A Pragmatic Approach to Deploying Broadband in LATAM with Standards-Based PON Technologies

A Technical Paper prepared for SCTE by

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1. Introduction

Today, broadband is recognized as an essential utility, on par with electricity and water. Gone are the days when broadband was used only for web browsing and entertainment. Today, education, healthcare delivery, and many essential services are delivered over broadband. Furthermore, today, broadband is a fundamental part of business models in most industries, particularly as the world goes through a tsunami of digital transformation. From video streaming to digital healthcare, remote education, wireless backhaul, work from home, intelligent farming, the metaverse and so many others, the opportunities are endless.

This has caused broadband consumption to soar and has created new requirements for operators such as reliability, latency, security, to name a few. It has led operators worldwide to increase capacity in served areas, and to extend broadband deployments to previously unserved areas. In doing so, they must juggle numerous parameters that include technology solutions, capex availability, competition, ARPU trends, and regulation to name a few.

2. The broadband opportunity

These days, broadband is no longer merely about connectivity. It has become a lifeline, a basic infrastructure, powering businesses and consumer markets. Some of the current and emerging broadband opportunities for operators include:

- Residential
- Small/Medium Businesses
- 4/5G Mobile Backhaul
- WiFi Backhaul
- IoT, Digitization, M2M
- Wholesale

These transforming markets are creating new opportunities, leading to new entrants and a hyper-competitive business environment but also challenges for operators: Ubiquitous broadband access is becoming essential, and indeed mandated by governments in some countries (though not in Latin America for the most part). Furthermore, the definition of broadband is changing. Gone are the days when broadband meant 25Mbps downstream and 3 Mbps upstream. In the United States, the FCC is pushing a 100Mbps definition of broadband and the market is evolving towards 10G symmetric broadband.

Evolution of the full-service operator. Cable operators today offer fixed line services but also mobile service. Customers increasingly do not view the two media as separate but expect broadband access wherever they are. Fixed and mobile convergence is finally possible.

The lines between business and residential are blurring. More business grade services are now delivered in the home, and this trend will only grow. For example, medical grade services are increasingly delivered in the home, more businesses are being conducted in residential settings and so on. These trends will impose new requirements on broadband delivery in the home, such as low latency, guaranteed bandwidth, security and others.

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Augmented reality is now a reality in many businesses, and the metaverse over time will be transformative not only in business environments but also in residential ones.

While Latin America is somewhat of a laggard in this respect, substantial public (and private) funding is going into broadband. In the United States, a staggering $100 billion is being invested in "broadband for all".

3. The broadband landscape in Latin America

The number of users in Latin America is growing rapidly. For example, Brazil, who had 182 million users in January 2023 is expected to have 190 million in 2027.

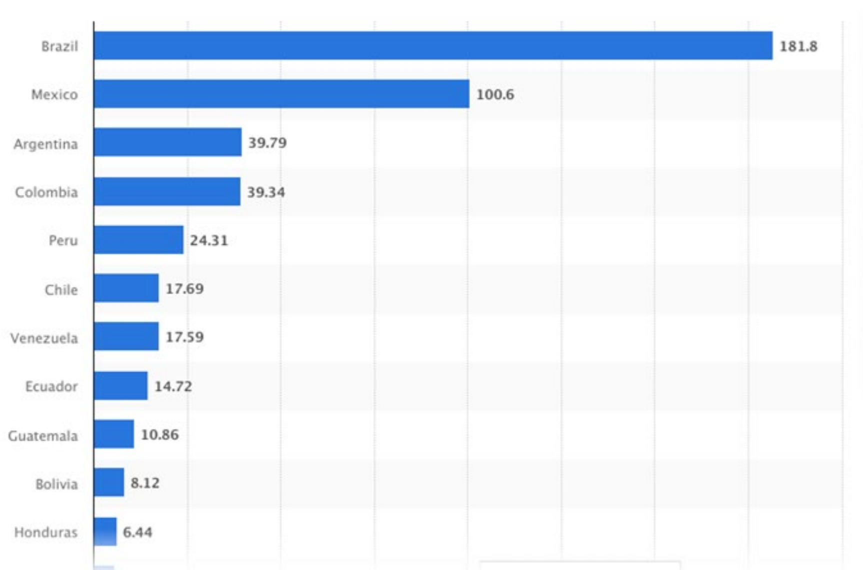

Figure 1 - Broadband users in key LATAM countries in Jan 2023 (in millions) [1]

However, growth in broadband use is not linearly correlated with ARPU growth. This is partly due to lack of affordability and causes challenges for operators who need to invest to add broadband capacity but cannot realize an attractive return on investment. This is compounded by the fact that unlike some developed countries where governments are investing massively in broadband (e.g. the BEAD program in the United States), in Latin America, governments are largely leaving it to the private sector to fund broadband expansion.

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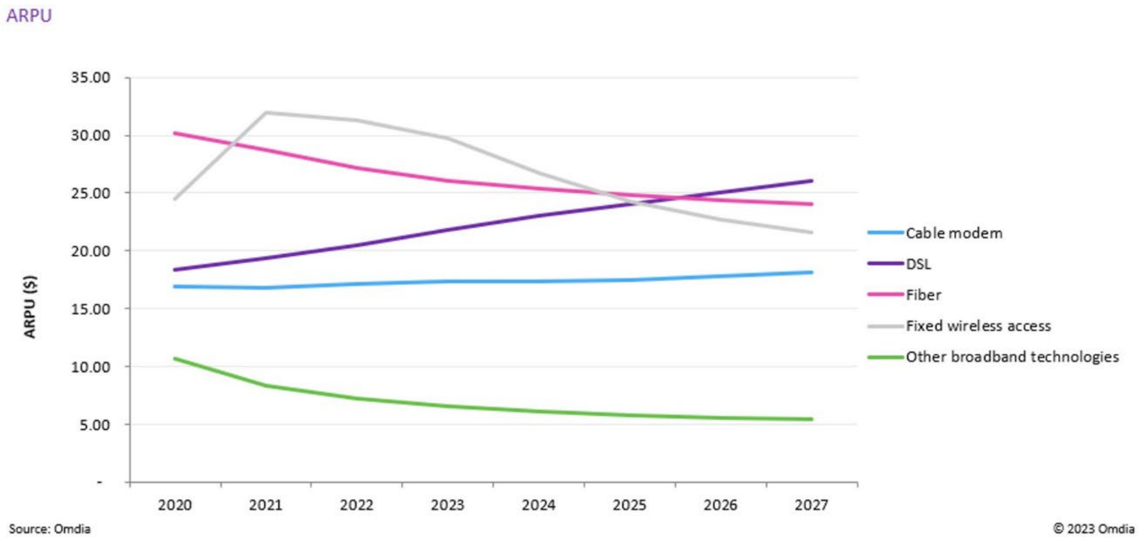

Figure 2 - More speed does not always result in higher ARPU [2]

Latin America and the Caribbean (LAC) is a large and diverse geographical region, encompassing 27 countries and more than 600 million people, and covering nearly 20 million square kilometers of forests, mountain ranges, glaciers, deserts, islands, and urban centers [3].

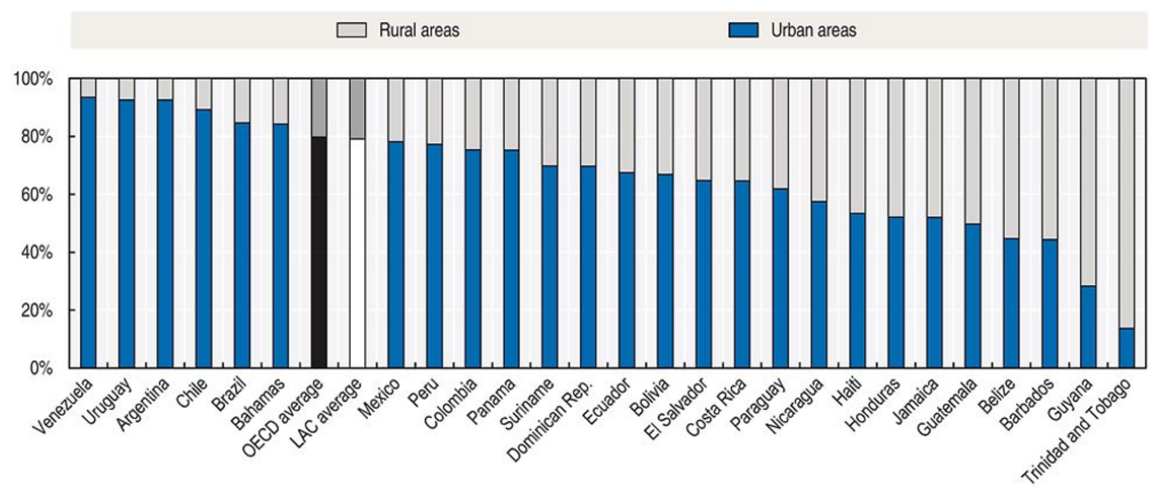

Figure 3 - Proportion of urban and rural areas in Latin America [3]

The regulatory framework in the region is also fragmented between countries, and sometimes within countries.

4. Scenarios for adding broadband capacity

Cable operators have primarily four scenarios for expanding their last mile, driven by market conditions.

- **Success based deployments** – for example developers demanding fiber builds, Small Office Home Office (SOHO) and other subscribers using gigabit symmetric services and businesses requiring increased Service Level Agreements (SLAs).
- **Greenfield** deployments, including multi-dwelling units (MDUs).

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- **Greenfield footprint expansion** into adjacent areas that leverage the existing plant to enable more home passings.
- **Brownfield and overbuild** – capacity additions in existing footprint, particularly in the upstream for symmetric services, and for meeting competitive pressure.

5. Technologies of choice for broadband deployments

Cable operators have primarily two technology approaches:

5.1. Hybrid Fiber Coax

HFC is the traditional technology used by most cable operators. It largely uses DOCSIS® protocols and continues to evolve to deliver more capacity upstream and downstream. Cable operators can use DOCSIS® 3.1, and mid-split (or high split in some cases), to add capacity and to improve upstream throughput. Some operators are using the distributed access architecture (DAA) approach to add capacity, either in a Remote-PHY or Remote-MACPHY approach. On the horizon is the migration to DOCSIS® 4.0, already being tested by major MSOs, using either Full Duplex DOCSIS (FDX) or Extended Spectrum DOCSIS (ESD).

Operators who have not committed to DAA and are looking for a technology with high throughput and significant future growth capacity or are deploying in a greenfield area are increasingly turning to passive optical networks (PON).

5.2. Passive Optical Networks

PON uses a point-to-multipoint fiber distribution network where one strand of single-mode fiber serves many end users, by sending data upstream and downstream through unpowered splitters and fiber distribution equipment. These passive elements of the PON are supported by optical line terminals (OLT)s in the network, that connect through the passive network elements to optical network terminals (ONT) which are at the subscriber's location. The PON enables the operator to bring fiber all the way to the subscriber's premise, thus delivering gigabit bandwidth.

However, bringing fiber to the premises can be a costly value proposition. The cost can vary from a few hundred dollars to multi-thousand dollars, depending on the terrain topology, distance, and many other factors. This makes PON deployments particularly challenging in the CALA region where average revenue per user (ARPU) is relatively low compared to the cost of equipment. Therefore, overbuilding an existing HFC network with PON can be cost-prohibitive, and difficult to justify and sustain.

5.3. Fixed Wireless Access

Fixed Wireless Access (FWA) uses radio links between two fixed points to provide wireless broadband. It consists of a base station connected to a fixed network. While widely used by large mobile network operators who own spectrum (for example Verizon and T-Mobile in the United States), FWA is not widely used among cable operators, particularly in areas where newer 5G technologies have limited deployments like in Latin America.

6. Selecting the right approach

PON technologies are typically well suited to meet the capacity needs of high bandwidth users but are often associated with high deployment costs. Therefore, operators should take a measured approach and

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consider multiple factors and evaluate many options as they set out to meet the needs of heavy users. Factors the operator should consider include:

- Brownfield or greenfield
- Spectrum availability
- Size of service group
- Trajectory of bandwidth usage and longevity of new infrastructure
- Availability of capacity in the HFC plant
- Topography
- Capex and Opex
- Available skillset
- Regulatory considerations
- Cost of overbuilding aerial fiber
- Subscriber mix and traffic consumption habits
- Size of the node and spare capacity

6.1. Success-based deployments

In areas of high bandwidth consumption, the operator can do an analysis to identify whether high bandwidth use is across most of the users in a service group, or a small subset. In some cases, a percentage of subscribers can be responsible for most of the heavy broadband use.

CommScope's internal research has identified the following trends in the CALA region:

- 25% of subscribers are responsible for 75% of bandwidth consumption in Central America.
- 30% of subscribers are responsible for 70% of bandwidth consumption in the Caribbean.

Measurement in service groups across several regions indicated that typically the 20/80 rule applies: 20% of users account for 80% of broadband use.

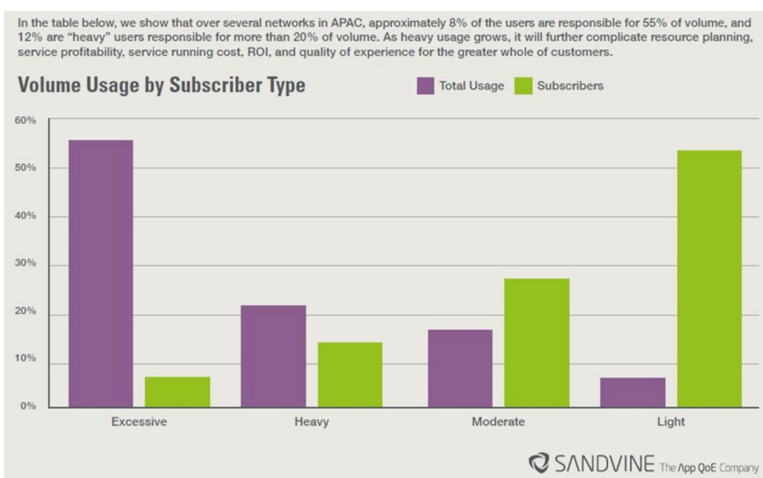

Figure 4 - Illustrative example of distribution of usage among subscribers [4]

For such deployments, operators can use a bandwidth shedding strategy where they use PON to selectively serve customers who pay for a higher tier of service.

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6.2. Greenfield footprint expansion

In this case the operator can tap into the existing network to build capacity into the adjacent greenfield area. Having infrastructure, including fiber, hubs or an HFC node in the vicinity of the new deployment enables the operator to expand cost effectively. Effectively, an operator can expand coverage to an adjacent greenfield by deploying a Remote OLT on the outside plant and thus take advantage to build the PON network from a location closer to the user.

The PON can effectively be deployed as an overlay network tapping into existing assets.

6.3. Greenfield deployments

The approach in this case depends on the density of the area, topology, and other factors. For example, in rural areas, or areas of low density, it makes sense to use long haul optics and use a remote PON technology to bring capacity to the area. In dense areas, a large chassis may be more appropriate.

6.4. Brownfield and overbuild

PON can be used effectively to offload traffic, mostly from heavy users, improving the QoE for all subscribers in the overlay area.

7. The PON overlay approach

An operator that has HFC network assets can selectively add capacity using DOCSIS® technology. For example, the operator can upgrade using DOCSIS 3.1 technology, with mid-split or high-split configurations to deliver more upstream capacity. Another common tactic adopted by operators is to decrease the service group size by node segmentation, and in recent years, DAA has been adopted as the preferred HFC capacity expansion method due to benefits such as smaller footprint on hubs and better performance.

However, in areas of market demand from high consumption users, or competitive offerings of symmetric services from other ISPs, PON is the most cost-effective technology to deliver the desired capacity, particularly if deployed as an extension of the HFC plant. If the node has sufficient room, a remote OLT (R-OLT) module can be inserted in the node. This module can initially deliver GPON speeds and provide a more extended reach due to a higher optical budget. If equipped with XGS-PON or dual SFP a typical service group of 128 subscriber can be served per port.

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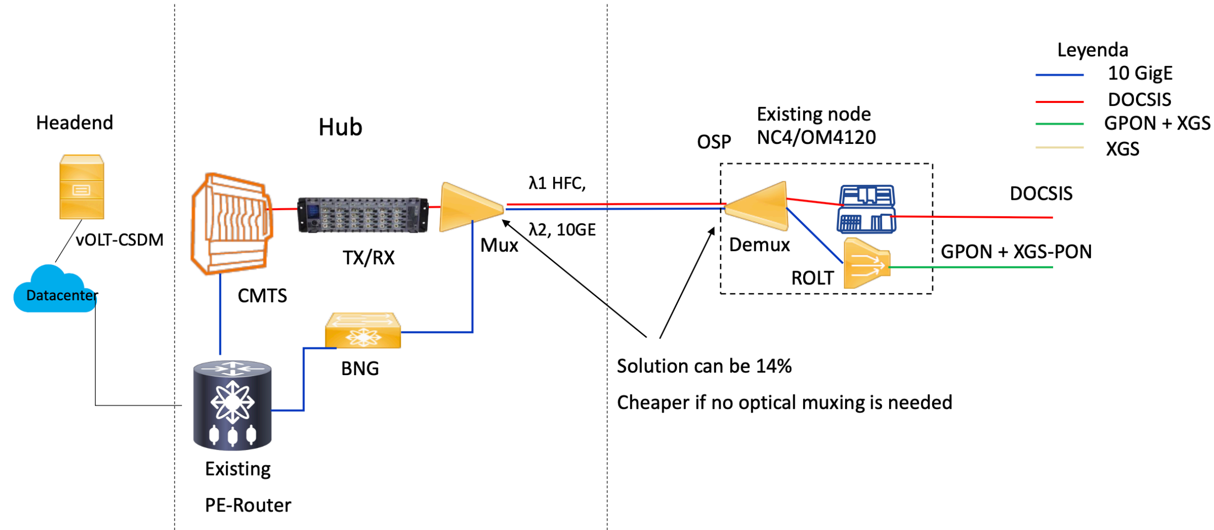

Figure 5 - FTTH overlay network with pre-connectorized tap terminals

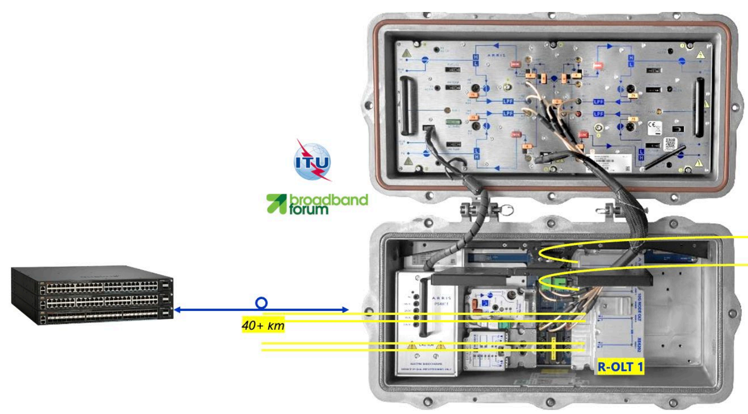

Figure 6 - R-OLT in existing node

There are many benefits for this approach:

- Using an existing cable path from the HFC network with aerial deployment means that no expensive underground feeder is required
- Minimizes future investment in HFC
- Meets the needs of heavy users, but at the same time frees capacity for remaining HFC subs, improving the quality of experience for all
- Solution fully compliant with ITU and Broadband Forum Architecture
- Requires minimal Day 1 investment.
- Enables a pay a cost-effective pay as you grow strategy.
- Possible to extend to 100% HP coverage whenever the decision is made to make full FTTH overbuild in the area.
- Is compatible with existing topology; can be housed in nodes and cabinets, which are common in the cable outside plant and leverage the power supply infrastructure already present in the cable network.

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- Has a common management environment with existing HFC infrastructure, which is software based and cloud-native and that uses modern technologies such as YANG and NETCONF.
- Prepares the access network to offer high speeds and low latency services to support new use cases such as 5G X-haul, Edge Computing connectivity, etc.

7.1. Pre-connectorized technology for cost-effective, speedy deployments

PON deployments can be costly, particularly if they require building new facilities and infrastructure to host and connect the OLTs. Therefore, a cost-effective approach is to use a small-form universal hardened connector system for high-density FTTH environments. These connectors replace splices, reducing installed cost. They limit splicing to an absolute minimum, are easy to install, and therefore have a low turn-up time and require less skilled personnel. These hardened OLTs are embedded into the access network at existing points of presence in nodes, cabinets and hub sites leverages existing fiber runs to multiple PON systems, by using long reach dense wavelength-division multiplexing (DWDM). This allows service providers to expand their network capacity while avoiding the need to pull new fiber. Deploying these energy efficient PON actives in proximity to subscribers maximizes the utilization of the OLT, enabling it to serve more subscribers. It also provides a launch point for expansion to serve customers in areas adjacent to the plant, enabling a targeted, pay-as-you grow strategy while optimizing capex and opex.

7.2. The advantage of R-OLT over C-OLT

The R-OLT approach, wherever feasible, presents many advantages over a centralized OLT (C-OLT) including a more efficient port utilization and the ability to optimize the area design for a 128 split.

While there are many configurations and parameters to consider, here is a sample comparison, that makes multiple assumptions; for example, the feeder network is underground, which adds to the cost, but some operators can deploy aerial feeding network. This comparison is for illustrative purposes only.

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	Centralized OLT		Remote OLT
OLT Location	In headend location, collocated with CMTS (ISP, shelf or chassis based)		ROLT In existing Cable node (or using new cable node)
Feeder network	**$$$** Requires new underground feeder		**0** reuse existing fiber to the node, WDM + GE backhaul
Fiber Access network	**$$$** **centralized** split with splitter near the OLT, more distribution fiber required	**$** distributed split architecture allows more economical OSP build	**$$** "Skinny fiber network" approach possible to minimize day 1 investment, build fast, and selectively target customers + extend later.
OSP Access Split Ratio	Max Split of 64 due to link budget	Max 64 Split, due to link budget distribute 1:4 – 1:16	Up to 128 split possible, optimize design for the area
OLT port usage	**$** OLT usage can be optimized, pay as you grow approach possible.	**$$$** Need to install OLT ports for 100% of homes passed day 1. Low port utilization.	**$$** Hardened OLT deeper in the network allows to guarantee high OLT port utilization. Expand as you grow in 2 port increments.
Upgrade path to XGS-PON	**$$**	**$$$** Lowest port utilization drives high number of ports to upgrade	**$** Few ports to upgrade, combo capability present day 1
TCO	**$$$**	**$$$**	**$**

* Link budgets and distances, fiber design and OLT port usage will vary greatly depending on the target area

Figure 7 - Comparing C-OLT to R-OLT (CommScope)

8. Managing and scaling the PON

A main advantage of next-generation PON networks is that management and control can benefit from key innovations, such as software-defined networking (SDN). The separation of the OLT control and management functions from the physical OLT, opens the way to the utilization of cloud native control and management software and the adoption of open protocols such as NETCONF and Rest APIs for installation, provisioning, and management.

When management and control functions are separated, it becomes easier to install and manage numerous OLTs embedded throughout the outside plant, even in remote locations. When the OLT's control plane software resides in the cloud, tasks such as initial software updates, system checks, and other start-up tasks can be automated by the cloud-based domain management function which recognizes new OLTs as soon as they are powered up in the field. It then uses automation to bring these devices online quickly, which has the benefit of obviating the need for busy technicians to commission new OLTs. This process converts OLT deployment into a routine task, with hands-free onboarding and less operational impact from PON rollouts.

Another advantage of adherence to standards promoted by ITU and BBF among others that have defined network functions, interfaces, protocols, and abstractions models for all network functions in the PON access network, allowing different vendor interoperability. The result is reduced capital and operational costs, a faster time to market and flexibility to use best of breed technologies from multiple vendors, easy integration into existing network environments, and less long and costly OSS/BSS integration projects.

The adoption of cloud-based domain management provides an opportunity to evolve network management, by shifting old Network Management Paradigm from NMS polling NE´s to NE's

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publishing in real time richer analytics to multiple consumer systems that may be subscribed to all or a subset of all network analytics.

9. Conclusion

Like all world regions, Latin America is seeing an unprecedented growth in bandwidth consumption, and an exploding need for broadband, higher speeds, symmetrical bandwidth, low latency to name a few. Like their peers across the world, Latin American operators are racing to meet the demand, but are judicious in deploying their capital and mindful of the limitations of their operating resources. Therefore, a pragmatic approach for them is to maximize the use of their existing deployed assets, primarily using DOCSIS®, and to use PON technologies to upgrade capacity where needed, for example in high consumption areas, areas adjacent to their HFC footprint, and greenfield areas. An R-OLT solution can be a cost effective, high throughput approach to satisfy market needs. Distributed R-OLTs can be managed by a standards-based disaggregated management and control environment, which reduces cost over the long run and minimizes vendor lock-in.

Abbreviations

ARPU	Average Revenue per Unit
BEAD	Broadband Equity, Access, and Deployment
BBF	Broadband Forum
BSS	Business Support System
DAA	Distributed Access Architecture
DOCSIS®	Data Over Cable Service Interface Specification
DWDM	Dense wavelength-division multiplexing
ESD	Extended Spectrum DOCSIS®
FCC	Federal Communications Commission
FDX	Full Duplex DOCSIS®
FWA	Fixed Wireless Access
GPON	Gigabit PON
HFC	Hybrid Fiber Coaxial
ITU	International Telecommunication Union
NE	Network Element
NETCONF	Network Configuration Protocol
NMS	Network Management System
OSS	Operational Support System
OSP	Outside Plant
PON	Passive Optical Network
REST	Representational State Transfer
R-OLT	Remote Optical Line Terminal
SDN	Software Defined Network
XGS-PON	10 Gigabit Symmetrical PON
X-haul	Backhaul-fronthaul
YANG	Yet Another Next Generation

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