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ON TOPIC

Advancements in the Upstream

ENDEAVOR BUSINESS MEDIA

How Cable Operators Keep Up with Exploding Upstream Demand

BY JIM WALSH

As we start 2022, much of the world is in a very different place vs. where we were a year ago. Most kids are back in school, and many of us are beginning to return to the office. Despite these baby steps toward normalcy, it is clear that broadband upstream demand and usage models have forever changed. Cable providers weathered the initial storm well and are now positioning themselves through innovation and industry-wide collaboration to remain ahead of the bandwidth demand curve.

	3 Primary Options for Upstream Capacity Expansion – Past vs Present	
	Was	Is
More Nodes	Node Segmentation or Business as Usual Node Splits	Node Splits via Distributed Access Architectures like R-PHY/R-MACPHY
More Hz	Adding carriers within 42/65 MHz US	Mid/High-Split Extensions
More Bits/Hz	16QAM→64QAM	OFDMA

Table 1.

Cable operators are not totally reinventing the wheel to stay ahead–the same three primary options for increasing upstream capacity that cable operators have relied on for decades still remain in play:

– **Mode Nodes** – Segmenting or splitting nodes to shrink service group sizes

– **More Hz** – Increasing spectrum available in which to widen and/or add carriers

– **More Bits/Hz** – Increasing modulations to gain higher spectral efficiency.

But how they go about leveraging these options is certainly changing (Table 1).

More Nodes (Via R-PHY/ R-MACPHY)

Distributed access architectures (DAA) like Remote PHY (R-PHY) and Remote MACPHY (R-MACPHY) are rapidly replacing standard node splits to appease hub rack space and power/cooling constraints. In the early days of DAA operational concerns existed about how to maintain and troubleshoot the plant once RF was no longer present in hubs/headends for ingress, leakage, and sweep tools. These

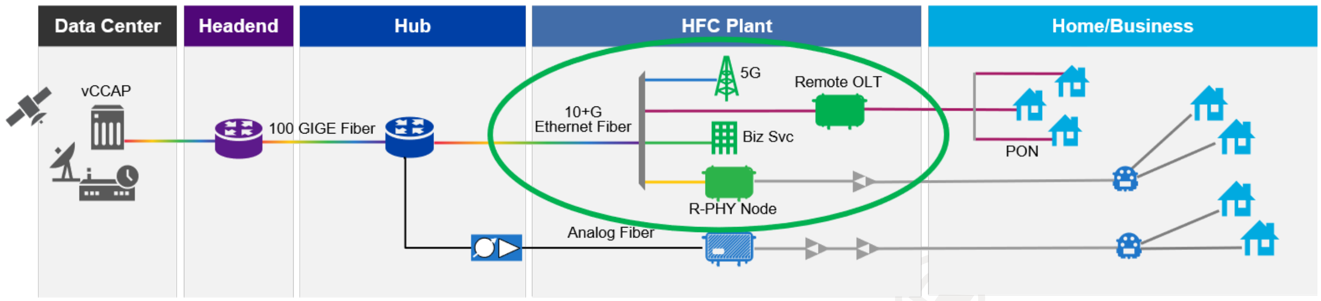


Figure 1. Converged Interconnect Network (CIN).

problems are now behind us as the functions previously handled by rack-mounted gear have been virtualized, enabling reuse of existing workflows and field meters. As with any new technology rollout, new challenges continue to emerge as deployments progress.

10+ Gbps Optical Ethernet in the Access Network – While the old point-to-point analog optical links for legacy nodes were finicky to set up and maintain, overall they were simple compared to the complex optical networks feeding some DAA nodes (Figure 1). Technicians in the field today often must be versed in DWDM technologies and be equipped with the proper tools to confirm that they have not just the right light levels but also at the right wavelength. Verifying network continuity through a vast array of switches and muxes/demuxes also creates challenges. Technicians must troubleshoot SFP issues, be aware of how PTP timing can impact services, and not forget the fundamental importance of fiber inspection and cleaning. No longer can cable operators rely on a small subset of fiber experts; now everyone must have this baseline knowledge and toolset.

RF Video Verification – Early adopters ran into unanticipated issues with linear video in early deployments. RF video is created for the first time at the Remote-PHY Device (RPD), so traditional test points in headends or RF combining networks are no longer available. Beyond just typical RF issues, opportunities exist for missing programs or packet identifiers (PIDs), stalled PIDs, out-of-band (OOB) carrier issues, logical/physical channel plan mismatches, and more. Each service group within each RPD/Remote-MACPHY Device (RMD) can have its own unique configuration, which makes being able to confirm that everything is correct for each service group a daunting task. Field meter-based solutions have since been developed to check everything above and more in about 5 minutes, minimizing this challenge and simplifying handoffs between field technicians and video engineering when necessary (Figure 2).

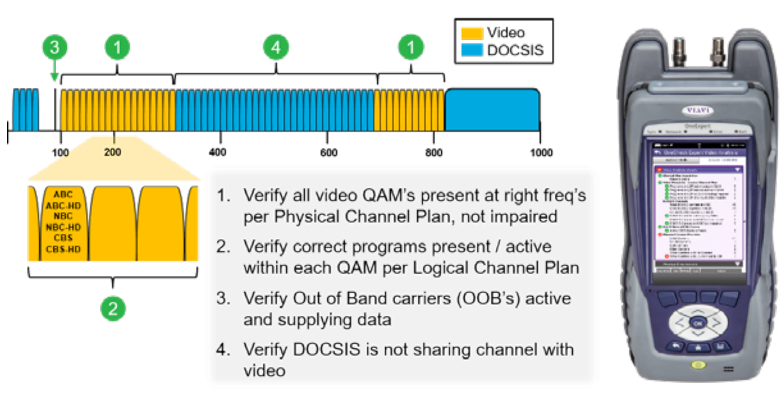


Figure 2. Linear video testing in DAA networks.

Flexible MAC Architecture (FMA) – The idea of managing the MAC layer from anywhere in the network has been alluring since the early days of DAA, and while some vendors have been offering R-MACPHY solutions for multiple years the true promise of ultimate flexibility and complete interoperability are just now heading toward reality. The underlying technology enabling FMA deployments is complex, but from a Tech Ops standpoint very little changes for monitoring and troubleshooting FMA networks. All of the systems developed to enable continuity of physical layer testing and troubleshooting from legacy to R-PHY networks work the same for R-MACPHY networks. The same generally goes for PNM and QoE monitoring; the transition will generally be transparent for maintenance techs in the field.

Many More–These are just a few of the test challenges created by DAA. Table 2 below is a summary of other test considerations associated with DAA deployment and maintenance.

More Hz

While node splits are typically the first option considered for increasing upstream bandwidth available to each service group, they are not always the most economical or practical option. Sometimes the best answer is to instead move from a sub-split (42 or 65 MHz) upstream to a high-split (204 MHz) architecture. While a typical node split will double the capacity/service group, a high split can yield a 5X increase or more vs. 42-MHz upstreams – eliminating or at least deferring the need for future node splits. It's important to note that the two aren't mutually exclusive; they can be deployed together for maximum impact.

High-split transitions aren't simple from an outside plant standpoint; every active and some passives must be visited before the full cutover can occur. Operators with 1-GHz or even 860-MHz networks can generally tolerate the downstream spectrum loss via analog reclamation and video compression techniques,

Headend/Hub Construction	Fiber Construction	RPHY Installation and Cutover	Maintenance
Network Equipment Installation Connector end face inspection DWDM Ethernet and Transport test MPO and AOC test GPS antenna test **Shelf RPD Verification** Characterize RF DOCSIS service test Video test Voice test	**Deploy new fiber link/Upgrade existing plant** Connector end face inspection Fiber Characterization (IL/ORL/OTDR/CD/PMD) **Install DWDM passive components** Connector end face inspection End-to-end channel loss and continuity (DWDM OTDR)	**RPD Install** Connector end face inspection SFP+ Optics test Ethernet test PTP test **RPD Configuration** Characterize RF DOCSIS service test Sweep	Leakage Ingress suppression PTP wander tests Video test DWDM Optical Power levels Fiber fault location • Break, bend Service Assurance Tests • Fiber, HFC, Ethernet **All construction and installation tests potentially applicable**

Table 2. DAA test considerations.

but 750-MHz and below plants typically need downstream expansions to compensate. Benefits of high-split transitions are limited to 204-MHz-capable CPE, but fortunately many recently deployed DOCSIS 3.1 CPE have switchable diplexers in place already. In addition to these fundamental challenges, other test-related challenges have emerged.

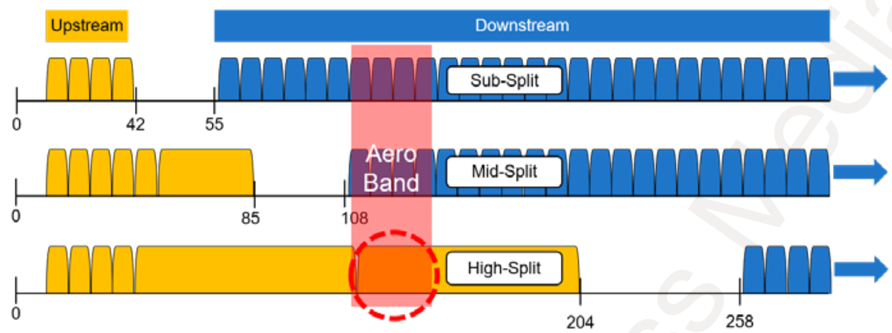


Figure 3. Signal leakage with high split.

Signal Leakage/CLI – Governmental regulations in some countries require aeronautical band (108-136 MHz) signal leakage monitoring, a task made simple by widely deployed downstream leakage monitoring systems. [High-split networks](#) break this paradigm as the aero band moves to the upstream band (Figure 3). Leakage systems designed to detect injected downstream signal "tags" or OFDM carriers leaking out from the downstream no longer have anything to detect. After evaluation of several alternative techniques, the industry has converged on detecting OUDP (OFDMA Upstream Data Profile) test bursts from CPE upstream transmissions for detection in high-split plants. OUDP burst functionality is already covered in current DOCSIS 3.1 specs for CPE/CCAP, and detectors from leading vendors are software-upgradable to provide OUDP burst detection. Whether it be for government-mandated testing or general plant hardening, good solutions exist for this "More Hz" challenge.

FM Ingress – FM ingress has been problematic for cable operators due to the always-on nature of FM signals. Anywhere there is a shielding weakness in a cable network, there are likely multiple FM signals ready to flood in and disrupt services. As with the aero band, the FM band moves into the upstream with high-split architectures (Figure 4). Now the funnel effect applies, creating a cumulative effect on the combined upstream signal and making localization more difficult. The wider OFDMA carriers specified for use above 85 MHz make ingress visibility even more challenging. Many operators are reporting success with using heatmap spectral analysis in headend systems and field meters to restore FM ingress visibility in the upstream for troubleshooting.

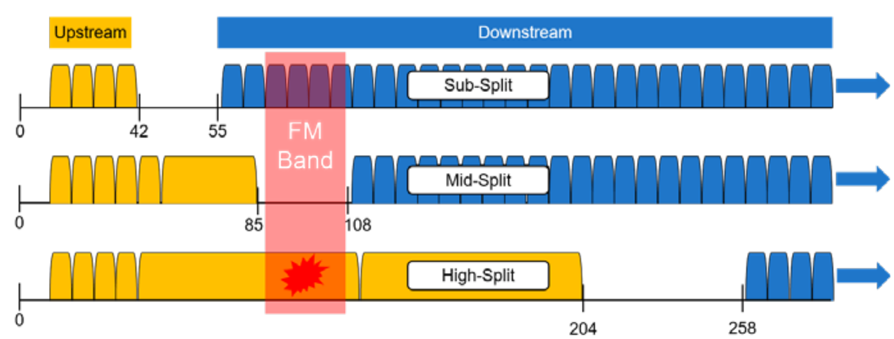


Figure 4. FM ingress with high split.

More Bits/Hz

The first two options have involved some pretty heavy lifts from a field operations standpoint – lots of truck rolls, plant impact, and project management challenges to deal with. Squeezing more bits out of each hertz of spectrum that you already have sounds much simpler – just turn on OFDMA and reap the benefits of a more-efficient pipe – right? This is partially true – there are a ton of DOCSIS 3.1-ready CPE deployed in many parts of the world and updating/configuring/licensing CCAPs to be capable is less intrusive vs. tinkering with the outside plant. But this doesn't mean that there aren't challenges to be overcome.

Ingress detection and troubleshooting – OFDMA, featuring Low Density Parity Check (LDPC) error correction, was designed to be more resilient against ingress, although mixed reviews have come in from early adopters regarding performance in bursty noise environments. Modulations can be adjusted on a per-subcarrier basis within profiles, but this is complex to manage without mature artificial intelligence/machine learning (AI/ML) solutions to help. Even as the industry learns to optimize configurations to fully realize OFDMA benefits, upstream ingress will remain the largest consumer of opex and largest creator of network-related trouble tickets. Again, heatmap-based spectral analysis has proven successful to help see both bursty and always-on ingress under these carriers (Figure 5).

Reverse Sweep – Return sweep in legacy SC-QAM networks generally involves placing sweep pulses in vacant spectrum and in the guard bands between the SC-QAM upstream carriers to minimize service disruption potential. With OFDMA carriers as wide as 96 MHz, new approaches must be considered for reverse sweep. How sweep is accomplished tends to vary by use case.

- **Critical Outage Troubleshooting** – During critical outages, traditional sweep is the go-to tool as it works even when DOCSIS services are down and provides instant feedback to any repair actions taken. Any minor service

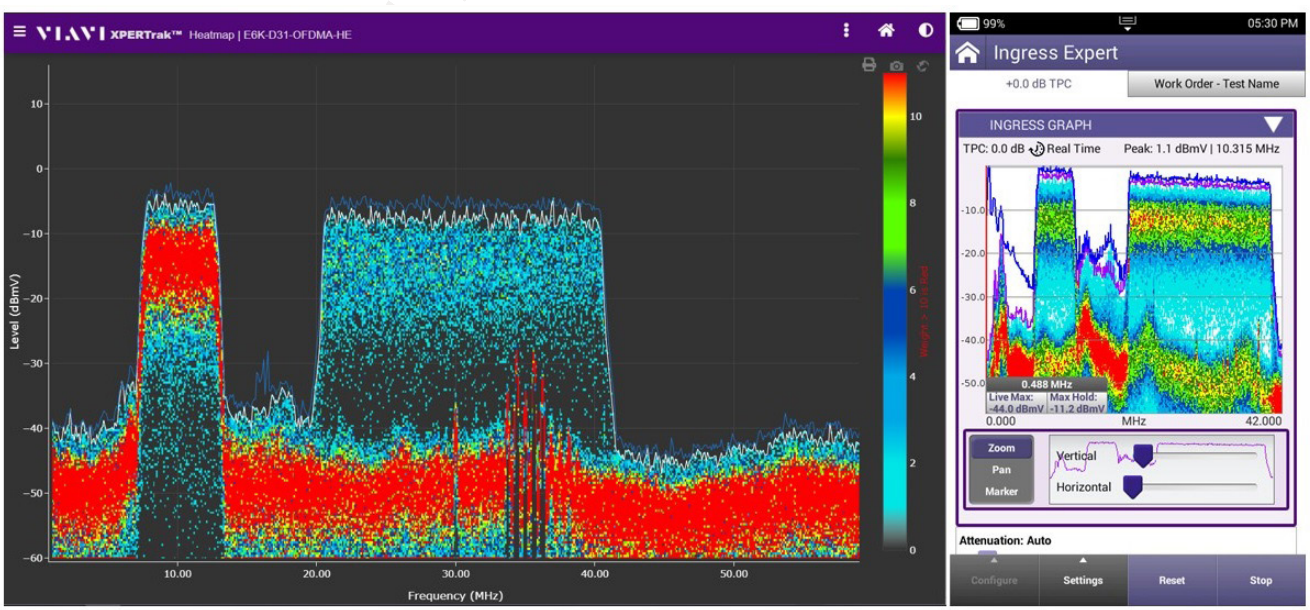


Figure 5. Heatmap spectrum analysis.

impact created by sweeping through OFDMA carriers is of minimal concern compared to restoring services during these times.

- **Amplifier Balance/Alignment** – Traditional sweep is generally used here also, including a new version that uses sweep pulses specifically designed to minimize any service impact for OFDMA carriers. Even absent the OFDMA-optimized sweep protocols, service impact is normally brief and minimal for most OFDMA carrier configurations.
- **General Plant Maintenance** – Sweepless reverse sweep is sometimes used for this use case as it requires no hardware beyond a field meter, instantly updates to any changes in channel lineups, and provides a higher resolution view of in-band response. The only downsides to return sweepless sweep are that it requires active DOCSIS services to work (not good during outages), is much less responsive (challenging to tweak amp alignment), and only covers occupied spectrum.

Conclusion

While the upstream demand spike that occurred in early 2020 has since backed off a bit, we are still left with a step change in upstream capacity and service quality requirements. The shock to the system caused by the pandemic and its disruption of steady growth models challenged the standard methods and processes that operators had relied on for decades, especially in the upstream. But as with past disruptive events and technologies, the industry showed innovation and dedication to overcome these challenges using the three proven pillars of upstream expansion. The future looks bright for HFC to continue as the broadband service delivery architecture of choice for many years to come.

Jim Walsh *is solutions marketing manager at VIAVI Solutions.*

Split Decisions

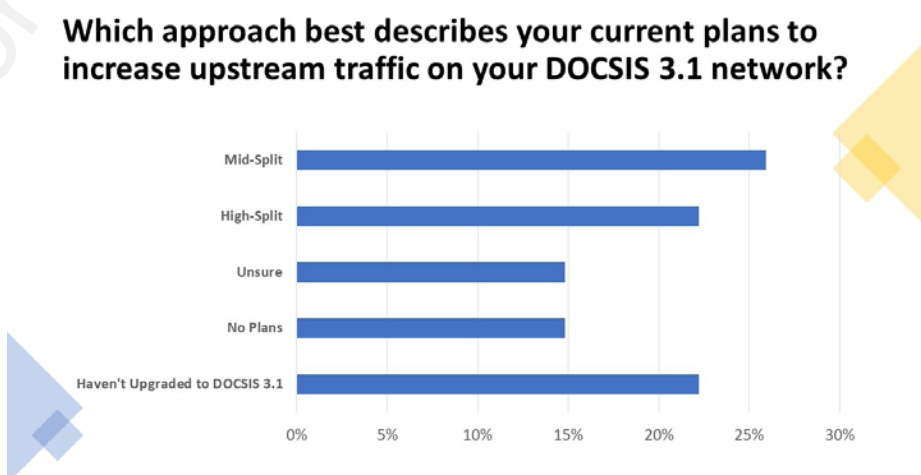
BY STEPHEN HARDY

Cable operators globally face the challenge of ensuring enough spectrum in their hybrid fiber/coax (HFC) plant to keep ahead of customer bandwidth demands. Particularly with an increasing emphasis on meeting upstream capacity requirements, the question of how best to invest now in spectrum additions, and then how to split that spectrum between upstream and downstream, is an important consideration in network planning. The need to add such capacity in the context of additional network evolutions, such as the move to Distributed Access Architecture (DAA) while prepping for DOCSIS 4.0, can complicate such planning as well.

Broadband Technology Report presented the panel "Where Do DOCSIS Cable Networks Stand Now?" as part of the High Speed Networking 2.0 online conference it produced in early June 2021 with sister site *Lightwave*. The session gathered representatives from industry and the cable operator community to discuss such issues as mid-split versus high-split for the upstream, extending downstream frequency limits to 1.8 GHz (perhaps in steps), and the current state of DAA deployments.

Splitting the difference

In North America, cable operators typically have run their DOCSIS networks with the 5 MHz to 42 MHz band devoted to upstream traffic. (In Europe, operators often extend this band to 65 MHz or more.) Current network upgrade plans, in particular within the context of the bandwidth spikes encountered during the COVID-19 pandemic, a move to either a mid-split (5 MHz to 85 MHz) or high-split (to 204 MHz) architecture. Of course, that additional spectrum has to come from somewhere and,



During the online conference session, audience members were polled on several issues. For example, opinions about mid-split versus high-split were fairly evenly divided.

rather than eat away at their downstream resources, operators frequently pair the addition of these upstream split architectures with additional downstream spectrum.

How far to go towards 1.8 GHz may depend on whether an operator feels more comfortable with mid-split or high-split. So far, mid-split appears more popular among North American and Latin American operators, according to panelist Jay Lee, chief technology and strategy officer, broadband access at ATX Networks. “It is abundantly clear that mid-split type activities are in motion or soon to happen and high-split seems to be either around the corner for some folks who are already starting mid-split or some folks who are waiting to jump into the high-split game,” he commented during the session. “There are a few issues associated with high-split that need to be sorted out. It’s a little bit more challenging of a move that has to do with legacy setup boxes. There are leakage issues that need to be addressed. But that’s an issue that is being addressed at the MSO level and at the CableLabs level.”

That said, Lee expects there to be a desire to go to high-splits directly. “If MSOs had their druthers, I would think high-split would be the more attractive option,” Lee said. “If you’re going out to change out amplifier stations to support mid-split, boy, it’d sure be nice to be dropping in high-split amplifiers.” But that might have to wait, Lee added, depending upon the challenges he mentioned previously as well as the fact that some operators may have installed cable modems with switchable diplexers that will only accommodate mid-split, which would mean these would have to be replaced as well.

Jeff Finkelstein, executive director of advanced technology at Cox Communication, reported during the session that his company has extended the downstream frequency of 85% of its HFC infrastructure to 1 GHz – with the ability to move readily to 1.8 GHz as well. So Cox has some flexibility as it decides which avenues to pursue. “It’s like a buffet,” he commented.

In practice, Finkelstein envisions Cox using both mid-split and high-split, as a particular infrastructure and market require. “We’re in the process of moving towards mid-split into some portion of our plant because we have this immediate upstream challenge that has been brought on by work-from-home, school-from-home, home healthcare, all those things that are most important to customers,” he explained. Meanwhile, “we will be moving towards a high-split/1.2 [GHz extension] in a portion of the plant…. There will be a much larger portion that we would do a high-split/1.2 in because that buys us quite a few years,” Finkelstein continued.

At the same time, Cox will ready the plant for further evolution. “While we’re doing this and probably while we’re doing some of the mid-split, we will be putting in 1.8-gig passives, 1.8-gig-capable actives, with a diplexer we can take from an 85 to 204, 396 [MHz], maybe 492 [MHz],” Finkelstein continued. “There are lots of options as we go forward in this. This sets us up for having the nodes that are capable of ESD [Extended Spectrum DOCSIS]. We’ll have amplifiers that are capable of these different splits. We’ll already be ready and opportunistically, from a success basis, we can undertake moving from where we are today to this sort of intermediate step, which then gets us even further along.”

Finkelstein envisions many of his fellow operators following a similar path – one that will take several years to navigate. "This is going to be the same kind of journey," he said. "There's going to be some mid-split. There's going to be probably more high-split. There's going to be ultra-high-splits or FDX. This is over a long period of time. So, it's really almost unfair to say, 'Are we going to do more mid-split or more high-split?' Because the answer is, yes, we're going to be doing both."

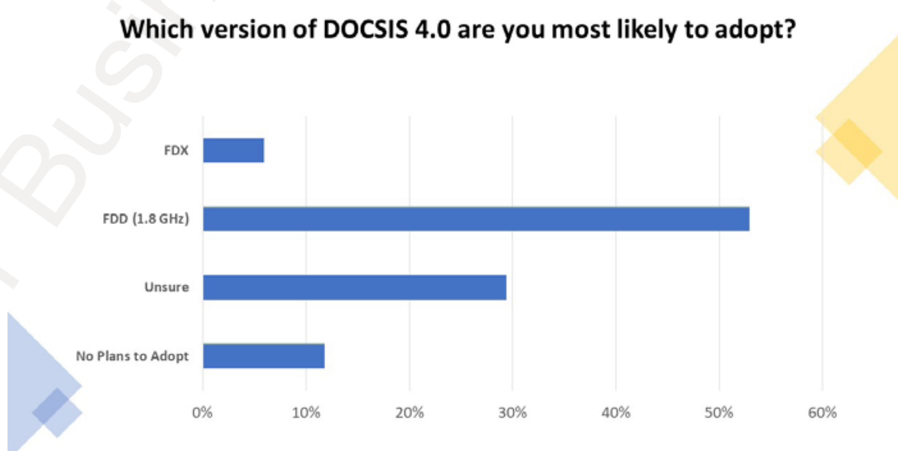
How widely distributed will DAA be?

The roll out of mid-split and high-split capabilities at Cox comes within the context of the operator's deployment of DAA infrastructure. Finkelstein revealed during the session that Cox has deployed nearly 10,000 Remote PHY devices. However, not many operators, particularly in North America and Latin America, are as far along.

"We have to appreciate that Cox has been a pioneering MSO moving DAA and Remote PHY to real deployments," commented Hanno Narjus, CEO of Teleste Intercept and senior vice president of one of the joint venture's parent companies, Teleste. (Antronix is the other parent.) "Whereas we are not seeing that many other MSOs – we're talking about 5, 10, something like that – who really seem to be rolling out DAA at this point in time."

Market analysts have pointed to pandemic-induced shifts in priorities for DAA deployment momentum slowing in 2020. As the world returns to normal, DAA deployments should quicken, they feel. However, the pandemic may not have been the only obstacle DAA roll outs have had to overcome.

"I think that DAA deployments have been held back for probably two main reasons," offered Paul Broadhurst, president, founder, and chief executive of Technetix Group Ltd., as part of the panel. "I think, number one, that most operators have quite a lot of legacy set-top boxes and, if you do node-splitting and roll out DAA, there are a lot of difficulties using them to support video, digital video. There are some solutions, but it's complex.



Audience members indicated a distinct preference for FDD over FDX.

"I think the other thing certainly is the power dissipation of the first-gen DAA equipment, especially in the U.S. for underground networks and in Europe for equipment in cabinets," Broadhurst continued. "The heating is a problem. And I think that with Gen 2 products that are much lower power dissipation and obviously will be able to do MACPHY, I think things will really start to move now and in 2022."

Regaining DAA momentum will be critical for the MSO community, Narjus insisted. "Now I think the heavy lifting has been done. Now I really would encourage that all the MSOs should start to look at what is their evolution path and their roadmap to start deploying DAA because that is the mandatory step to get anywhere on this 10G track," he said.

Stephen Hardy *is editorial director of* *Broadband Technology Report.*

Fiber and the Art of Next-Generation PON

BY ANA PESOVIC

Fiber is the bedrock of modern telecommunications technology that underpins the industry's spectacular growth. It plays a crucial role in connecting people, businesses, and smart cities. Fiber networks have virtually unlimited bandwidth potential, and every new generation of passive optical network (PON) technology unlocks more of that potential by running faster on new wavelengths (or colors of light).

Today, most fiber access networks use GPON technology to deliver speeds of 1 Gbps. There are >300 gigabit networks worldwide, many of them in the U.S. By adding a new wavelength with XGS-PON technology, operators can add 10X capacity to their existing fiber network.

The need for speed is driven by more bandwidth-hungry applications, more users, and more devices per home. But speed is not the only driver. The "big pipe" of XGS-PON allows operators to converge more services on the same fiber infrastructure, create more revenues, and accelerate network monetization.

Figure 1. The benefits of 10G PON.

Enter XGS-PON: the game changer

XGS-PON is well placed to address the bandwidth requirements for both consumers and businesses. It is forecasted that XGS-PON will overtake GPON shipments in as little as two years and become the mainstream PON technology. Now that evolution truly is a game changer for numerous reasons:

1. XGS-PON delivers unbeatable symmetrical speeds (in upstream and downstream) suitable for business connectivity and premium user experiences.
2. It creates significant savings and revenues by converging business, consumer, and 5G transport services on a single network.
3. It attracts new investment in fiber; alternative operators, tower companies, investors, etc.,

have been quick to recognize this as a market-disrupting opportunity.

4. It allows regional communication services providers (CSPs) to protect their market from bigger players. By seamlessly jumping onto XGS-PON, they can provide an ultra-fast and reliable network to their customers, while making their market less attractive for competition.
5. It lets multiple system operators (MSOs) complement their cable deployments and compete with CSPs.
6. XGS-PON is easy and cost-effective to upgrade on an existing PON infrastructure and supports symmetrical bit rates.

Given the ability to overlay XGS-PON over the existing GPON network, the return on investment is accelerated, with the payback period reduced by at least 20%. And XGS-PON enables opportunities for additional revenues. Besides adding wholesale, business, and mobile transport revenues, operators should consider tactics to increase revenues in the consumer segment. Consumers are often willing to pay a premium price for a premium service, as witnessed in many real-world networks. High-capacity and low-latency XGS-PON offers opportunities to monetize a variety of special-service packages such as "gamer broadband packages," "working from home packages," "edge computing" for medical and financial branch offices, etc.

So, what should your PON migration strategy be?

Given the rapid evolution in technology and consumer requirements, it is imperative to implement a plan that is future proof. Let's explore a few options based on the type of your existing network infrastructure:

Greenfield deployments: In deployments where fiber is being newly laid, starting with XGS-PON makes the most sense. Given that laying fiber (installing cables, ducts, etc.) takes the lion's share of costs and needs to be done anyways, the cost delta between GPON and XGS-PON deployment is very low.

Upgrade strategy in brownfield deployments: For those with existing fiber networks, there are new techniques available that enable a seamless evolution. The multi-PON approach, also called a combo approach, has recently gained a lot of traction. It combines GPON, XGS-PON, and a co-existence element on the same PON port in the access node. So not only can you easily upgrade your network but also enjoy a smaller cabling, equipment, and migration effort. In other words, your GPON network is actually 10G ready from day 1, and when needed, XGS-PON can be activated remotely.

XGS-PON gets even better with 25G

To maximize the benefits of XGS-PON, some vendors now enable three generations of PON technologies (GPON, XGS-PON & 25G PON) to be implemented on a single piece of hardware. This means that all operators who deploy such optical line terminals (OLTs) today automatically have 25-Gbps capabilities in their network. In addition, such OLTs support the capabilities needed in future fiber networks–low latency for 5G transport and 50% less power consumption than previous generations.

The significant advantages of such multi PON OLTs have been established by the fact that they have been adopted by nine out of ten top

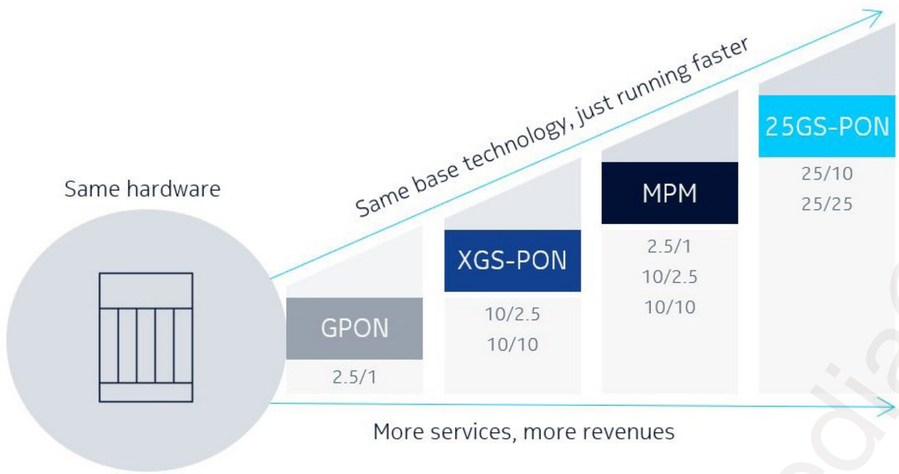


Figure 2. 25G PON is the simplest way to future-proof fiber networks.

CSPs in the U.S. Meanwhile, many Tier 2/3 CSPs and utilities, including Frontier, Hotwire, TDS, EPB, and Shentel, have also signed up for it.

Future infrastructure now

There is no stopping with fiber. Higher-speed 25-Gbps PON is available today and was proven in a live network. Standardization work on a 50 Gbps network is also underway, and earlier this year the industry saw the first to demo 100-Gbps speeds on a PON. While 50G and 100G PON are still a long way from commercially availability, 25G PON is here now. But with XGS-PON largely capable to handle current demand, is there really any need for a next next-generation PON?

The short answer is yes, because the possibility of easily increasing capacity creates new opportunities for broadband providers. CSPs see the need for >10 Gbps for enterprises, for dense 5G transport, and for more efficient delivery of multi-gigabit speeds in dense areas.

And 25G PON is the simplest way to supercharge your XGS-PON. It is available on the same hardware deployed today for XGS-PON and can co-exist with GPON and XGS-PON. It's not a new upgrade cycle, or a disruptive technology, but an incredibly simple way to future-proof your XGS-PON deployment.

Ana Pesovic *is marketing director, Fixed Networks, at* *Nokia*. *She has more than 20 years of experience in fiber access technologies.*

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