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10G AND FTTP:

DRIVERS, CONSIDERATIONS AND STRATEGIES

A Technical Paper prepared for SCTE by

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Introduction

Armstrong is well recognized as America's 11th largest multiple system operator (MSO), serving thousands of homes and businesses across Pennsylvania, Ohio, West Virginia, Kentucky and Maryland. Their first broadband Internet customer was connected in 1997 and over the years they've earned a reputation as a fast-to-market and efficient disruptor.

As other MSOs debate fiber-to-the-premise (FTTP), Armstrong actually made the decision to build FTTP – 15 years ago … using radio frequency over glass (RFoG) technology to reach down to ten homes per mile in rural areas. With over 27,000 RFoG FTTP customers, four years ago Armstrong made the switch to light up the same 1x32 distributed split passive optical network (PON) infrastructure with gigabit passive optical networking (GPON). In fact, in dense areas, Armstrong activates GPON on the same glass as RFoG allowing one customer at a time to be moved from RFoG to GPON.

Why did Armstrong pursue FTTP in the first place and what drove the later transformation with XGS-PON? In this paper, we will explore the business, network, operations and financial reasons as to why Armstrong pursued this path to 10 gigabits per second (10G) and bypassed other options. We also outline how these network advancements and market factors have caused consumers to enhance their home wireless fidelity (Wi-Fi).

The Original FTTP Decision by Armstrong

Armstrong has experienced an impressive compound annual growth rate (CAGR) of combined bandwidth consumption for all Armstrong customers across the entire network. Historically, it had been 42%. More recently, the average usage CAGR has been 55%; daily average usage jumped from 290 Gbps (gigabits per second) in Feb 2020 to 450 Gbps a year later, (Gbps) on 2/1/2020 to 450 (Gbps on 1/31/2021 as shown in Figure 1.

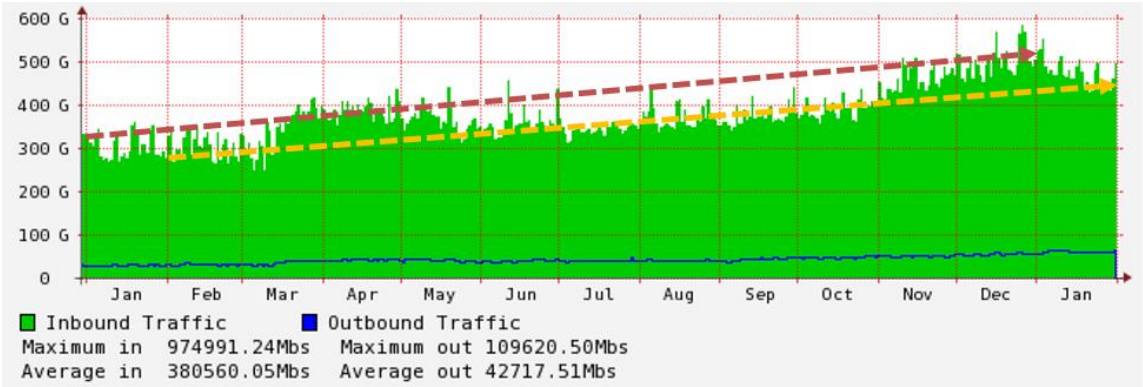

Figure 1. Cumulative Usage for (Wide Area Network) WAN Plus (Content Delivery Network) CDN and Peering Cumulative Ports (Jan'20-Jan'21). (Source: Armstrong)

To achieve and sustain the stated goal of "growth in perpetuity," the company pivoted to a fiber-fueled growth strategy. Armstrong realized that each Data Over Cable Service Interface Specification (DOCSIS®) upgrade would be costly and, at the current growth rate, could likely be oversubscribed upon being fully rolled out.

Even though FTTP was not the lower cost solution Day 1, it would be Day 2. To reach a fact-based decision, Armstrong created a spreadsheet containing all available historical data. "All the numbers proved out the fiber decision," according to Michael Scardina, Director of Network Strategies and Technologies at Armstrong. Mid-term and long-term evaluations showed FTTP to be both the lower cost and longer life solution – enabling Armstrong to remain highly competitive long into the future.

Power Savings

A significant HFC and DOCSIS operating expense is electricity (e.g., powering the nodes and the downstream amplifiers.) Switching to fiber and PON would yield a substantial energy savings in millions of dollars annually. Then, there's the labor savings resulting from a major decrease in the need for hybrid fiber-coaxial (HFC) plant maintenance (e.g., avoid ingress/egress leakage repair, eliminate battery upkeep).

Customer Premises Equipment (CPE) Costs

Another financial factor in Armstrong's decision process involved CPE costs as they form a significant part of any network upgrade. Upgrading to DOCSIS 3.1 (then 4.0) or FTTP requires replacing CPE. For Armstrong, a GPON ecosystem was more mature and costs were more predictable. And a GPON 1Gbps system is easily upgraded to a XGS-PON 10Gbps system, with no change to outside plant necessary. XGS-PON also provides higher capacity and, like GPON, offers a very simple and scalable method to extend high throughput layer 2 connectivity to enterprise customers on the same fiber route. Armstrong uses these layer 2 connections to extend a full suite of enterprise services by virtually and securely connecting the customer to the hub distribution router. There are substantial financial and operational benefits to this as it typically removes the need for dedicated direct fiber with MPLS CPE routers. According to Scardina, "The cost of XGS-PON CPE is 1/10th that of MPLS CPE used for enterprise customers." For Armstrong, it was a more economical use of last mile fiber.

Upstream Limitations

Consumers and their behavior also played a key role in Armstrong's decision. The need for speed applied not only to the downstream, but also the upstream. Inherent upstream limitations made DOCSIS technology a less viable path on which to continue. Upgrading to DOCSIS 3.1 technology would be "a stopgap solution at best" says Scardina. "Moving to orthogonal frequency-division multiplexing / orthogonal frequency-division multiple access (OFDM/OFDMA) is one thing, but moving the forward/reverse split to add upstream spectrum is a much more complex problem with compounding effects."

Scardina continues, "For example, while Armstrong's HFC plant architecture from the mid-1990s would allow amplifier module-only change to move from 5-42 megahertz (MHz) sub-split to 5-85MHz, because of limits in the legacy set-top box command and control downstream channel, upstream frequencies above 85MHz would require new diplex filter technology to notch the upstream to support a small amount of downstream. 5-85MHz isn't enough upstream spectrum to support growth demands and 5-204MHz isn't either in the long term. For the time being, Armstrong uses node/distribution leg splits to reduce the number of modems sharing the 5-42MHz upstream as FTTP replacement of HFC fully ramps."

The HFC plant change from sub-split to mid-split, as shown in Figure 2, enables up to 300Mbps in the upstream. However, for the reasons articulated by Scardina above, the shift to a high-split to support symmetrical 1Gbps speeds is more complex and costly.

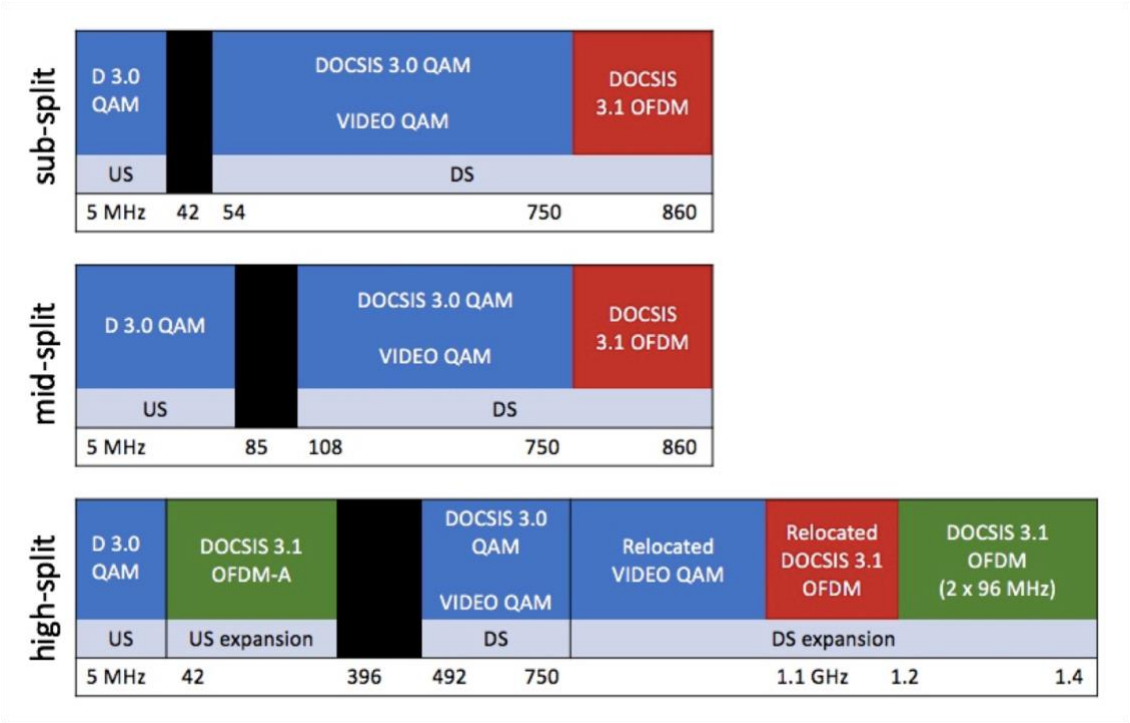

Figure 2. HFC Spectrum Impact of Support for Higher Speed Services

The Consumer Electronics Show (CES) Horizon

The annual CES show in Las Vegas also provided ample proof that this was the right decision. Viewing the event as a "weather forecast" of what is on the horizon, Scardina took note of what the Armstrong network would need to support with the emergence of augmented reality (AR) and virtual reality (VR) centric gaming applications. Beyond software used in the home, there's the proliferation of devices. "On average, four new devices entered each home in one month earlier this year," according to Scardina. Washers, dryers, dishwashers, exercise equipment have all evolved into IoT devices – connected to the network. "There are so many new bandwidth uses that we simply didn't have in the past."

Field Tech Training & Equipment

In deciding upon fiber, Armstrong had an important operational consideration: the degree of difficulty to transition from DOCSIS technology to FTTP. What impact would this decision have upon the people, the processes and the equipment? Armstrong discovered that the technical skill sets honed through years of DOCSIS deployments could fairly easily be transferred to the deployment of fiber. Many of the same basic concepts applied. The move to fiber yielded a simpler process in the field as handheld splicing tools took the place of complicated connectorized cables. As for the use of spectrum analyzers, the technique that puts radio frequency (RF) signals in a radio spectrum for DOCSIS signals applies in a very similar way to optical signals in a fiber. And PON meters are simpler to operate than RF signal level meters.

The rationale for Armstrong's FTTP decision has been validated time and time again. An additional lesson that has been learned is that the company could have deployed FTTP even faster. With Rural Digital Opportunity Fund (RDOF) and other broadband initiatives driving increased fiber rollouts, Armstrong now competes with new and existing fiber entrants for the same labor and materials,

challenging the rate that fiber expansions can be built. However, broader operator adoption of fiber is a double-edged sword and Armstrong benefits from lower technology prices as a result. In fact, cost declines contributed to Armstrong's move from GPON to XGS-PON.

Provisioning: DOCSIS to GPON

"We initially started with Ethernet passive optical network (EPON) because of the DOCSIS Provisioning of EPON (DPOE) standard", says Scardina. "However, EPON didn't work out. DPOE and its virtual cable modem approach performed as expected, but the available CPE and services delivery did not. So after investing many months and the need to pacify angry customers, we switched to GPON due to its proven track record. A GPON system utilizes its own set of service templates for provisioning customers and a DOCSIS Provisioning of GPON (DPoG) standard never came to fruition. Nonetheless, by layering in commercial middleware, we were able to convert DOCSIS service codes to GPON templates; an outcome that surprised us in its simplicity."

Scardina continues, "Manual provisioning just wasn't an option, so we initially purchased middleware to marry our back office DOCSIS provisioning system to the GPON Network Management System (NMS). That worked very well and remained in place for more than a year. We then explored replacing the commercial middleware with internal resources for OpEx savings. In less than a week, an in-house developer was able to replace the commercial middleware with our own adapter. Additionally, designing our own middleware to interface between our traditional billing and CPE provisioning systems created an agnostic approach to flow-through provisioning. This allows field premise techs to provision a cable modem, GPON ONT, Wi-Fi, Telephony multimedia terminal adaptor (MTA)/number porting, and video set-top boxes all from one mobile application on their smart phones. Change can be hard, but it doesn't have to be as hard as you think."

The 10G Platform with XGS-PON and Combo PON

Armstrong's innovation with FTTP did not end with their original decision. For some Armstrong customers, GPON fits their needs perfectly. But, for the high-bandwidth consuming customers, there was a need for a smooth shift to accessing higher speeds. Service providers can co-mingle GPON and XGS-PON on the same fiber strand to provide more network flexibility and better address customer demands. For example, you can maintain customers on GPON while utilizing XGS-PON as a higher-end option for commercial customers (Figure 3). According to Scardina, "there's no need for a dedicated fiber using different technology to a single customer. Instead, we use an XGS-PON wavelength to deliver prioritized services."

"Armstrong was able to simplify its deployment process of XGS-PON over its existing GPON network through the use of Combo PON technology, which allows providers to combine these disparate technologies over the same infrastructure – from a single OLT port," according to Jess Beihoffer, Director of Sales Engineering at ADTRAN.

The need for separate overlay networks to serve homes and businesses can now be avoided. The technologies can be converged on the same platform. A single fiber. A single PON (up to 128 customers). All yielding economies of scale. Armstrong recently announced the launch of 10Gbps services starting in the town of Wexford, Pennsylvania using this architecture on a 32 PON split.

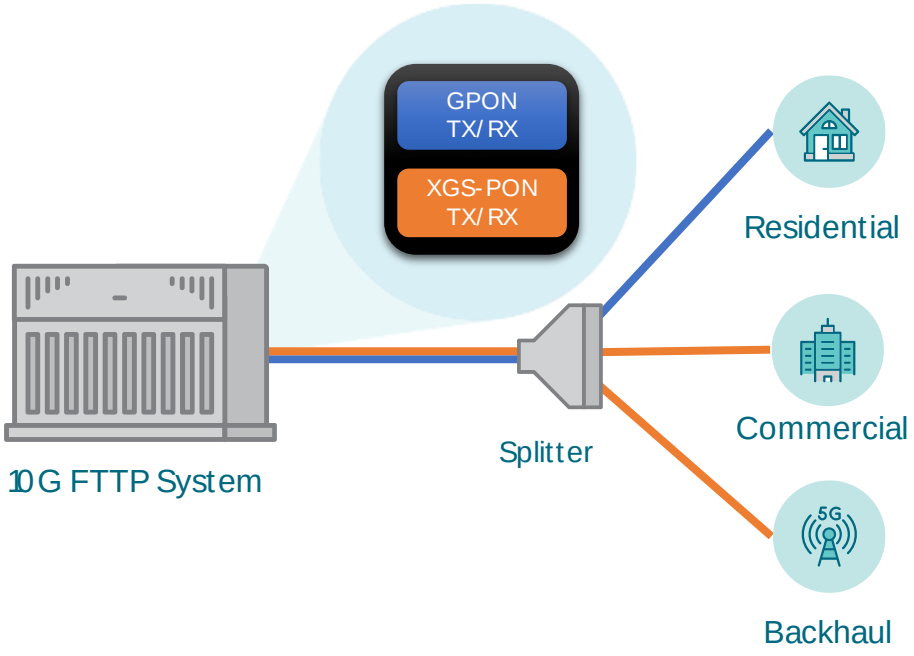

Figure 3. Combined XGS-PON and GPON technologies on a common optical distribution network (ODN) and optical line terminal (OLT) system. (Source: ADTRAN)

The co-existence of PON technologies enabling backward compatibility has been a point of discussion since the inception of 10G PON standards in 2009. By combining both wavelengths within the OLT optics, Armstrong not only simplified the optical distribution network (ODN) when introducing higher capacity XGS-PON, but also took advantage of added port density as a single port can now simultaneously support both GPON and XGS-PON. Armstrong was able to gain greater network flexibility. The growing popularity of this technology has led industry and analysts such as Omdia to converge around the term Combo PON. Refer to Figure 4.

This technology is seen as key to simplifying the path to 10Gigabit networks, as well as providing improved economics for operators building new FTTP networks or modernizing existing GPON fiber networks to support the economic and social development of the communities they serve.

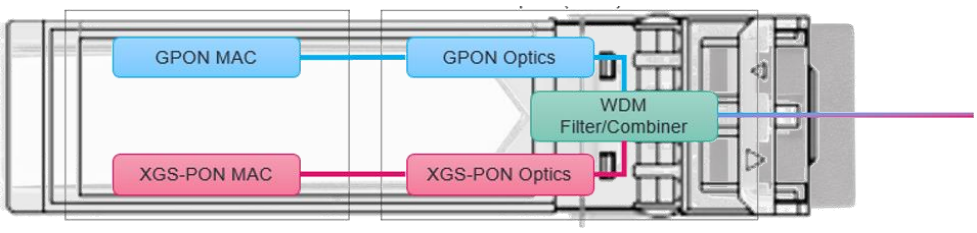

Figure 4. Combining XGS-PON and GPON technologies within a common OLT module. (Source: ADTRAN)

Some of the immediate economic benefits that providers are seeing is a reduction in power consumption (50+%) as well as rack space (up to 50% lower), mitigating two of the major concerns that providers face in their hubsites.

A more flexible network contributes to higher customer satisfaction. Moving high-usage GPON customers to the XGS-PON overlay alleviates congestion for customers staying on the GPON network and results in improved performance for those who remain and those who migrate. As Scardina explained, "If you have one customer on a street that is a very high bandwidth consumer, you can easily shift them over to XGS-PON to better fit their broadband needs without causing any disruption to your other customers in the area."

Next generation FTTP technology like Combo PON provides all of the XGS-PON capacity and operational benefits, affords the opportunity to leverage the full value of mass market GPON technology, while further simplifying fiber network modernization processes. The promise of such a network should serve to "demystify the perceived level of effort and lessen intimidation," according to Beihoffer of ADTRAN. "It's not a forklift upgrade. Folks shouldn't be scared to touch PON."

With 10G networks historical bottlenecks no longer exist in the access network. The bottlenecks have migrated into the home and the backbone. Regarding the home, a stellar Wi-Fi experience is all-important – especially since most consumers view Wi-Fi as the Internet.

Delivering the In-Home Gigabit Experience

The in-home experience is critical. "If 10G is at the side of the house but can't be accessed by the client device, what's the point?" Scardina noted. The importance of excellent home Wi-Fi was recently confirmed with executives at Tier 2-3 service providers. They cited that the primary benefits of offering a residential managed Wi-Fi solution are Improved Customer Experience and Reduced Churn – two sides of the same coin. Not surprisingly, every executive said "Wi-Fi coverage throughout the house" is a very important to their residential customers.

Managed Wi-Fi

As MSOs increasingly focus on being broadband-first providers, they are focusing on providing a high-quality managed Wi-Fi service within the home. They also know that their customers view Wi-Fi as synonymous with the Internet and a Wi-Fi issue often triggers a customer service call. By providing a managed Wi-Fi solution, the service provider can ensure that their customers are leveraging the latest technology (currently Wi-Fi 6, soon to be Wi-Fi 6E), and placing advanced Wi-Fi system components throughout the house to ensure maximum coverage.

Analytics and Insight

Leveraging cloud-based data and analytics packages integrated into the Wi-Fi system solution, operators are given a window into the customer's network, behavior, and experience. They are then equipped to efficiently provide enhanced customer service and present new offerings tailored to the subscriber.

The Core Network: Scaling to 100G

The backbone network between the OLTs and the core is another area that requires focus. As the last mile access network scales to 10G, Armstrong also is further strengthening and scaling core network and

transport systems to support the growing needs of the last mile. “Don’t just look at your last mile, it all comes back to your core. Build your core and make sure it’s highly scalable and redundant”, said Scardina. Several years ago, Armstrong began upgrading its core network backbone links from multiple (N) x 10 gigabit Ethernet (Nx10GE) ports to (N) x 100 gigabit Ethernet (Nx100GE). As XGS-PON deployments increase, Armstrong is preparing for similar upgrades to the uplinks from their 10G fiber access, aggregation and transport platform. Refer to Figure 5.

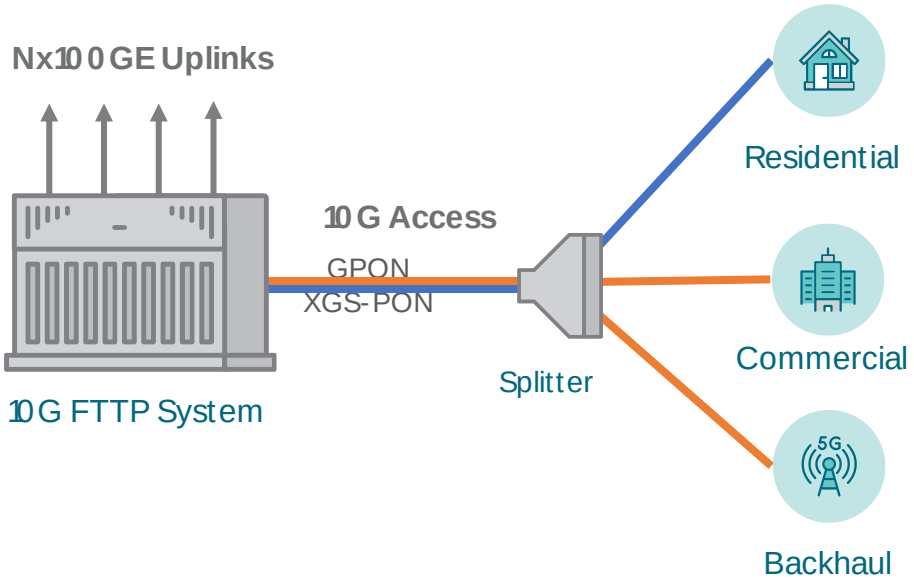

Figure 3. Strengthening the Network Core for 10G Access. (Source: ADTRAN)

Why Not DOCSIS 3.1 / 4.0 (with fiber deep)

If service groups are kept small enough, DOCSIS 3.1 technology can reliably support the speeds that GPON enables (at least in the downstream direction), but not those delivered with XGS-PON. To achieve speeds approaching 10G, DOCSIS 4.0 Extended Spectrum or Full Duplex DOCSIS techniques are required. These are certainly valid choices for some, but many will find that the plant upgrades required to extend the spectrum to 1.8 GHz and beyond, and to modify the split and/or change the architecture to Node + 0 can add these complications that are not found with an FTTP overlay, or with an upgrade from GPON to Combo PON:

- Service disruption during upgrade activities;
- No operating cost reduction;
- Disruption of legacy services due to interference from new upstream channels (requiring installation of filters or change of CPE), and
- Multiple upgrade steps may be required on the way to 10G.

Conclusion

The Armstrong FTTP story is a compelling one. The business, network, operations and finance reasons as to why Armstrong pivoted to FTTP long ago are ones which other MSOs could well use today to make a strong argument in favor of this transformative move. These are just some of the reasons which are as relevant as ever:

- Performance of bandwidth-hungry (gaming) applications and escalating volume of connected internet of things (IoT) devices;
- Long-term, competitive, lower cost solution;
- Lower labor expense with reduction in plant maintenance;
- Significant energy savings, and
- Maturity of fiber and PON ecosystem due to greater FTTP adoption by more operators.

That argument is only bolstered by the advantages realized with XGS-PON together with Combo PON technology. Service providers can co-mingle GPON and XGS-PON on the same fiber strand to provide more network flexibility and better address customer demands. Combo PON technology yields a significant reduction in space use, power consumption and capital expense which enabling a longer GPON life span and an increase in gigabit service coverage.

As Scardina states, “The time for XGS-PON is now. Find a way to do it that makes financial sense. Spend the capital expense (Capex) once and be prepared for when customer demands increase. Be proactive, not reactive.”

Abbreviations

100G	100 gigabits per second
10G	10 gigabits per second
AR	augmented reality
CAGR	compound annual growth rate
CapEx	capital expense
CDN	content delivery network
CES	Consumer Electronic Show
CPE	customer premises equipment
DOCSIS (3.0, 3.1, 4.0)	data over cable service interface specification (version)
EPON	Ethernet passive optical network
FTTP	fiber to the premises
Gbps	gigabit per second
GPON	gigabit passive optical networking
HFC	hybrid fiber-coaxial
MHz	megahertz
MSO	multiple system operator
MTA	multimedia terminal adaptor
Nx100GE	number (N) x 100 gigabit Ethernet
Nx10GE	number (N) x 10 gigabit Ethernet
ODN	optical distribution network
OFDM	orthogonal frequency-division multiplexing
OFDMA	orthogonal frequency-division multiple access
OLT	optical line terminal
ONT	optical network termination
PON	passive optical network
QAM	quadrature amplitude
RDOF	Rural Digital Opportunity Fund
RF	radio frequency
RFoG	radio frequency over glass
SLA	service level agreement
Virtual Reality	virtual reality
WAN	wide area network
Wi-Fi (6, 6E)	wireless fidelity (version)
XGS	10 gigabit symmetrical