up (preferably both) will need to be found.

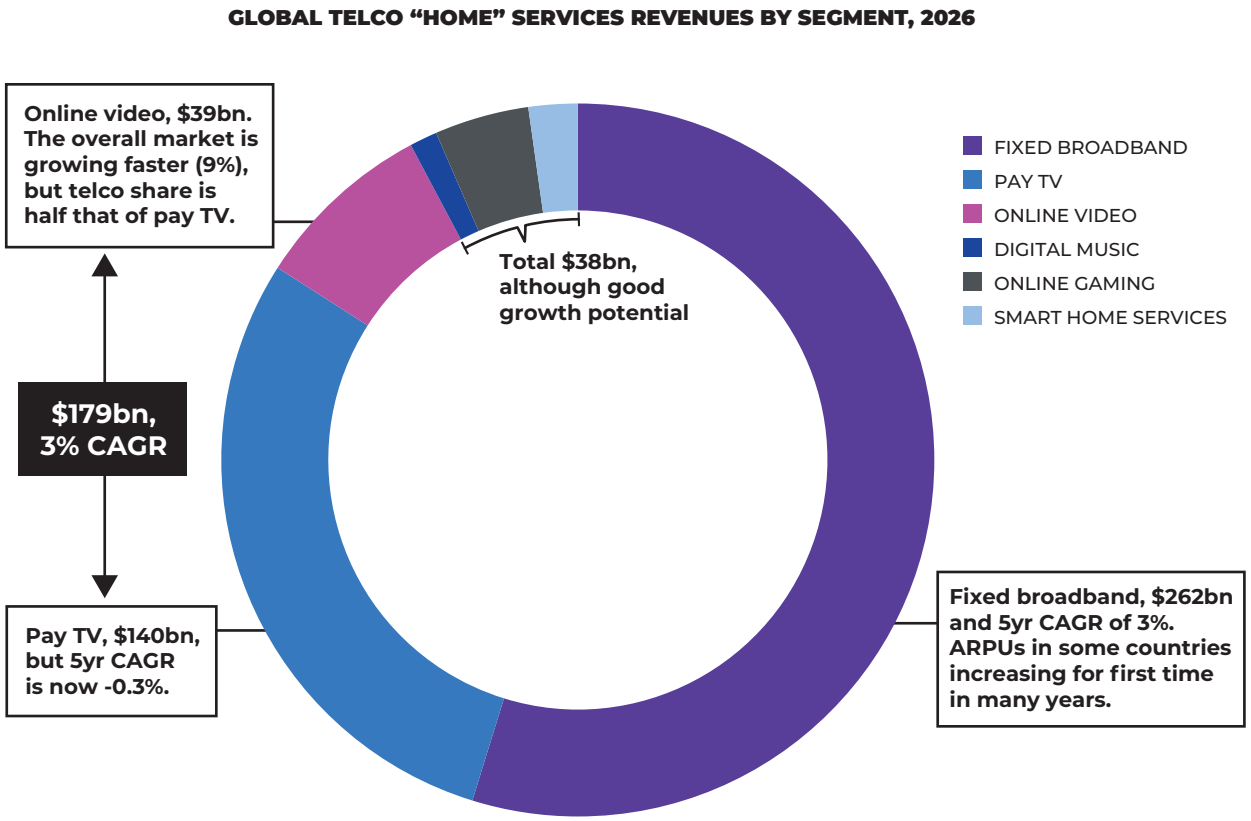
TELCO FIXED REVENUE GROWTH OPPORTUNITIES

FOR CONSUMERS, BROADBAND ACCESS IS STILL KING

Fixed broadband will be the core revenue stream for fixed telcos for many years to come, commanding 56% of global consumer fixed revenue by 2026 (see **Figure 7**). With a relatively flat global ARPU for many years, it has often been predicted that revenue growth from broadband access would stall alongside subscription growth and with it one the main drivers of telco growth. However, with a growing recognition of the importance of broadband access to users' lives and livelihoods, there has recently been an active movement of users up the broadband tiers to secure superior quality of service. Many operators around the world have therefore recently witnessed record growth in terms of both subscriptions and ARPU, resulting in a growing ARPU for the first time in many years.

Beyond broadband access, telcos have invested in other digital services, most notably TV and video and, to a lesser extent, digital applications such as music, gaming, and smart home. Although traditional pay-TV services are struggling at a global level because of OTT competition, the decline is offset by telco's own video ambitions, and therefore overall telco video services are set to continue to grow with a CAGR of 3% over the next five years. Other media services such as music, gaming, and smart home offer higher levels of growth but start from a much smaller base and will remain relatively small revenue drivers over the forecast period. Indeed, because of its large scale, a global ARPU growth of just $2 in broadband access would be the equivalent of the telco revenue portion from music, gaming, and smart home services all put together.

FIGURE 7: BROADBAND ACCESS STILL OFFERS GROWTH OPPORTUNITIES



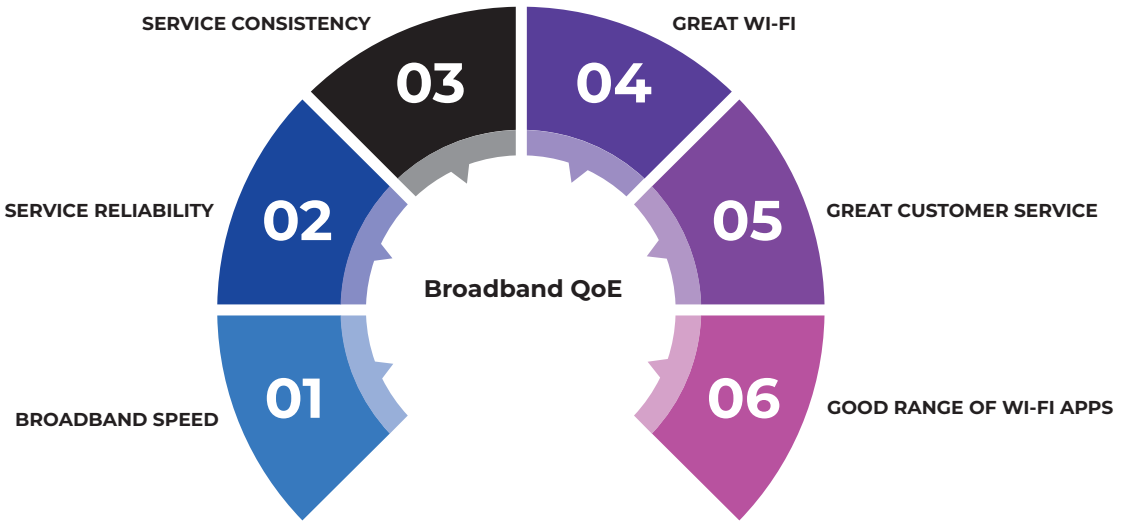
SOURCE: OMDIA

Maintaining a central role in the connected home is therefore central to the fixed-telco's growth strategy. As discussed later in this report, doing this maximizes the telco's opportunity to grow broadband ARPU and enables its other fixed strategies around video, media services, and smart home.

THE FOCUS ON QUALITY OF EXPERIENCE DRIVES BROADBAND ARPU

For many years the market focus for broadband was purely on speed. However, although speed is still an important element of the broadband service, it is not the only one that defines a good service experience. Based on a survey of more than 13,000 consumers, **Figure 8** shows what users most value from their broadband service. Although speed is still the top feature, other features such as reliability, consistency, great Wi-Fi in every room, a high level of customer service when things go wrong, and a good range of Wi-Fi applications follow closely behind. If a service provider focused only on top-line speed but let its service levels fall in the other areas, then even with a high-speed offering there is still a good chance of customer dissatisfaction and churn.

FIGURE 8: TOP FEATURES CONSUMERS VALUE FROM THEIR BROADBAND SERVICE

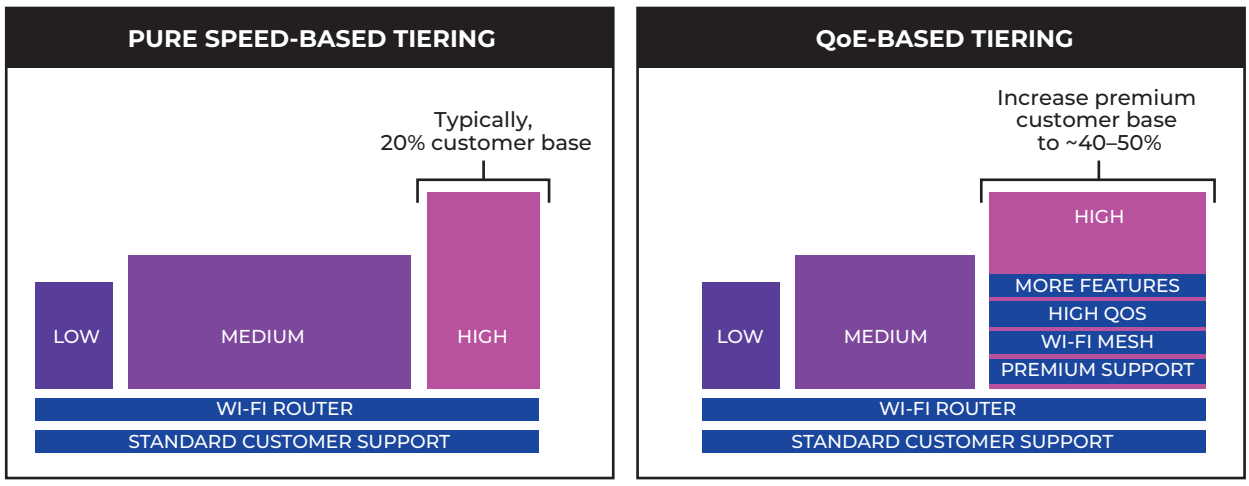


SOURCE: OMDIA DIGITAL CONSUMER INSIGHTS 2021

On the other hand, however, active investment to maximize performance in all areas can lead to an overall high customer Net Promotor Score and brand differentiation. Indeed, new broadband pricing tiers can be created by offering enhanced experiences not just in speed but in multiple service feature areas, essentially creating broadband tiers around service experience rather than just speed.

One fallout of the COVID-19 pandemic is the acknowledgment by all users of the importance of high-quality broadband services. Tiering broadband around quality has therefore proved to be a successful way of getting a higher percentage of users to move up the broadband stack, increasing broadband ARPUs in the process (see **Figure 9**).

FIGURE 9: ADDING MORE VALUE INTO THE TIERS EXPANDS THE PREMIUM CUSTOMER SEGMENT



SOURCE: OMDIA

One successful example of this type of strategy is Bezeq in Israel. Bezeq was an early investor in FTTH networks and was one of the first broadband service providers to launch a smart Wi-Fi platform and gateway. More recently it has announced it will soon offer its top customers fiber-to-the-room (FTTR) technology to enhance their connected-home experience even further. This focus on high-quality broadband services has led to 13% of its broadband customers being

connected to its premium FTTH services, 70% being connected to the premium smart Wi-Fi router, and 37% also taking the mesh APs. This high take-up of premium broadband features has led to an increase in broadband ARPU, which has seen a 7% growth over 1Q21–1Q22 alone.[1]

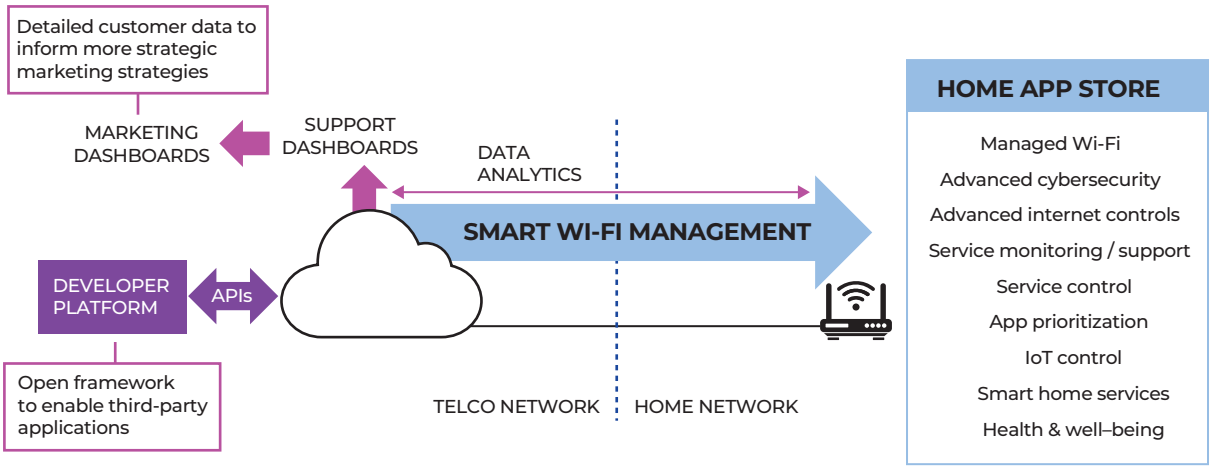
SERVICE-ORIENTED NETWORKS AND HOME APP STORES

One of the interesting features of the new Wi-Fi 6 standard is the concept of network slicing. Just as in 5G mobile networks, network slicing over the home Wi-Fi paves the way for multiple virtual, service-oriented networks to be created over the same physical infrastructure. In theory, therefore, a service provider could offer multiple different services, for example, a standard broadband internet service and a "working from home" service over the same broadband connection but with different network characteristics designed to meet the needs of each service. In this basic example, standard best-efforts speed and latency characteristics are offered for the standard service, and there is a speed and low-latency guarantee for the "working from home" service.

Such a capability has the potential to completely transform the broadband business model from a standard one-service-for-all model to one more focused around the services and applications that different users in the home need. This would enable the service providers either to charge an additional premium for a second network slice or to charge separately for different services, perhaps in the case of a working-from-home service, for example, that may be paid for by the employer rather than the home user.

In addition to new application-aware network slices, utilizing software containers over the smart Wi-Fi platform means a range of new services and applications can be efficiently delivered to the gateway device, in effect creating a service provider app store for the home (see **Figure 10**). Using the service provider's home Wi-Fi application as the interface, users can select and interact with a range of applications such as Wi-Fi management, advanced parental controls, smart home, and e-health. Many of these applications will have future potential premium revenue opportunities.

FIGURE 10: UTILIZING GATEWAY PLATFORMS AND SOFTWARE CONTAINERS TO CREATE THE HOME APP STORE



SOURCE: OMDIA

[1]https://ir.bezeq.co.il/static-files/30eaac2b-ff77-4126-8ead-1ccda2426f65

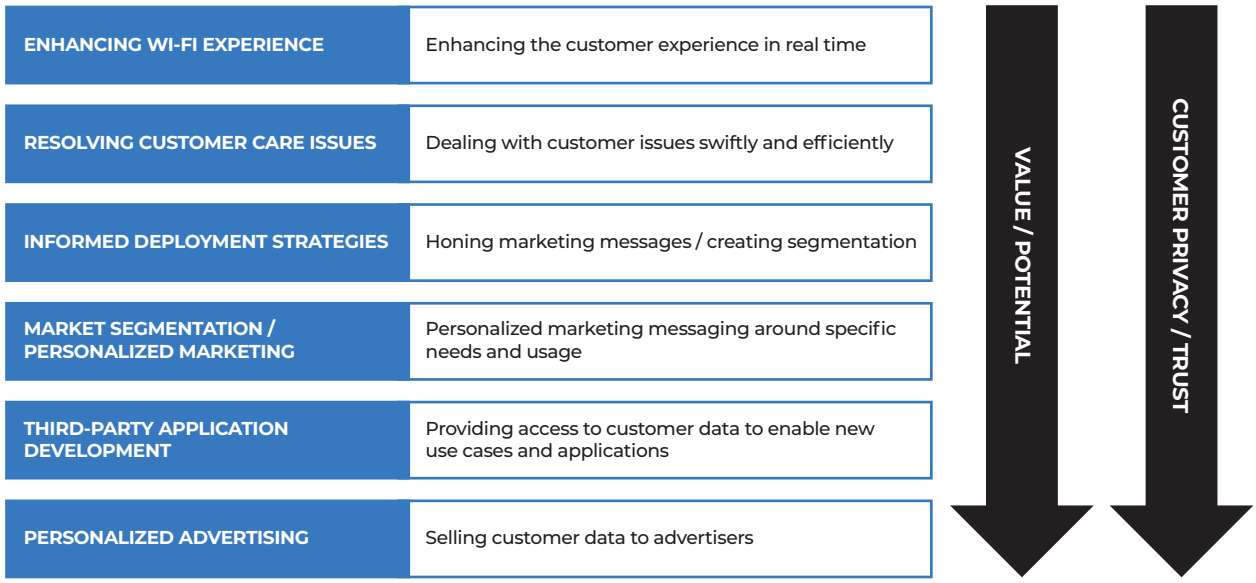
UTILIZING CUSTOMER DATA FOR NEW BUSINESS MODELS

End-user data has become essential to modern broadband service providers. By utilizing AI data analytics, service providers can gain a much clearer picture of how end users are using the broadband network and of the experience they are currently receiving, potentially spotting and correcting service quality issues before the customer is even aware of them.

Utilizing real-time end-user data to dynamically optimize end-user experiences has led to significant reductions in customer service calls, reduced customer churn, and improvements in broadband ARPU. However, this same data can be used by service providers in many other ways, such as customer service operations or the creation of new advertising-based business models (see **Figure 11**).

The details of these different models are out of the scope of this report; however, we acknowledge the importance of customer data to new broadband business models and recommend further research into this topic in future reports.

FIGURE 11: CUSTOMER DATA PRESENTS SIGNIFICANT POTENTIAL, AND POTENTIAL PRIVACY ISSUES



SOURCE: OMDIA

SUSTAINABILITY IS BECOMING AN INCREASINGLY IMPORTANT DRIVER

Sustainability is fast becoming a focal point of telecom service providers' agendas. The CO2 footprint of the telecom industry is roughly 2% of the global footprint—similar to that of the airline industry—while 80% of e-waste is discarded, burned, or illegally traded, and telco and IT equipment is a major contributor.

By addressing their own energy deficiencies and by enabling sustainable solutions in other industries and ways of living in general, telecom service providers have the potential to affect up to 15% of global CO2 emissions. Digitalization in general and broadband in particular can contribute by cutting transportation, creating gains in productivity and efficiency, and boosting economic growth for companies, individuals, and society as a whole.

The majority of telecom service providers worldwide now embed sustainability strategies into their everyday business decisions. Many are aiming to become carbon neutral by 2050, and major telcos have set out specific 2030 targets for emissions, waste, and the share of renewable

energy, which will not only reduce the companies' own carbon footprint but will enable customers and other industries to become more climate positive.

Adopting an efficient sustainability strategy has major benefits for service providers' revenue growth and operational performance. Some of the key benefits include the following:

- Reducing or even eliminating carbon footprint by decreasing energy consumption through more efficient operations and transition to renewable sources of energy, while cutting costs as a result
- Having a positive impact on other industries and customers, enabling them to reduce their own environmental impact and opening new revenue streams for service providers
- Reputational benefits among consumers and business customers, leading to enhanced customer loyalty and long-lasting customer engagement in recognition of a strong sustainability track record
- New business opportunities in areas that were previously not available to telecom service providers such as venturing into renewable energy provision (e.g., teaming up with or investing in utility providers or even becoming utility providers themselves)

See Omdia's paper for the WBBA *Importance of Environmental Sustainability in Telecom Service Providers' Strategy* for further details.

NEW INDUSTRY STRUCTURE

Deploying new advanced fiber-based networks is an expensive and complex exercise. The challenges are many and varied but include issues such as getting planning permission, access to labor, the cost and public inconvenience of accessing or laying new duct, and seeking wayleave permissions. Although there are benefits for a service provider in owning and controlling its own network, having multiple service providers all building their own network to cover essentially the same customers is a significant waste of investment, much of which is only focused on certain key urban areas.

To encourage more competitive operators to enter the market, historically most incumbent broadband operators have been required to open up their broadband infrastructure on a wholesale basis. However, since the incumbents also normally provided retail services they have not always been seen as neutral partners, and as the world moves away from traditional copper-based infrastructure to more modern fiber networks, they might now not also manage the largest network.

To both speed up and maximize fiber coverage, therefore, there is a growing trend for the creation of neutral wholesale fiber network providers that can gather investment from multiple stakeholders—including government sources where relevant—and can build once for the benefit of all service providers. Just one example is Fibrasil in Brazil, which was created by Telefónica, Telefônica Brasil (Vivo), and the global investment group CDPQ (Caisse de dépôt et placement du Québec). Fibrasil will deploy and operate the network and provide wholesale access to FTTH in various midsized cities outside of the state of Sao Paulo. Its initial plan was to reach 5.5 million FTTH homes passed within four years.

In addition to the creation of new neutral network providers, there is also a growing number of examples of the functional separation of the traditional incumbent operators' network operation into standalone entities for the purpose of providing equal and fair access to local infrastructure. Some notable examples of this include

- BT Openreach in the UK
- Telecom New Zealand, which evolved into Spark (retail) and Chorus (wholesale)
- Telstra in Australia, which was required to complete a functional separation and hand over copper network assets to the National Broadband Network but also recently completed a voluntary structural separation
- Telkom SA, which voluntarily separated Openserve in South Africa

- CETIN, which separated from the state-run telco in the Czech Republic with Telefónica and O2 as the primary investors, was later spun off from O2, and is now owned by PPF Group and which provides infrastructure services in Czech, Bulgaria, Hungary, and Serbia

With the functional separation of incumbent network assets and the creation of new open network providers in other areas, the broadband industry in many territories is heading toward a structure based on wholesale and retail functions.

HOW REGULATION WILL AFFECT THE EMERGENCE OF NEXT-GENERATION BROADBAND

Many aspects of the future broadband generational roadmap will be strongly influenced, either directly or indirectly, by the rapidly changing regulatory landscape across the world. Change is currently being spearheaded by regulation in the EU. While little of this regulation is specifically targeted at either accelerating or inhibiting the growth of broadband, its implementation will have an impact on areas such as

- How quickly the industry can adopt AI in the autonomous management of key operational aspects such as the infrastructure, customer engagement, and so on
- How operators can capture and use customer data to improve operations and generate new revenue opportunities
- The business models that the telcos can operate offering differentiated levels of service to different customer types
- Leveling the playing field between telco operators and the so-called OTT players in terms of required universal service obligations

ARTIFICIAL INTELLIGENCE

Some of the most relevant emerging legislation that telcos need to keep an eye on relates to when and where AI can be applied in the network and how it can be used:

- **AI strategy and regulation:** [2] This focuses on defining the appropriate legal and ethical framework for AI use within the EU. The main initial focus will be on topics such as biometric identification, surveillance, and so on.

DATA REGULATION

There is a wealth of emerging regulation that will affect how operators of next-generation broadband can capture and use customer data to either optimize operations or generate new services or platform offerings. This regulation places strict rules on user identity and privacy and on how the infrastructure provider must behave when interacting with enterprise customers. In no particular order, these include the following:

- **E-privacy:** [3] This provides more detail to the EU's General Data Protection Regulation (GDPR) specifically for datacomms and the protection of personal metadata. (This is important to anyone in the advertising industry.)
- **eIDAS:**[4] EU identity regulation addressing authentication and security is currently being updated.
- **Platform-to-business (P2B) regulation:**[5] This introduces new rules to the relationship between platforms and business users with the purpose of promoting fairness and transparency for business users and tackling unfair contractual clauses and trading practices.

[2] https://ec.europa.eu/commission/presscorner/detail/en/IP_21_1682
[3] https://digital-strategy.ec.europa.eu/en/policies/eprivacy-regulation
[4] https://www.eurosmart.com/wp-content/uploads/2019/07/EUIDCard-1.pdf
[5] https://digital-strategy.ec.europa.eu/en/policies/platform-business-trading-practices

- **EU Digital Services Tax:**[6] This concerns where tax is to be paid for digital services (where value is generated generally).
- **EU Data Governance Act:**[7] This is all about establishing trusted intermediaries for data sharing within the EU. It will embrace initiatives such as GAIA-X.

NET NEUTRALITY

There is important legislation that limits how flexible the operator can be in how it offers differentiated levels of service for different customers or customer types:

- **EU Open internet – Net Neutrality – Regulation (EU) 2015/2120):**[8] Under the EU rules, operators are prohibited from blocking or slowing down internet traffic, except where necessary. The exceptions are limited to traffic management to comply with a legal order, to ensure network integrity and security, and to manage exceptional or temporary network congestion, provided that equivalent categories of traffic are treated equally. The provisions enshrine in EU law an end-user's right to be "free to access and distribute information and content, use and provide applications and services of their choice." Specific provisions ensure that national authorities can enforce this new right.

UNIVERSAL SERVICE

Finally, there is important legislation emerging that begins to level the playing field for telcos and OTT players in terms of the universal service obligations that they must meet:

- **The European Electronic Communications Code (EECC)**[9] represents a revision of the entire EU regulatory framework for the telecommunications sector and among other things changes the Universal Services regime applicable to electronic communications. This is currently being enshrined in national laws in EU states. For example, at the start of 2022 Germany introduced a new law that broadly expands the scope of application to so-called interpersonal telecommunications services. As a result, many OTT service providers that did not previously fall within the definition of telecommunications service providers may now become regulated. For the first time, OTT service providers may need to notify the regulator of their activities. Among these newly regulated services are email services, connected wearable devices, and an array of other OTT applications, such as audio, video, and other streaming media content to the extent that they are delivered over the internet.

The operators and the whole ecosystem are going to need to take all of this emerging legislation (and more) into account as they define the next-generation broadband roadmap.

ROADMAP TO ACHIEVE THE NETWORK OF 2030

The scope of a future network 2030 system can be described in terms of six dimensions. Three of them are direct enhancements of existing dimensions that inform other industry roadmaps:

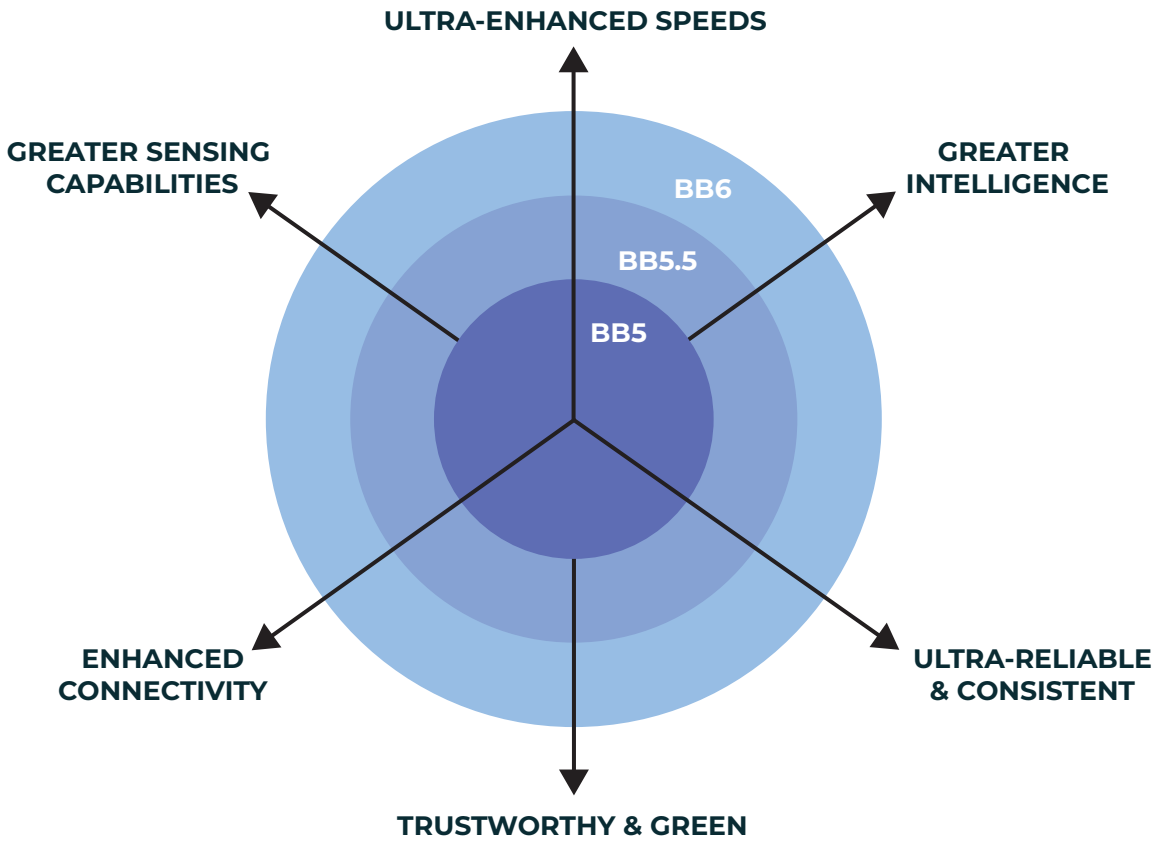
- Ultra-enhanced speeds
- Ultra-reliable and consistent
- Enhanced connectivity

In addition, the WBBA roadmap adds three further dimensions:

- Greater intelligence
- Greater sensing capability
- Trustworthy and green

[6] https://taxfoundation.org/digital-tax-europe-2020/
[7] https://data.europa.eu/en/highlights/data-governance-act-open-data-directive
[8] https://www.berec.europa.eu/en/all-you-need-to-know-about-the-open-internet-rules-in-the-eu-0
[9] https://digital-strategy.ec.europa.eu/en/library/proposed-directive-establishing-european-electronic-communications-code

FIGURE 12: WBBA'S ROADMAP DIMENSIONS



SOURCE: WORLD BROADBAND ASSOCIATION

ULTRA-ENHANCED SPEEDS

Application bandwidth has been growing at a rate of about 40% per year, and this is expected to continue. The sources of this growth include the increase in the number of endpoints, the proliferation of more and more applications, and the expansion of usage of existing applications. The fixed network needs to keep up with this growth, and that implies modernization of the transport, access, and home networks.

Bandwidth requirements have expanded from traditional home, access, and transmission to include campus networks. With the advent of the new network 2030, site access may be upgraded from 10G to 25G, 50G, or 100G. In addition, campus services, such as hybrid office and production network access to cloud, drive the development of campus networks from 1G to 10G capacity. The campus network will evolve from Wi-Fi6 to Wi-Fi7 and Wi-Fi8 with more flexible networking and wide coverage, driving the backbone network to be upgraded to 400Gbps and beyond.

ULTRA-RELIABLE AND CONSISTENT

The emergence of ultra-high definition (UHD) immersive-experience services is a major driver for reducing latency in networks.

Other important drivers are industry applications where the communication is mainly between machines, usually requiring immediate action-reaction times. In fact, the automation and digital transformation of industrial control systems require novel industrial networking to provide connections with in the order of 20μs latency, 20ns jitter, zero packet loss, and 99.9999% reliability.

Optical L1 hard pipes, real-time optical communication, industrial-grade security, and electromagnetic anti-interference capabilities are used to extend optical networks to industrial

sites and provide industrial optical transmission, meeting strict industrial control requirements. The digital transformation of the vertical industries requires hard-pipe connections with high bandwidth and reliability. The hard-pipe technology should provide flexible bandwidth from 2Mbps to 100Gbps, low latency of 1ms, and connections with 99.999% reliability and physical isolation, facilitating digital transformation of industry production networks.

ENHANCED CONNECTIVITY

Both the network scope and number of endpoints are expected to increase to support more services and coverage, in addition to the ongoing cloud-network synergy that is built on the underlying network. The Broadband Network 2030 aims to serve as the cornerstone of the network by providing a high-capacity, high-performance, and high-reliability ubiquitous intelligent bearer for the cloud and digital transformation. It will thus focus on the entire all-optical network that is divided into backbone, metro, access, and DCI optical networks. Different physical layers of networks have different requirements and are supported by different technologies. The service plane is supported by the different layers of the all-optical networks, with further enhancements in backbone and intercity networks.

Driven by the global digital transformation trend, industry digitalization and smart manufacturing drive the future IoT to provide simpler, safer, and smarter IoT capabilities. The demand for smart IoT connections in industries such as urban management, transportation, and finance will increase explosively. By 2030, the number of IoT connections worldwide is expected to reach 10 times its current value.

GREATER INTELLIGENCE

The integration of computing into the network has several benefits and possible directions. We need to differentiate between the use of computing and the provision of computing. Computing is used in the network for intelligent operation of the compute-integrated network. The model to provide compute and storage as a service to customers is more of a way to allow for additional value-added services.

The other aspect of integrating compute is the way of using AI to make things more intelligent. Again, this means that AI is used to improve the cleverness of operating the compute-integrated network and orchestrating the various services provided to customers. But in addition, AI in the network can be provided as a service to customers, which poses different challenges to the communication network.

To operate compute-integrated networks, autonomy levels need to be raised to “high autonomy,” according to TM Forum’s paper “Autonomous Networks: Empowering Digital Transformation For Smart Societies and Industries.”[10] This allows for self-configuration, self-healing, and self-optimization in network operation, which in turn improves the user experience and service quality in several dimensions, including

- Automatic provisioning, reducing the fulfillment time
- Reliability guarantees through increased fault-handling efficiency
- Smart diagnosis of the network quality, enabling fast fault localization and predictive maintenance
- Optimization of rollout and capacity through intelligent network planning through predictive capabilities

Another aspect of computer-integrated networks is the capability to increase the service richness. There is much more freedom to create attractive services beyond pure communication. Since the infrastructure allows the creation or operation of that plethora of services, smart management of those services is a prerequisite.

[10]https://www.tmforum.org/resources/whitepapers/autonomous-networks-empowering-digital-transformation-for-smart-societies-and-industries/

GREATER SENSING CAPABILITY

Sensing technologies introduce a new dimension to networks by enabling awareness of the surrounding environment. This will leverage enhancements to network operations and will add value to network resources through the development of new services based on this network capability.

Optical networks are today the fundamental backbone of all types of communication. Ubiquitous optical cable networks will require digitalized management and enhanced environment awareness capabilities.

Optical cables, being passive resources, can leverage optical-sensing capabilities to introduce huge enhancements to their management, namely the accurate identification of real-time optical cable degradation and health prediction, advance warning of a possible failure occurrence, detection of shared-route situations where the same cable and same duct are wrongly used for the working and protection route, to name just some of the potential uses.

Furthermore, the sensing capabilities of optical networks can unleash a new world of non-network-related applications. Enabling the real-time and high-precision capture of a multitude of environment parameters such as positioning, vibration, temperature, and stress allows the development of multiple use cases. Applications being studied include

- The oil and gas industry, where optical sensing can warn of minute-level intrusion and sabotage risks around the clock, provide meter-level awareness with 99% accuracy, and implement unattended inspection, significantly improving pipeline security protection and reliability
- Enhancing digital 3D map generation, and indoor robot navigation in smart factories
- Early prediction of earthquakes through optical submarine cables

The wide area of application for sensing technologies, in fixed and wireless optical communications and in Wi-Fi, is a very relevant new dimension for the evolution of the network.

In the future, with the ever-increasing demand for computing power, 70% of data is generated and processed at the edge. Edge computing power is widely used. Cloud-edge-device computing power collaboration requires flexible computing power allocation, efficient transmission, perception scheduling, and global visibility. Application awareness and distributed computing power awareness will help 2C/2H/2B/2N (nonterrestrial networks) to build advanced intelligent networks.

TRUSTWORTHY AND GREEN

With the development of ICT such as wireless broadband, radio frequency identification, information sensing, and network services, information networks will more comprehensively and deeply integrate the physical space and abstract information space between people, people and things, even things and things. This will evolve into the ubiquitous network. As networks and applications become ubiquitous in the future, the network attack surface will grow exponentially and will constantly change. Security must be able to respond quickly to changes in the network and service environment while still protecting user privacy. Ensuring end-to-end information security for sensor collection, network transmission, and service authentication on ubiquitous networks and building a user-centric, controllable, and trusted network support system oriented to ubiquitous applications further shortens problem detection time and reduces the response time in minutes.

The transition to green energy is a global challenge. The European Green Deal approved in 2020 is a set of policy initiatives from the European Commission with the overarching aim of making the EU climate neutral in 2050. One goal is to decarbonize the energy system and reduce greenhouse gas emissions by using clean energy from renewable resources and prioritize energy efficiency. More than 75% of greenhouse gas emissions[11] within the EU are related to the production and use of energy.

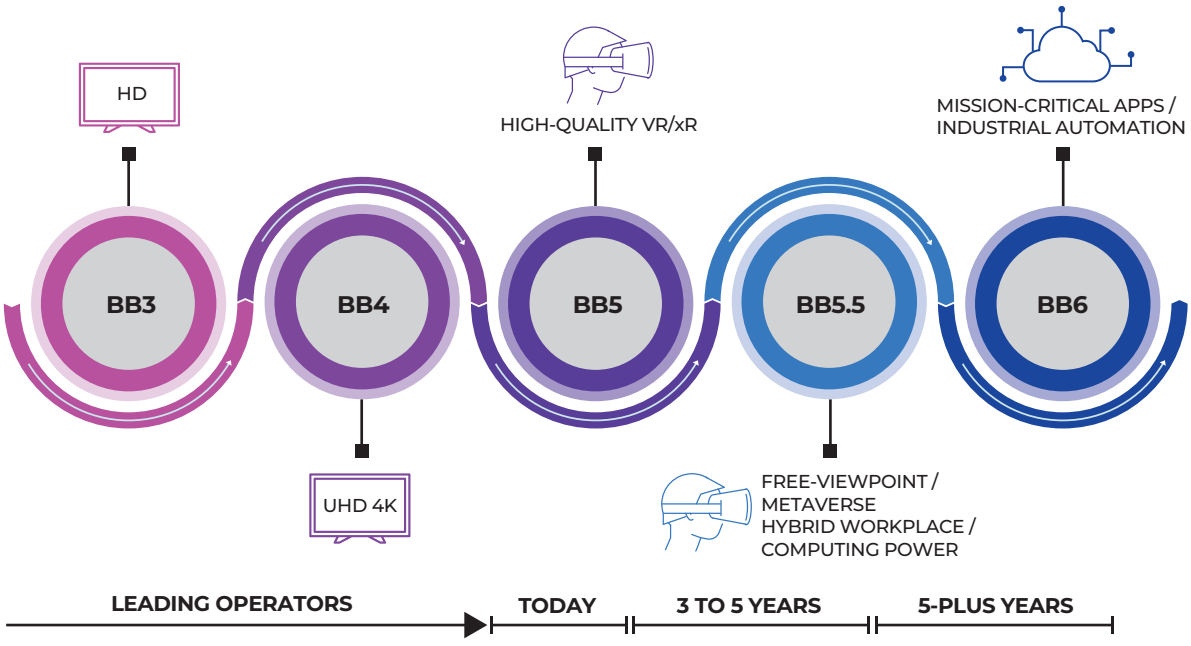
[11] https://en.wikipedia.org/wiki/Greenhouse_gas

ICT, and specifically future broadband networks, can contribute significantly to the above targets, both directly by bringing energy efficiency gains through a transition to more energy-efficient optical networks in communication systems and data centers and indirectly as those networks enable novel ways of working and meeting (e.g., through AR/VR applications with excellent user experiences, which reduce the need for user mobility), improving energy efficiency in other sectors. ICT with optical network IoT-enabled services can even provide the tools for reliably measuring energy consumption of (consumer) electronics, internet and cloud services, or any other energy consuming-device or service to raise awareness among governments, industries, and citizens about energy consumption and thereby enable consumer choice when it comes to choosing the more efficient service.

2030 BROADBAND ROADMAP

Figure 13 and **Table 1** show the different generations of broadband, illustrated by reference application and timeline for leading broadband operators, together with the current view of the typical network characteristics that each generation will require. It should be noted that there were earlier generations before BB3; however, we assume there is only a small installed base remaining based on those characteristics. The timing of the different generations (BB3 to BB6) is difficult to project and depends on local market conditions, the localized business case, and the applications requested by customers. However, the assumption is that generation BB5 is being deployed today by early-adopter operators. The expectation is that BB5.5 will be deployed by advanced early–adopter operators in the 2025–27 timeframe. Finally, BB6 might be deployed by early adopters in the 2030-plus timeframe.

FIGURE 13: BROADBAND GENERATION ROADMAP WITH REFERENCE APPLICATIONS



SOURCE: WBBA

TABLE 1: BROADBAND GENERATION NETWORK CHARACTERISTICS

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

Note: *Speeds listed are speculative given the timeframe, and further work by the WBBA will explore this in more detail in future reports.

SOURCE: WORLD BROADBAND ASSOCIATION

APPENDIX

FURTHER READING

Blockchain Technology and Adoption Trends (December 2019)

Service Provider Routers & Switches Market Tracker - Q4 2019 (February 2020)

"Blockchain is good for more than just Bitcoin" (September 2019)

"CenturyLink goes 'colorless' and takes on the edge cloud" (February 2020)

WORLD BROADBAND ASSOCIATION

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