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Routed PON:

Transforming Broadband Access with Converged PON Architectures

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Table of Contents

Executive Summary

The demand for high-speed broadband services continues to grow as consumers and businesses increasingly rely on digital connectivity for work, entertainment, and communication. This white paper explores the business case for Routed Passive Optical Networking (RPON) as a solution to meet the increasing demand for enhanced broadband services. Routed PON is a cutting-edge technology that leverages advancements in pluggable optics, network programmability, and interoperability to expand existing metro networks and PON infrastructures.

GlobalData's global fixed broadband revenue forecast projects a 4.6% compound annual growth rate (CAGR) from 2021 to 2026, driven by operator investments in fiber to the home/building (FTTH/B) and government initiatives to fund fiber infrastructure investment. This growth highlights the opportunity for operators to capitalize on the increasing demand for high-speed broadband services.

Routed PON offers operators a compelling solution to monetize PON technologies and meet the capacity and connectivity requirements for new use cases, such as streaming video, AR/VR, gaming, and enterprise services.

By leveraging routed optical network integration, pluggable optical technologies, and network programmability, operators can incrementally add broadband connectivity and enhance the efficiency of their transport network architecture.

Routed PON provides numerous advantages, including reduced operational expenses, scalability, assured services, and the ability to adapt to changing network demands. These capabilities enable operators to offer premium services and better compete with over-the-top (OTT) services.

Routed PON is a game-changing technology that enables operators to meet the growing demand for high-speed broadband services and compete effectively in the market. Routed PON is ready for deployment and offers significant benefits for operators looking to stay ahead in the evolving broadband market.

The following includes an overview of the growing fixed broadband market, describes how to better monetize PON for greater service revenue, details the benefits of a Routed PON architecture, and outlines its readiness for deployment. Detailed market forecast by region and funding initiatives are provided in Appendices 1 and 2, respectively.

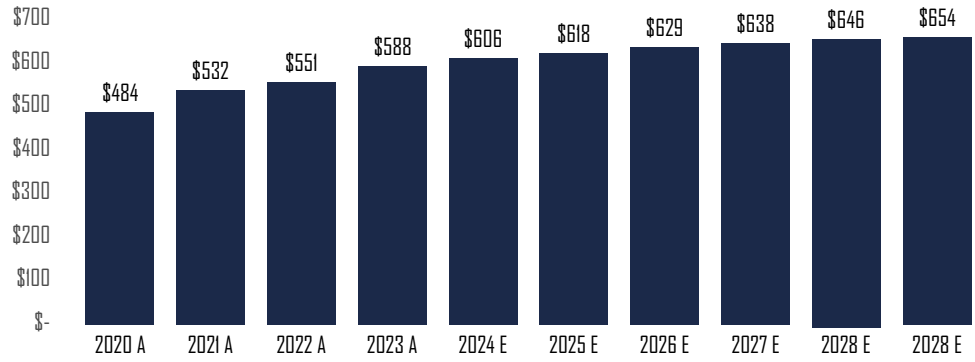
Fixed Broadband Market Overview

This section provides insight into the global and regional fixed broadband forecasts, which indicate robust growth and a shift towards fiber-optic technologies. This shift represents a significant opportunity for service providers to provide enhanced connectivity and services for consumers. GlobalData research indicates that this growth is driven by advancements in optical technology, increased investments into infrastructure (fiber) by industry and government entities, software-defined network management, and strong user demand for ubiquitous and high-capacity broadband services.

Fixed Broadband Revenue Forecasts

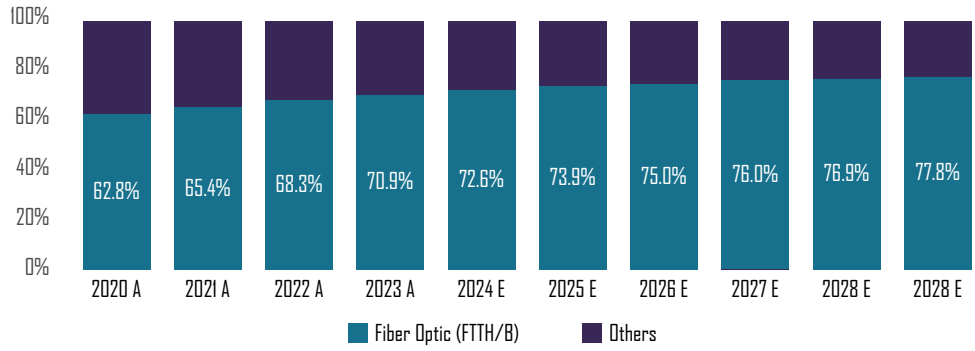
GlobalData projects fixed broadband revenue to grow at a 4.6% CAGR from 2021 to 2026, primarily due to increased operator investments in FTTH/B and government initiatives to fund fiber infrastructure investment. As noted in Figure 2, fiber-based revenue significantly outpaces other fixed access revenues.

Figure 1: Global Fixed Broadband Revenue, 2020 to 2029 ($bn)



Source: GlobalData Fixed Communications Forecast, June 2024

Figure 2: Global Fiber Optic (FTTH/B) Broadband Revenue Share of Total Fixed Broadband Revenue, 2020 to 2029 (%)



Source: GlobalData Fixed Communications Forecast, June 2024

Fiber is expected to remain the leading fixed broadband technology from 2023 to 2028, representing 45.6% of total fixed broadband lines, growing at a CAGR of 8.7%. Although fixed broadband service revenue is expected to increase marginally at a CAGR of 0.4%, FTTH services will see slight growth in subscriptions, contributing to the overall segment's stability. Competitive pressures, however, will drive operators to enhance their digital channels and customer engagement strategies. Appendix 1 provides a more detailed overview of regional forecasts and market drivers.

Government Initiatives and Private-Public Partnerships (PPPs)

GlobalData has found that government initiatives and PPPs play a crucial role in the expansion of fixed broadband services in urban and rural areas to enhance connectivity, reduce the digital divide, and stimulate economic development. Appendix 2 provides additional detail regarding the key investment factors by region, initiatives, and their intended market impact.

Monetizing PON – Assured Services

The monetization of PON technology through assured services presents a lucrative opportunity for service providers. By offering reliable and high-quality services, operators can attract and retain customers, ultimately driving revenue growth. Enterprises can also use the solution to future-proof their campus networks and increase bandwidth where needed.

Assured services, such as guaranteed bandwidth and service-level agreements (SLAs), provide customers with a superior broadband experience. This is particularly important in business settings where uninterrupted connectivity is essential for productivity and efficiency. Today, operators have ceded much of the networks value to OTT players due to the lack of SLA guarantees. OTT players have leveraged use cases such as streaming video services (Netflix, Hulu, etc.) and social media, which have a high-touch relationship with the subscriber and relegate the operator value to connectivity.

However, operators can leverage the latest advancements in PON technology to deliver these assured services and counter OTT players. Routed PON networks offer high capacity and scalability and are well suited for meeting the demands of businesses and residential users. Combining the latest PON technology with programmable routers and AI-driven management systems forms the foundation for offering profitable and dependable broadband services.

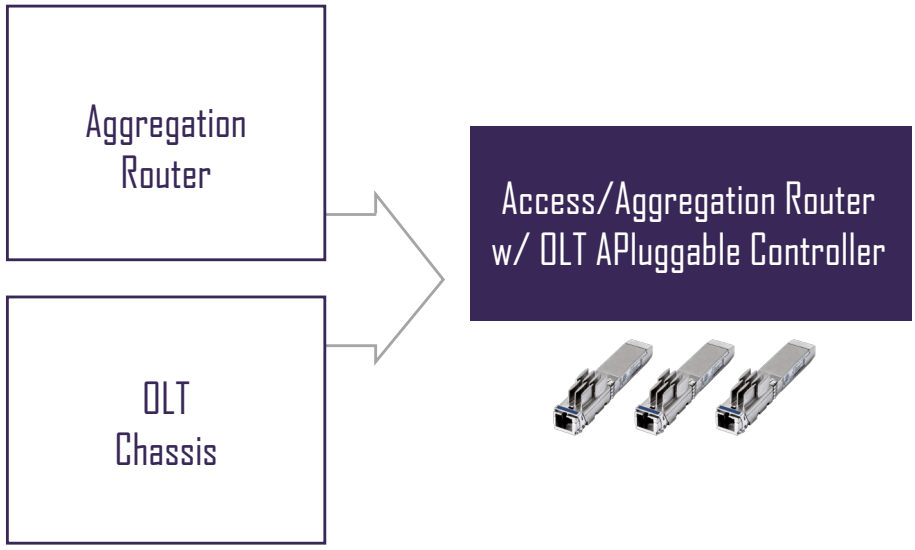
Furthermore, the implementation of quality of service (QoS) mechanisms built into the latest PON technologies ensures that critical applications, such as video conferencing and cloud-based services, receive priority and provide a superior quality of experience - this strengthens the value proposition of assured services, leading to an increase in network value and return on investment.

Providers should use a customer-centric approach to effectively monetize their PON investment. This involves understanding the specific user requirements and tailoring service packages based on customer requirements. By offering flexible plans, customizable features, and competitive pricing, operators can attract and support a diverse range of customers and maximize revenue potential.

Routed PON Architecture

Routed PON architecture differs widely from traditional optical line terminal (OLT)-based models. Advances in PON technologies, such as pluggable form-factor optics, the maturation of IP/optical network management, and the demand for high-speed, high-quality connectivity, provides the business and technical basis for operators to invest in delivering assured services for enterprises and residential areas. Earlier barriers to success have been lowered significantly or eliminated entirely through innovations in ASIC design, network programmability, automation, network intelligence, and convergence of IP and optical networks. The new PON OLT pluggables enable increased availability, flexibility, and cost effectiveness of PON infrastructures. Additionally, the use of PON pluggables brings architectural simplification, as shown in Figure 3.

Figure 3: Routed PON architecture



Source: GlobalData

Comparison Traditional PON OLT - OLT Pluggables

The differences between traditional PON implementations and routed PON are noted in Table 1 below. Routed PON provides the ability to converge the operator's IP/optical network with the latest PON technologies, eliminating today's OLT silos, vendor lock-in, lack of SLAs, and higher OPEX.

Table 1: Traditional PON versus Routed PON

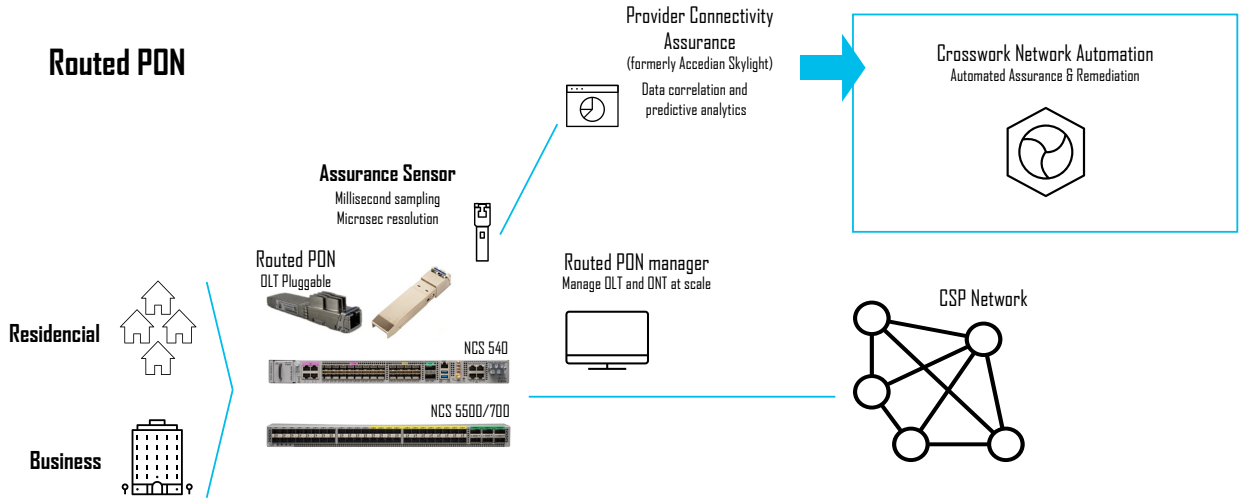
Traditional OLT	OLT Pluggable
Vendor lock-in - proprietary ecosystem for hardware and software	Pluggables compliant with ITU OLT specifications
Dedicated power and space requirements - higher operational cost	Single converged hardware platform
Inflexible deployment model	Port-based scalable pay-as-you grow model
Upgrades difficult - from 1G to 10G/25G/50G becomes a heavy investment	Easy upgrade to new pluggables
Operators must maintain both routers and OLTs	Simplified management and orchestration
Lacks differentiated service capabilities	MEF compliance services, SLAs

The differences between traditional PON implementations and routed PON are noted in Table 1 below. Routed PON provides the ability to converge the operator's IP/optical network with the latest PON technologies, eliminating today's OLT silos, vendor lock-in, lack of SLAs, and higher OPEX.

Building a Converged Broadband Access Architecture

Integrating PON into the broader IP/optical metro network enables the delivery of all services over a common infrastrucuture. This includes broadband services (FTTH, cable), wireless backhaul, and business connectivity services. Architecturally, integration requires three components: a pluggable PON OLT, a PON agent/ controller, and a PON manager. With the pluggable PON OLT being a port hosted in an access router, PON can become an integral part of an end-to-end service delivery architecture, rather than a separate network domain, as noted in Figure 4.

Figure 4: End-to-End SDN Transport

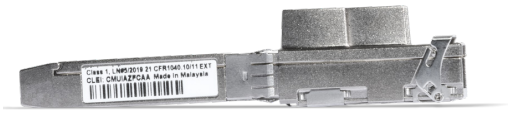


Source: Cisco

PON Pluggables

Pluggable PON optics have made their way into mainstream IP/optical networks, which has resulted in significant changes in how networks are constructed. PON pluggables enable broadband access/router convergence, leading to TCO benefits and deployment flexibility, as shown in Figure 5.

Figure 5: Cisco XGS-PON OLT SFP+



Source: Cisco

Pluggables are ideal for converging PON services along with existing Ethernet services onto a single transport network, delivering high-bandwidth connectivity at scale. PON pluggables are available in multiple variants to perform the OLT role. As the pluggable market evolves, so have relevant standards, which protect investment, enable interoperability, and manageability. Key drivers for pluggables include: hot-swappable form factors, embedded Ethernet-PON OLT MAC bridge, compliance with ITU-T specifications such as G.9804-1/G.9807.1 XGS-PON, and environmental Restriction of Hazardous Substances (RoHS) compliance.

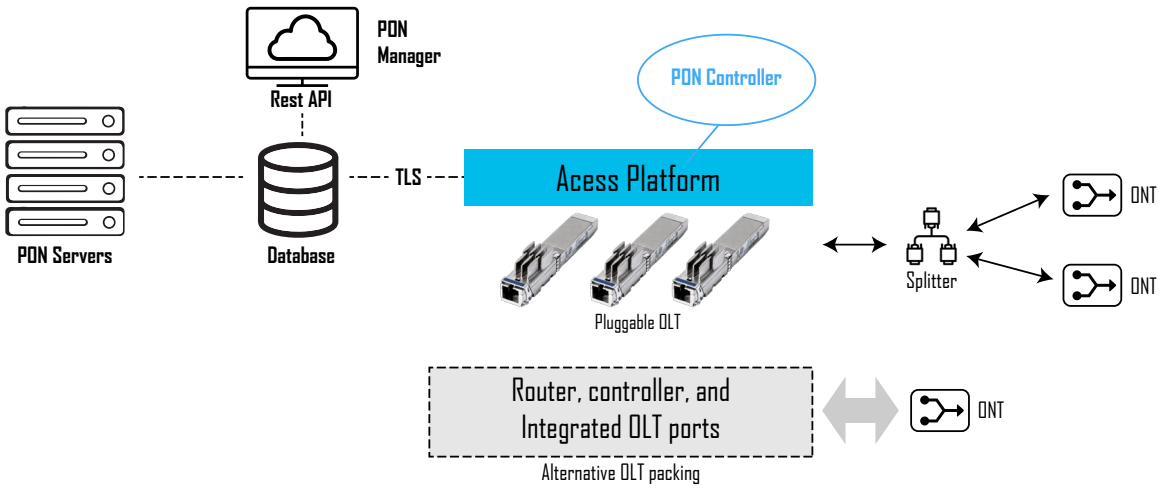
10G PON is commercially available, meets most user requirements, and is being broadly deployed. 25G and 50G PON technologies are beginning deployment to address higher performance use cases. 50G PON is a ratified ITU standard (ITU-T G.9804.3) supporting 50G symmetrical or 50/25 (download/ upload) asymmetrical services.

Integrated PON Management

PON Controller and Management: The PON controller is hosted by the access platform (typically a router) and provides the interface between the PON endpoints and the network. A database, MongoDB or similar, which serves as the keeper of configurations, status, and provides the northbound API for a PON controller to communicate with the PON manager. For service providers, the access platform can be an IP router with pluggable OLTs. Figure 6 provides an overview of a typical Routed PON deployment, noting the key components and their functions.

For scenarios such as campus or enterprise networks, alternatively a purpose-built router/ controller with integrated OLTs could be deployed. This configuration provides the technology advances, but scaled to meet smaller PON network configurations, right-sized for enterprise deployment.

Figire 6: Typical PON Architecture



Source: Cisco, GlobalData

Benefits of a Converged PON Solution

By integrating PON into a metro IP network, services can receive the same capabilities as Ethernet traffic, including SLAs for assured services, monitoring, and elevated service assurance. SLAs can be established to provide guaranteed 1G and 10G services, and be monitored to ensure the service meets established criteria (delay, congestion). Assured connectivity provides the foundation for service providers looking to upsell service value. PON services also benefit from the advances in AI within IP networks.

Operators are demanding vendors simplify the management and orchestration of network resources. This is made possible through advancements in IP/optical interoperation, enhancements to management systems (controllers), and the use of AI-driven automation, which enable operators to cost effectively deploy and manage broadband infrastructures capable of generating profitable new revenue streams. Routed PON architecture addresses these major operator concerns and provides the following advantages, as noted in Table 2.

Table 2: Key Network Objectives and Benefits of Router PON

Network Goals	Benefits
Improved Economics	A disaggregated architecture with pluggable OLTs inside the access router, or alternatively with a purpose built PON controller for enterprise applications, improves the economics of broadband network deployment.
Network simplification	Converged access for PON, active ethernet, backhaul, and a consistent end-to-end network with open APIs for automation drastically simplifies network management and provides service continunity across all access media.
Improved ARPU	Providing assured services enables users to experience greater value and help operators. Studies have shown that users will pay a preimum if they preceive greater value.
Leverage Automation and AI	Routed PON can benefit from the use of automation and AI to monitor end-user traffic, optimize quality of service, and and provide closed-loop feedback to better manage network resources.

Converged PON architectures significantly influence the telecommunications landscape by enhancing operational efficiency, scalability, and service delivery. Pluggable OLTs, programmable routers, and SDN-based management solutions have been game changers for the PON market. Below are the key impacts and new capabilities.

Upgrades and infrastructure utilization
Converged PON architectures facilitate upgrades to higher speeds, such as 25G or 50G PON, while allowing the use of existing infrastructure to deliver new services. This adaptability may lead to the decline of dedicated, single-purpose PON OLT chassis, as operators can leverage their current setups for enhanced capabilities without complete overhauls.

Cost efficiency and revenue generation
As operators and enterprises seek to streamline fiber-to-the-premises (FTTP) operational models, a converged PON approach aids in achieving cost savings. It also opens new revenue streams by broadening the FTTP service portfolio to include wholesale and enterprise use cases, thus enabling service providers to cater to a wider range of customer demands—and for large enterprises, to leverage a converged PON architecture to re-engineer their private networks.

Scaling for 5G Transport
The projected role of PON in 5G transport necessitates significant scaling of OLT capacity. Converged architectures are crucial in meeting the higher requirements for capacity and synchronization, which are essential for supporting advanced services like network slicing in 5G environments.

Integration with Optical Transport
Converged PON architectures promote tighter integration of OLTs with optical transport networks. This integration helps to unify the fixed access and optical transport layers of the network, enhancing overall network efficiency and reducing operational complexity.

Diverse Services
The evolution towards converged PON systems allows for the simultaneous support of multiple PON technologies (GPON, XGS-PON, 25G PON, and 50G PON, for example) on a port-by-port basis. This capability enhances service flexibility and customer satisfaction by enabling a variety of high-bandwidth FTTP services.

Advancements in Technology
The shift towards converged architectures is also driven by advancements in silicon technologies and pluggable optics. These innovations offer more versatile modules that enhance operational efficiency and support a broader range of transport use cases, thereby transforming network operations.

Reshaping the PON Landscape

PON solutions, which include pluggable OLTs and routers, are entering early deployment cycles driven by a variety of service providers, each leveraging their unique technologies and partnerships to enhance network capabilities. The integration of pluggable OLTs with programmable IP routers is a significant trend that allows for more efficient, scalable, and cost-effective broadband solutions. The need for effective automation, sustainability, and flexible business models to address both residential and enterprise use cases is the common driver for these initial deployments.

Converged PON architectures are reshaping the telecommunications industry by enabling higher speeds, cost efficiency, and integration with existing networks, thus preparing the operator and enterprise networks for future demands, particularly in the context of 5G and beyond. Advances in routed optical technologies establish a proven implementation model that is easily expanded to support the latest PON pluggables.

Cisco's Routed PON Solution is reshaping the PON landscape by providing service providers a combination of the latest PON pluggable technology coupled with a converged access, assured services, and simplified end-to-end management and orchestration.

Cisco Routed PON Solution

Internet service providers face a complex balancing act between pursuing economic viability and fulfilling their social responsibility to expand internet access. Today, approximately 2.6 billion people globally still lack internet access, highlighting the significant digital divide that requires attention.

To address this, recent innovations have revolutionized the deployment of PON and Fiber-to-the-X (FTTX) technologies for broadband access to both residential and business customers in rural, suburban, and urban environments.

With the Cisco Routed PON solution, operators can transform the economics of their network and FTTX deployments while helping to bridge the digital divide.

Cisco Routed PON enables differentiated broadband services through a software-defined broadband network, delivering numerous advantages to operators, including:

- **Disaggregation:** Cisco Routed PON replaces the typical chassis-based OLT with a small form-factor pluggable (SFP) that is simply inserted into a router port. This reduces power, space, and cooling, and allows investment protection with a pay-as-you-grow model.
- **Converged access:** By converging Cisco Routed PON with active Ethernet and backhaul, the network can be greatly simplified. This results in better network resource utilization and planning.
- **SLA differentiation and management:** Cisco Routed PON's underlying technologies, including segment routing coupled with assurance, enable providers to offer highly differentiated services to business and residential customers, enhance the subscriber experience, and monetize the network. Cisco Provider Connectivity Assurance delivers granular service-centric performance visibility and "provider-grade" assurance for operators and any business or public sector entity that operates their own private network. Continuous, real-time visibility into end-to-end network and service quality enables operators to proactively identify and resolve performance issues across the entire network infrastructure.

To learn more about how providers can reinvent the broadband access network and deliver differentiated high-quality services to residential and business customers with Cisco Routed PON, click here: https://www.cisco.com/go/routedpon

Appendix 1 - Broadband Market Drivers and Forecast by region

North America

North America is expected to generate a cumulative revenue of $1 trillion in fixed broadband services between the years 2023 and 2028. This growth is attributed to factors such as national broadband plans and public infrastructure projects that will facilitate rollout of services across the region, providing opportunities for telecom companies and equipment vendors.

Additionally, the average revenue per user (ARPU) for fixed broadband in the Americas is projected to increase from $51.56 in 2023 to $53.72 in 2028, reflecting a CAGR of 0.8% during this period.

Fixed broadband lines are anticipated to reach 291 million by 2028, with FTTH/B accounting for 45.6% of total. Additionally, internet services revenue is expected to represent 91.1% of total fixed service revenue by 2028. The region is expected to witness a steady growth in the fixed wireless, with a growth percentage of around 10-15% annually, driven by the demand for high-speed internet connectivity in rural and remote areas that are not served by fiber connectivity.

Europe

Revenue for Europe is expected to grow from $71.8 billion in 2023 to $83 billion in 2027, reflecting a CAGR of 2.9% during this period. This growth is attributed to the increasing adoption of fixed broadband services as coverage improves and the implementation of fixed-mobile convergence (FMC) plans to support the revenue growth in the sector over the forecast period.

In terms of specific countries, the UK is projected to register the highest growth rate in fixed broadband revenue, achieving a CAGR of 3.5%, with an estimated revenue of $15 billion. However, in some countries, such as France, fixed broadband revenue is forecasted to decline due to subscription losses in cable internet and DSL services, as well as a decrease in average revenue per user (ARPU)—reflecting intense competition in the broadband services market

Asia Pacific

Fiber to the Home (FTTH) and Fiber to the Fiber to the home (FTTH) and fiber to the building (FTTB) are experiencing significant growth in the Asia-Pacific region. As of 2022, the region accounted for 76.4% share of the total revenue generated by fiber-optic technologies. The region is projected to continue expanding, driven by the increasing demand for high-speed internet services and aggressive network expansions fueled by government investment and incentives.

Fiber-optic technology is expected to be the fastest-growing broadband technology in Asia, with a CAGR of 2.8% from 2023 to 2028. By 2028, FTTH/B will represent an impressive 96.1% of total fixed broadband lines in the Asia-Pacific region.

Country-Specific Insights

Singapore is anticipated to lead the region with the highest share of FTTH/B lines, reaching around 99.8% of its total fixed broadband lines by 2028. Following Singapore, China is expected to have 99.5%, Malaysia 98.1%, Vietnam 97.61%, and Thailand 97.56%. China has made significant strides in fiber-optic infrastructure, with major telecom operators like China Mobile and China Telecom expanding their fiber networks extensively.

Household Penetration:

The penetration of fixed broadband in households is forecasted to rise from 24.2% in 2023 to 27% in 2028. This growth is attributed to ongoing investments in broadband expansion across various countries, including countries such as Brazil, Mexico, and Colombia.

Overall, the global fixed wireless access market is expected to witness significant growth across all regions, driven by the increasing demand for high-speed internet connectivity and government initiatives to bridge the digital divide. However, for operators to deliver on this vision, the network architecture needs to change and become software-driven with the ability to adapt to dynamically changing user needs.

Appendix 2 - Funding and Infrastructure Development

North America

Government-backed programs such as the Broadband Equity, Access, and Deployment (BEAD) Program and the FCC Rural Digital Opportunity Fund are allocating billions of dollars to improve broadband connectivity in rural communities in the United States.

Europe

Government funding programs to support the deployment of fixed broadband, particularly FTTH initiatives, are aligned with the broader goals of the European Commission's Gigabit Society vision to provide high-speed broadband connectivity across the continent. These funds aim to support infrastructure projects that facilitate the deployment of high-speed internet services, thereby helping rural residents access reliable broadband for work, education, and entertainment.

Asia Pacific

Governments are implementing various initiatives to enhance broadband services, particularly focusing on rural and underserved areas. These initiatives often involve PPPs and government investments aimed at expanding internet access and improving connectivity. Key projects include the following: Net Pracharat Project (Thailand), BharatNet Project (India), National Broadband Plan (Philippines), Palapa Ring Project (Indonesia), China's Fiber Network Expansion, and New Zealand's Ultra-Fast Broadband Program. These initiatives reflect a significant commitment to improving broadband connectivity across the region to bridge the digital divide and ensure that high-speed internet access is available to all.

The Rise of Fibercos

In addition to direct government funding, there is a growing trend of structural separation of fiber-optic assets where telecom operators are creating separate entities (fibercos) to manage and deploy fiber networks. These PPPs combine government funding with private sector investment, making it a cost-effective strategy for expanding broadband access.

North America

Several notable fibercos have emerged. For instance, SDC Capital Partners, a fiber-based ISP located in North Florida. Regional ISP FiberOak received a significant investment of $150 million from InfraRed Capital Partners in July 2022 to expand its operations in Florida and Georgia. These investments indicate a growing interest in fiber infrastructure within the region.

Europe

The landscape of fibercos is also developing rapidly. Cellnex is a prominent player operating around 135,000 sites across various countries, including Spain, Italy, the Netherlands, France, Switzerland, the UK, Ireland, Portugal, Austria, Denmark, Sweden, and Poland. Furthermore, KKR has made substantial investments in European fiber services, notably in FiberCop in Italy and Hyperoptic in the UK, highlighting the trend of international investment in the European fiber market. Additionally, Everest Infrastructure Partners acquired Blue Sites Telco, which operates over 300 towers in Portugal. This acquisition reflects the ongoing growth and consolidation within the fiber and telecommunications sectors across Europe.

Middle East & Africa

The region has a mix of state-controlled joint ventures and pure-play fibercos. Qatar QNBN and Oman Broadband are state-controlled fiber company focused on expanding fiber connectivity. Fiber Tech, a joint venture between the electrical utility JEPCO and the telco Umniah, utilizes existing electricity infrastructure to deploy fiber networks and wholesales services. DFA and FiberCo are part of the broader investment strategy in the South African fiber market. The region also has pure play fibercos, including Dark Fiber, Link Africa, Lightstruck, and Frogfoot, whose coverage is primarily limited to urban areas.

Alternative Technologies

Fiber remains the dominant connectivity medium, but alternatives can be used to fill gaps in fiber-based coverage. The rollout of 5G fixed wireless access (FWA) technology is becoming increasingly significant in rural areas where fiber deployment is delayed or is not practical due to rough terrain or other factors.

Alternative technology allows mobile operators to utilize existing wireless assets to provide high-speed internet where traditional optical infrastructure may be lacking. Additionally, projects like Starlink that offer satellite internet services (non-terrestrial networks) are emerging as viable alternatives for delivering broadband access to remote locations and for disaster recovery. These advancements are supported by governmental initiatives that aim to diversify broadband access methods.

Funding Summary

The state of technologies and government initiatives is significantly impacting the rollout of fixed broadband services in rural areas by providing substantial funding, facilitating infrastructure development, promoting technological advancements, and addressing the digital divide. These efforts are vital for ensuring that rural communities can fully participate in the digital age.

Advancements in PON technologies, as noted above, allow for delivery of differentiated, high-throughput services ranging from one gigabit to 50 gigabit, and eventually 100/200 gigabit services over coherent PON.

To be effective, PON must be supported by converged end-to-end management, which addresses existing or legacy PON, new PON variants, and advances in programmable IP/optical network management. Optical pluggables play a game-changing role in extending the carrier IP network using PON to cover last-mile connectivity.

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NEW YORK
441 Lexington Avenue
2nd Floor
New York
NY 10017
USA
Tel: +1 646 395 5460

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