ON TOPIC

Addressing Network Test Challenges

Networks have become more complex than ever – which means the challenges have become greater. The articles in this On Topic examine network testing and management from a variety of angles, including next-generation PON testing.

ADDRESSING NETWORK TEST CHALLENGES

BTR BROADBAND TECHNOLOGY REPORT

THE PERILS OF USING A BROADBAND POWER METER IN A MULTI-SERVICE PON WORLD

By deploying selective PON power meters and testers for activation and repair of multi-service PONs, providers will improve the efficiency of service activation and repair groups and reduce costs.

BY SCOTT PETTYGROVE, NIKI KIRSCHENMANN

For single-technology, single-wavelength PON deployments, the simple broadband power meter has been an excellent and sufficient tool for PON activation and troubleshooting. However, the existing PON fiber infrastructure can carry light power across many wavelengths simultaneously and—for all practical purposes—without interference. Based on this concept, new, next-generation PON technologies are being deployed on the same fiber plant as current-generation technologies but using independent wavelengths. Powerful new PON capabilities can thus be quickly rolled out to customers over the existing infrastructure by simply changing the equipment at the ends of the fiber.

However, the presence of multiple wavelengths on the same fiber or within the same PON infrastructure presents significant problems for those engaged with PON activation and troubleshooting and who are equipped with only broadband (unfiltered) optical power meters. There are two primary use cases where these problems will surface:

1. In coexistent PON service structures where two PON services at different wavelengths are carried on the same fiber simultaneously, use of a broadband power meter will result in erroneous and misleading power measurement as explained in more detail below.
2. In parallel PON service structures where two services at different wavelengths exist in the same footprint, the network will be constructed such that a given fiber will carry either one service (wavelength) or the other but not both. In this use case, it is very easy to accidentally connect a customer to the wrong service through patching or provisioning errors. Use of a broadband power meter in this scenario runs the risk that power measured in the PON may seem good, but in reality, the wrong wavelength is being delivered. Unnecessary customer-premises equipment (CPE) swapping, long troubleshooting sessions, and needless escalations can result if you can't immediately identify the simple fact that the wrong wavelength is present at the customer premise.

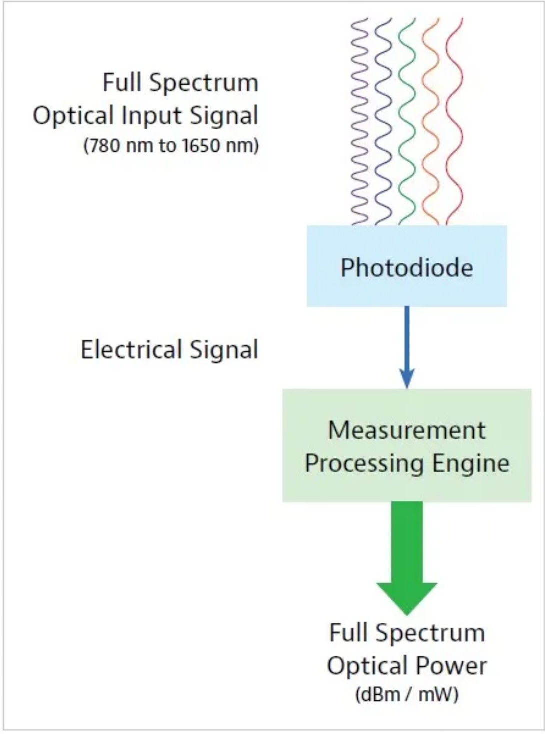

Figure 1. Broadband optical power meter schematic.

INSIDE AN OPTICAL POWER METER

Optical power meters employ photodiodes that detect the number of photons striking the photodiode surface per unit time and convert that photonic rate into a measured light power. The photodiodes in most broadband power meters can detect light energy across a broad spectrum of wavelengths, normally between 780 nm and 1650 nm. Power meters constructed in this way will measure photonic energy from any and all wavelengths of light within the photodiode's wavelength range and will produce a single power measurement proportional to the sum of all photons from all wavelengths per unit time (see Figure 1).

As a specific example, if a broadband power meter is used to measure a PON with coexistent GPON (1490 nm) and XGS-PON (1577 nm) services, the output of the broadband power meter will be the sum of the powers of both the GPON and XGS-PON wavelengths. The user will have no idea what the actual power and margin are for either of the two PON services on the link. Also important is the fact that even in networks that are intended to have a single service on the fiber at a time, a broadband power meter cannot tell you which service (wavelength) it is currently measuring. Errored provisioning and connection/patching will go undetected until the CPE fails to activate service.

For these reasons, PON power meters designed for use in multi-service environments include optical filters in front of their internal photodiodes to ensure that only the power for a specific wavelength of interest is measured. In the case of PON power meters that are designed for GPON and XGS-PON (both coexistent and parallel networks), two filtered photodiodes are

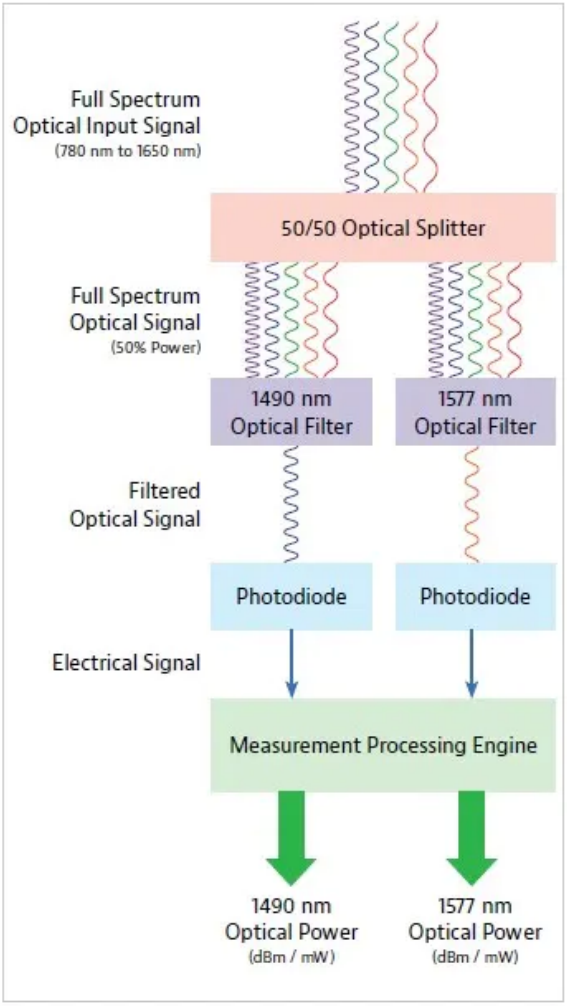

Figure 2. Selective optical power meter schematic.

normally used. More specifically, the light from the measured fiber is split inside the power meter to two independent photodiodes, passing through two selective filters in front of those photodiodes. One filter is for GPON wavelength of 1490 nm and the second filter is for XGS-PON, at 1577 nm (see Figure 2).

PON power meters constructed as such can instantly and simultaneously measure the optical power for the filtered wavelengths accurately and independently, preventing the misleading measurements delivered by broadband power meters in a coexistent environment and identifying the specific wavelengths associated with those power measurements for both coexistent and parallel PONs.

CONSEQUENCES OF APPLYING THE WRONG TOOL IN A MULTI-SERVICE PON

As discussed above, when using a broadband power meter in a coexistent GPON/XGS-PON network, the measured power will appear artificially high when both GPON and XGS-PON signals are present on the fiber at the same time. This can have two types of impacts during service activation:

1. Power measurement could look good, but the actual power of the individual GPON and XGS-PON signals are too low to operate equipment, causing a false pass and driving:
    - unnecessary CPE swap-outs
    - troubleshooting complications, increasing the amount of time required to complete the installation
    - needless escalations.
2. Power measurement could measure too high, causing a false failure and driving:
    - unnecessary call-backs to the central office for incorrect requests for provisioning checks or changes
    - extensive time spent troubleshooting a problem that does not exist
    - unnecessary escalations and truck-rolls.

In parallel GPON/XGS-PON where network design intentionally routes either GPON or XGS-PON to the premises (but not both), using a broadband power meter could result in measuring good power at the end of the drop fiber without realizing that the wavelength associated with the power measurement is wrong. Something as simple as connecting to the wrong type of splitter in the splitter cabinet or connecting the drop fiber to the wrong drop terminal port can easily create such a scenario.

More recently, mis-provisioned optical line terminal (OLT) ports are an increasing cause for the wrong wavelength appearing at the end of a customer's drop. As PON OLT equipment has matured, there has been a natural migration from dedicated, single service OLT ports to dual-function OLT ports (configurable as one service type or another), to multi-service OLT ports (providing simultaneous PON services and internal coexistence functions within the same OLT port). Both provisioning and connection/patching errors will once again drive:

- Unnecessary CPE swap-outs
- Troubleshooting complications, increasing the amount of time required to complete the installation
- Unnecessary escalations and truck-rolls.

AVOIDING CROSS-CONNECTION ISSUES

When a new customer signs up with a service provider they trigger several activities. The first steps include scheduling an installation date along with ordering the optical network terminal (ONT) and any other CPE. However, simply connecting any ONT to a live PON network does not ensure activation of services. If that were the case anyone could purchase an ONT and connect it to get service for free. The other step that happens is telling an OLT that it will be responsible for and approved to deliver services to a specific ONT device. This is referred to as provisioning the service, meaning that a specific OLT port is assigned to provide support (data) to a specific ONT serial number.

If you connect the ONT to the correct drop terminal port, which routes back to the OLT port where the service has been provisioned, then the service will turn up as it should. However, if you connect to the wrong drop terminal port and therefore an OLT port where the service has not been provisioned, the ONT may boot up but the service itself will not activate. This is because the OLT is expecting the ONT to appear or communicate on a different port, so it won't deliver service to that ONT. Wrong light, i.e., a downstream wavelength from an OLT port where the service was not provisioned, is a fairly common problem with FTTx deployments.

The drop terminal enclosure typically includes labeling to show which port is which, but in the real world it's all too easy for labels to be illegible, missing, or wrong, often because the distribution fiber routing has been altered by a previous tech. To ensure the right fiber cable is connected to the right OLT port and to enable easy handling of installation error tickets, the technician needs a device that identifies the type of OLT and the OLT-ID at any network location. This device must be able to evaluate the PON-ID, a unique identifier that is standardized by ITU-T and is a frame in PLOAMd carrying PON-specific information (such as OLT-ID, ODN class), and the transmitted optical level from the OLT. If you can extract and read it, you can compare the provisioning information and state for certain that the OLT port a customer is connected to is the right one or not.

ADDRESSING THE CHALLENGE

A range of selective PON power meters and multi-service testers have reached the market that can meet the needs of any field workgroup that is migrating to next generation, multi-service PONs. From pocket-sized selective power meters to instruments that address downstream and upstream multi-service PON power measurements and others that add GPON-ID and PON activation analysis, these tools enable field technicians to quickly and accurately:

- Confirm that there is sufficient power to operate a resilient PON service
- Confirm that the measured power is on the correct wavelength for the desired service
- Segment problems down to a specific portion of the fiber plant, avoiding unnecessary CPE or drop fiber replacements and increasing the accuracy of escalation calls.

CONCLUSION

Next-generation PONs deliver many business-critical advantages to providers compared to current PON technologies, including higher service-rate offerings, improved service rate symmetry, increased split ratios, and the convergence of multiple applications into a single optical distribution network (ODN). As many providers transition from BPON, GPON, or EPON to next-generation technologies like XGS-PON or NG-PON2, a new test paradigm is required, as the potential for negative business impacts associated with continued use of broadband power meters in a multiservice PON environment is a real and immediate concern. However, by deploying selective PON power meters and testers for activation and repair of multi-service PONs, providers will improve the efficiency of service activation and repair groups and avoid the increased costs associated with longer installation and troubleshooting times and unnecessary escalations and truck rolls. ●

Scott Pettygrove and Niki Kirschenmann are in global product line management at VIAVI Solutions.

HOW CABLE OPERATORS KEEP UP WITH EXPLODING UPSTREAM DEMAND

Cable operators are not totally reinventing the wheel to stay ahead. The three primary options for increasing upstream capacity that cable operators have relied on for decades remain in play. But how they go about leveraging these options is changing.

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.

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).

	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

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 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.

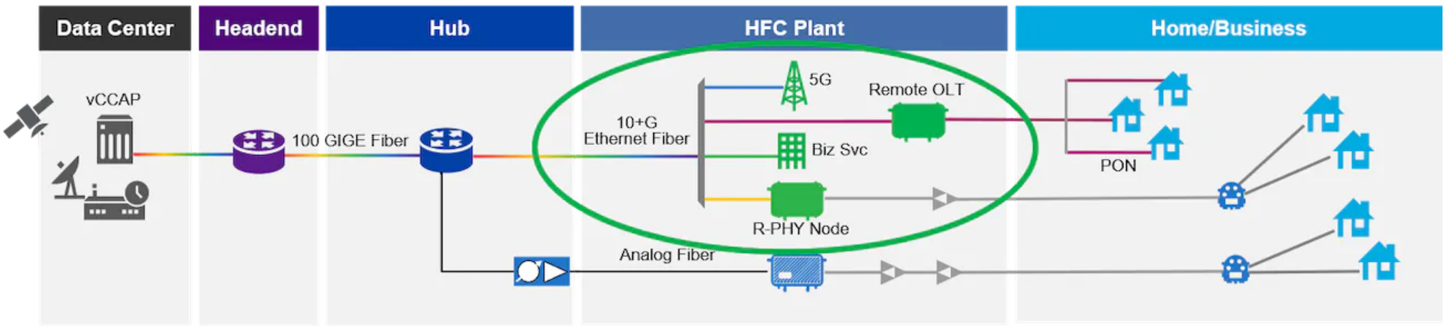

Figure 1. Converged Interconnect Network (CIN).

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).

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

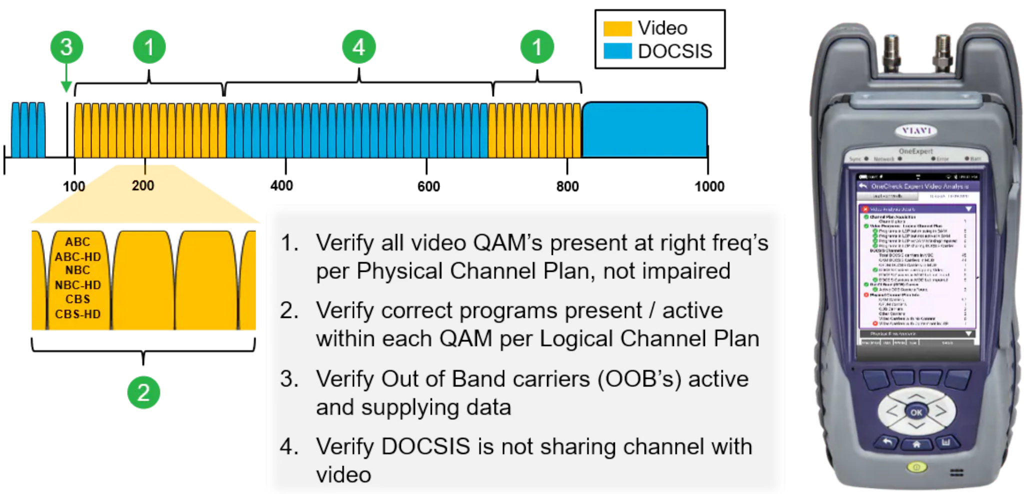

Figure 2. Linear video testing in DAA networks.

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.

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, 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.

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

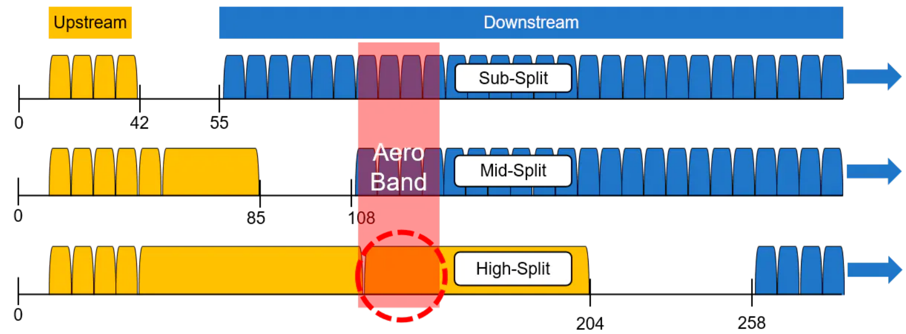

Figure 3. Signal leakage with high split.

to restore FM ingress visibility in the upstream for troubleshooting.

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.

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

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

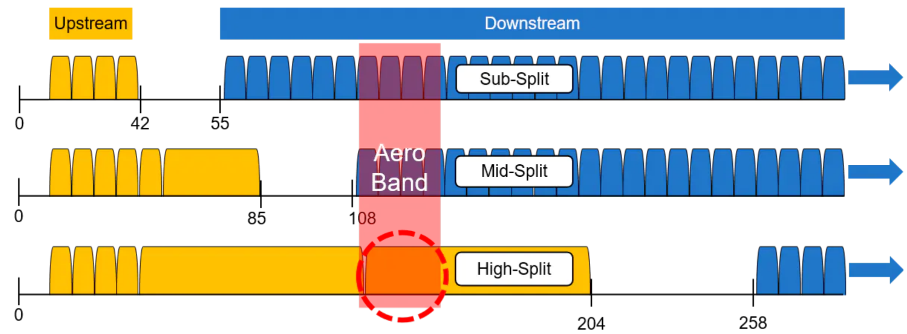

Figure 4. FM ingress with high split.

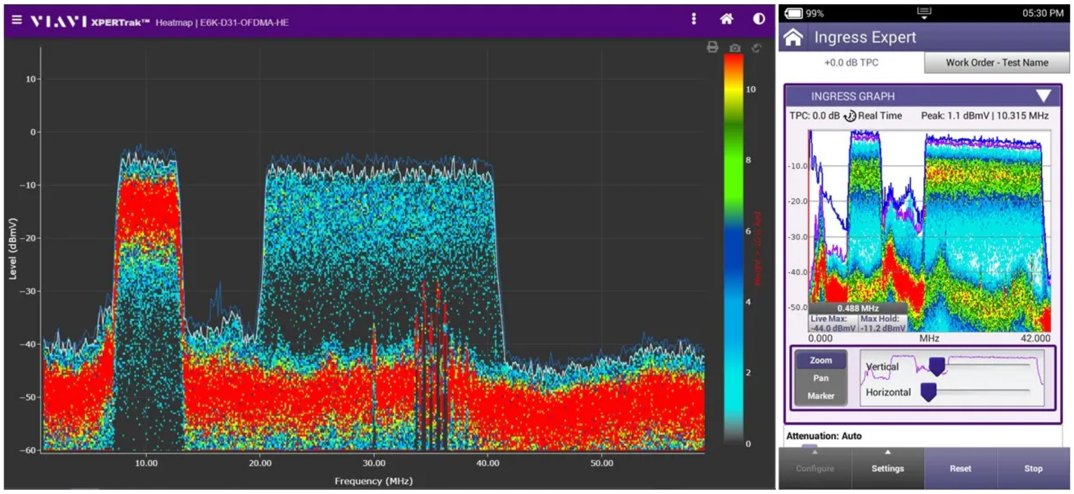

Figure 5. Heatmap spectrum analysis.

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 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.

USING PREDICTIVE ANALYTICS IN MONITORING NETWORK PERFORMANCE

Predictive analytics has been used in multiple applications. In this article, we will discuss how predictive analytics can be used in monitoring network performance.

BY TOM AYLING

In modern times, the network is becoming an integral part of operations for business subscribers. The majority of organizations operating worldwide rely on the network to process business transactions, interact with clients, access enterprise applications, etc. Any disruption in the network can cause business operations to stop and induce a huge loss to the organization.

In most cases, a dedicated team is responsible for fixing network issues and ensuring that the network is functional and performing optimally. They operate in conjunction with the network operations center, which notifies support teams when they receive a ticket or an alarm from a network monitoring tool. From there, the team starts troubleshooting the network to find the root cause of the issue.

This approach, however, is reactive as it waits for issues to occur before taking action instead of preventing problems in the first place. With **predictive analytics**, network engineers will have the ability to detect potential network disruption and performance issues before they affect operations.

IMPORTANCE OF PREDICTIVE ANALYTICS IN NETWORK PERFORMANCE

Predictive analytics is a subsection of data analytics that makes use of historical data to predict future events. It uses different algorithms and techniques to identify patterns and project trends that can be used to deduce what can happen next. The concept has been used in multiple applications such as in sales forecasting, risk assessments, and many more.

Predictive analytics is already being used in the network space as a tool to help identify potential network disruption. To further understand its importance, we have listed some benefits of using predictive analytics in monitoring network performance.

PREVENTS NETWORK DISRUPTION

A network disruption can have a huge impact on the operation of a customer's business. Such disruptions can be caused by an issue in the network like a faulty network device, a fiber cut, or an overloaded link or hardware. With network predictive analytics, these issues can be prevented or can be resolved faster.

For example, the network analytics shows that a link has been hovering around 90% utilization and packet drops are being seen due to this in the past 7 days. If there is a redundant link, the network engineer can proactively failover to the more stable link to avoid the link being overutilized should a spike in traffic occur in the future. If there is no redundant link, bandwidth on the primary link can be upgraded to cater to the increase in traffic.

FASTER RESOLUTION OF ISSUES

Network issues can be more complex than simply having a highly utilized link as described in the previous example. In such cases, the time it will take the network engineer to troubleshoot and fix the issue will be longer. This is common for issues where you start troubleshooting from scratch and gather data from the physical to the application layer. With predictive analytics, you can have a quick overview of the network performance in a specific time frame.

For example, a user has been experiencing network issues in the past 3 days. The engineer looked at the data before the issue happened and he noticed that there have been incrementing errors in the port where the customer's internet is connected. With this data, he was able to easily determine that it was a physical cabling issue, which saved time in troubleshooting instead of communicating with the customer back and forth. (More information on this strategy to rapidly and reliably diagnose with low mean time to repair is available in this whitepaper.).

NETWORK PERFORMANCE OPTIMIZATION

Apart from having a network connection, it is also important for a business customer to have fast and stable network performance. Imagine if a user needs to download a file from the internet which is 10GB in size and the network speed is only 5 Mbps and is shared by multiple users. It will take the user a long time to download this compared to the convenience of having a 50-Mbps (or greater) network speed.

Predictive analytics uses network trends to identify potential issues that may occur in the future. If the trend shows that the bandwidth has been over-utilized in the past few months consistently, the network engineer can proactively suggest a bandwidth upgrade.

Another good example would be a situation where data shows an incrementing latency trend in an internet circuit over the past few days.

> IN THIS CASE, THE ENGINEER CAN EITHER MANUALLY FAILOVER THE TRAFFIC TO ANOTHER CIRCUIT OR CONFIGURE A NETWORK DEVICE TO AUTOMATICALLY FAILOVER TRAFFIC TO ANOTHER LINK IF A SPECIFIC LATENCY THRESHOLD HAS BEEN REACHED.

PROTECTION FROM SECURITY THREATS

Cybersecurity is significant to any business, but especially national infrastructure. Protecting data assets and sensitive information from attackers is one of the highest priorities. Hackers are continuously targeting national infrastructure and looking for weak points in security. With predictive analytics, the network operator can analyze and identify any abnormal behavior which in turn can prevent the attacker from causing further damage.

In summary, predictive analytics will be one of the most helpful tools in the next decade and eventually one that every company deploys at scale. This tool will help telecoms decrease resolution times, improve network performance with increase protection against incoming threats. ●

Tom Ayling is CEO of Gisual, a software that automates the workflow of diagnosing and correlating off-network outages. Gisual proactively notifies telecoms of the outage source, root cause and restoration time. This reduces mean-time-to-repair, eliminates trucks rolls, and decreases cost-per-call.

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