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ON TOPIC
Distributed Access Architecture Update

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Vendors making moves in the DAA space

MONTA MONACO HERNON

Migration is as consistent and continual for cable operators as it is for the geese that pass through the northern skies.

The reality is that cable operators are faced with the evolution from current HFC and DOCSIS networks to 10G DOCSIS HFC networks that will become increasingly necessary as data demands change. As Doug Johnson, senior software architect, Vecima Networks, and Colin Howlett, VP of architecture, Vecima, eloquently wrote recently in *BTR*, Distributed Access Architecture (DAA) is a "key architecture for enabling the 10G vision, and flexible access technology a key mechanism to achieve that vision." And a Remote-PHY (R-PHY)-based DAA offers the ability to use Ethernet-based digital fiber and PHY processing at the edge, which will reduce hub space and power requirements, improve RF capacity, and improve fiber utilization.

Along this vein, Vecima recently upgraded its Entra DAA node portfolio by adding support for two RPDs in a single node. Specifically, the Entra Access Node for DAA is a single DOCSIS RPD node that is segmentable to support increasing capacity demands. The Entra EN8112 node has a single RPD supporting one downstream service group and two upstream service groups. Alternatively, operators can

start with two RPDs equipped as the EN8124 node, which supports two downstream and four upstream service groups. Full spectrum OFDM/OFDMA is supported in hardware for each downstream and upstream service group. Upgrade kits from single RPD to dual RPD support are available.

"Bringing a truly full capacity segmental DAA node solution to the market is a game changer," said Scott Raaf, VP of product management at Vecima. "The cable industry has been relying on segmentable nodes to alleviate capacity constraints for more than two decades. Operators need a segmentable solution today because I can't go replace a single legacy node, which was segmented several years ago, with two DAA nodes. Full capacity segmentation is required for the industry to truly operationalize DAA."

Vecima's other Entra products include the Remote PHY Monitor (RPM), Video QAM Manager (VQM), Interactive Video Controller (IVC), and Legacy QAM Adapter (LQA). They are all designed for interoperability with other vendors' equipment. The Entra node family has R-PHY operational support including integration with leakage detection and upstream spectrum capture systems, NDR/NDF, and support from the Vecima Entra Remote PHY Monitor monitoring and configuration platform.

At Cable-Tec Expo last fall, the VQM was awarded four Diamonds in *BTR*'s annual review. The product enables engineers to integrate video in a DAA with existing infrastructure such as edge QAMs or bulk video encryptors. Operating as a Converged Cable Access Platform (CCAP) auxiliary core, the VQM instructs RPDs on how to create broadcast and narrowcast QAM video services using one or more standards-compliant video engines. "As operators move toward DAA, the Entra Video QAM Manager should help streamline rollouts," a Diamonds judge said.

Also at Expo, CommScope highlighted its own advancements in this realm, including the DAA Aggregator, which enables DAA Remote PHY devices (RPDs) to feed previously fielded nodes while increasing the number of homes passed to between 150 to 300. The technology is housed in a standard RPD node, which means that operators can leverage existing infrastructure. This followed the announcement last summer that the company had expanded its DAA portfolio with the RD1322 2x2 RPD for both traditional segmented and fiber-deep architectures. The RD1322 fits into CommScope's portfolio of outside plant solutions that is intended to allow operators build on their installed base of nodes while supporting Extended Spectrum DOCSIS, Full Duplex DOCSIS, DAA, remote PON, wireless backhaul, and DOCSIS 3.1. The DAA Aggregator and the RD1322 are part of CommScope's DAA portfolio, which also includes Remote PON, R-PHY Shelf, Video Unified Edge (VUE), ICX Switch family, and hybrid E6000 I-CCAP/CCAP Core products, as well as virtualized products like the E6000 Virtual Core (vCore) and vManager framework of tools.

"As global operators continue to invest in tomorrow's 10G networks, the outside plant will represent a primary budget focus," said Kevin Keefe, SVP and segment leader, network & cloud, CommScope. "We have an unmatched portfolio and breadth of experience in helping global operators deliver next-generation networks reliably and at scale."

"CommScope has one of the largest footprints of optical nodes among cable operators worldwide," said Jeff Heynen, research director, broadband access and home networking, Dell'Oro Group. "As cable operators continue to distribute their access networks and increase both upstream and downstream bandwidth, the RD1322 2x2 RPD is an option, as operators choose from a variety of DAAs and pathways as they bridge to tomorrow's networks."

VIAVI has the DAA Test-Ready Certification Program, which it created in partnership with leading DAA vendors, in an effort to help serve providers maintain and troubleshoot the cable plant when deploying certified DAA solutions. The company says there are challenges inherent in R-PHY deployment that can cause hurdles for network testing and maintenance. The physical layer electronics from the headend or hub to the R-PHY node and removal of RF test points from hub sites disrupts current procedures that rely on hub-based monitoring gear such as signal leakage detection, return path monitoring and sweep. VIAVI's certification program identifies vendors who support or have implemented a roadmap for CableLabs-specific functions used by the VIAVI sweep/ingress solution. Gold partners include Casa Systems, Cisco, Harmonic, Nokia, Teleste and Vecima; Silver partners are CommScope and BKtel.

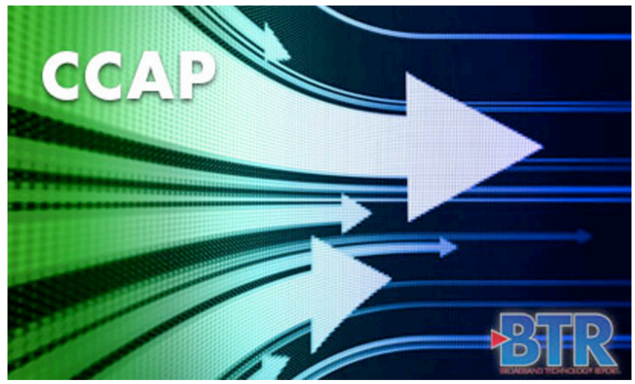
"Gold certification in the VIAVI DAA test-ready ecosystem will help operators deploy the Cisco Remote PHY solution with confidence, achieving increased throughput while assuring quality of service with existing test and maintenance processes and tools," said Tom Kennedy, director of product management, cable access business, Cisco."

Monta Monaco Hernon *is a Contributing Writer for [Broadband Technology Report](#).*

CCAP video and DAA migration

LINAS UNDERYS

Entering 2019, most cable operators are either planning out their adoption strategies or actively migrating to a distributed access architecture (DAA) that will allow them to push fiber deeper into their network and realize business-enhancing performance and operational benefits. But some of these infrastructure migration initiatives are facing setbacks due to lingering limitations around encryption licensing and interoperability associated with the installation of CCAP video cores.



CCAP video and DAA migration

Migrating video streams previously handled by edge QAM resources to a CCAP video core is in most cases a prerequisite to moving to a distributed architecture. But limitations around the encryption capabilities of CCAP video cores are threatening to delay the move to DAA, as well as the resulting benefits. Overcoming this roadblock, at least until some of these issues are ironed out, requires a QAM-to-IP video engine, also known as an RF R-PHY gateway, that allows operators to leverage already in-place edge QAM resources to pass encrypted video to IP-based CCAP video cores, which then feed the encrypted video streams to R-PHY Devices (RPDs) through the Converged Interconnect Network (CIN).

A QAM-to-IP pass-through solution also saves MSOs time and reduces complexity by allowing them to proceed with DAA migrations without having to integrate and reconfigure muxes and broadcast lineups in the CCAP video core. Instead, cable operators can continue to use existing back-office tools, systems and procedures. And by enabling MSOs to sidestep encryption issues associated with CCAP migrations, an RF R-PHY gateway provides cable operators with greater freedom in the selection of a CCAP supplier by eliminating the potential of compatibility issues between the CCAP and installed base of set-top boxes.

Not only does the RF R-PHY gateway provide MSOs with the opportunity to migrate to RPD-based nodes while they build out their CCAP video cores, it can also serve as a substitute for a full-blown CCAP video core for cable operators that are likely to transition their video services to IP in the near future. This is a particularly attractive option for MSOs with fewer QAM input-only legacy set-top boxes in the field and that are focusing their DAA transformations on data delivery components, like a CCAP-based CMTS that facilitates both data and IPTV video delivery via DOCSIS. In these instances, the RF R-PHY media gateway offers a cost-effective alternative to building out a CCAP core. The RF R-PHY video engine would function as a transitional CCAP video core, delivering RF QAM video services from existing edge QAMs directly to the CIN and RPDs (with DEPI encapsulation). In-service edge QAMs and the stand-in video core could then be decommissioned as soon as the MSO is in a position to cost effectively replace or eliminate all QAM-based set-tops in its network.

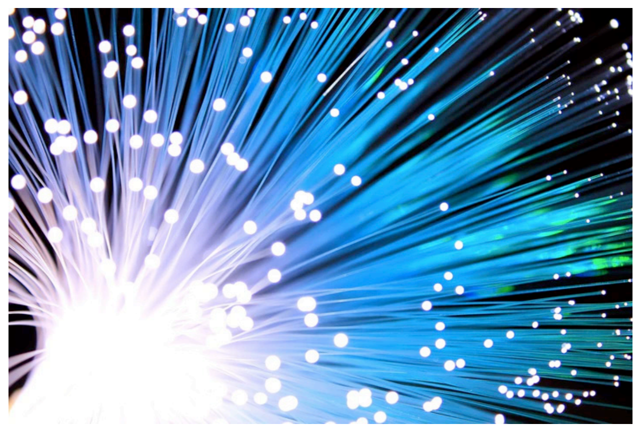
Moving to a distributed architecture for most MSOs means reaping significant cost, performance and complexity benefits associated with the replacement of RF and analog optic-based transport links with high-speed digital transport links and the pushing of the optical-to-RF conversion deeper into the network. Digital links between headends and RPDs will drive performance and capacity increases by accommodating more wavelengths over longer distances. Similarly, cable operators can deliver better performance with less complexity through the coaxial portion of their networks by reducing or eliminating the number of amplifiers at the far end of their infrastructures. But these and other benefits associated with a migration to DAA remain outside the grasp of MSOs that are currently beset by CCAP video core encryption issues.

By solving those issues, a RF R-PHY video engine offers the innovation that will enable MSOs to start enjoying the benefits of a distributed architecture today.

Linas Underys is VP of Media Gateway Products at ATX Networks.

Fiber Deep and Node+0 Architectures: Understanding Cabling and Component Changes

DAVE KOZISCHEK



To stay ahead of demand for high-bandwidth capabilities and to deliver on the promise of emerging services and applications, multiple system operators (MSOs) are evolving their hybrid fiber/coax (HFC) networks. Architectures like Remote PHY and DOCSIS 3.1 depend on fiber-based bandwidth deep into the CATV network. That's why many operators are pursuing "fiber deep" initiatives to create Node+0 architectures.

So how can operators bring fiber closer to their subscribers while optimizing the installed optical base? In many instances, a multiwavelength architecture like coarse wavelength division multiplexing (CWDM) and dense wavelength division multiplexing (DWDM) can deliver the best value – along with changes and challenges to the cabling infrastructure. This article, which provides background information on multiwavelength technology and why the move to fiber deep is taking place now, is the first in a series that describes several aspects of the extension of fiber deeper into cable networks. Other articles in the series cover WDM component technology and specification parameters, multiwavelength transmission choices and the impairment factors that should be considered, and network architecture and cabling strategies.

Background on today's fiber deep migration

CATV operators have been deploying fiber since the early to mid-1990s. HFC networks were traditionally designed using one or two wavelengths (1310 and 1550 nm), with fiber delivered (or "fed") to a node and coax then used to "distribute" the RF signal to the customer.

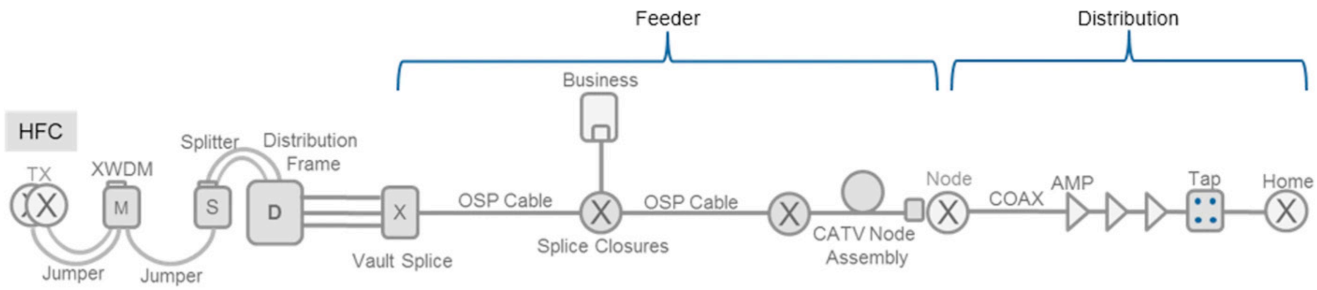


Figure 1. HFC network.

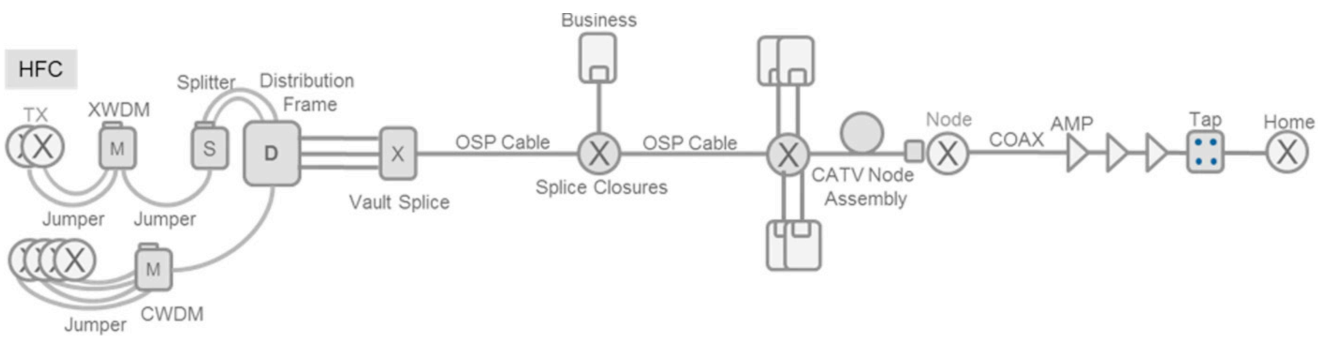


Figure 2. HFC network with CWDM.

See these "feeder" and "distribution" sections in Figure 1.

In this network configuration, the feeder fibers are used to service the nodes and businesses are given a dedicated fiber – a winning approach until operators began running out of fibers. To counter this fiber depletion, operators began deploying CWDM to deliver wavelength services to businesses. This network was overlayed on the existing infrastructure and is shown in Figure 2.

Today, operators are driving fiber deep for Node+0 architectures. Again, fibers in the feeder portion of the network have been depleted but operators this time have turned to DWDM to deliver fiber deeper or closer to the customer. The DWDM wavelengths are delivered to a "parent" node, then distributed deeper into the network to a "child" node. In many cases this network is overlayed on top of existing infrastructure, driven by the desire to reuse as much feeder fiber as possible and to add new cable to the child nodes (see Figure 3).

Moving from diplexors/triplexors (1-2 wavelengths) and CWDM (16-18 wavelengths) to DWDM (40+ wavelengths) will bring network cabling and components changes. To get a better understanding of what these changes may bring to the network, let's dive into the CWDM and DWDM standards.

CWDM and DWDM standards and definitions

The International Telecommunications Union (ITU) is the standards body that provides guidance for CWDM and DWDM. One of its three divisions, the ITU Telecommunication Standardization Sector (ITU-T), coordinates

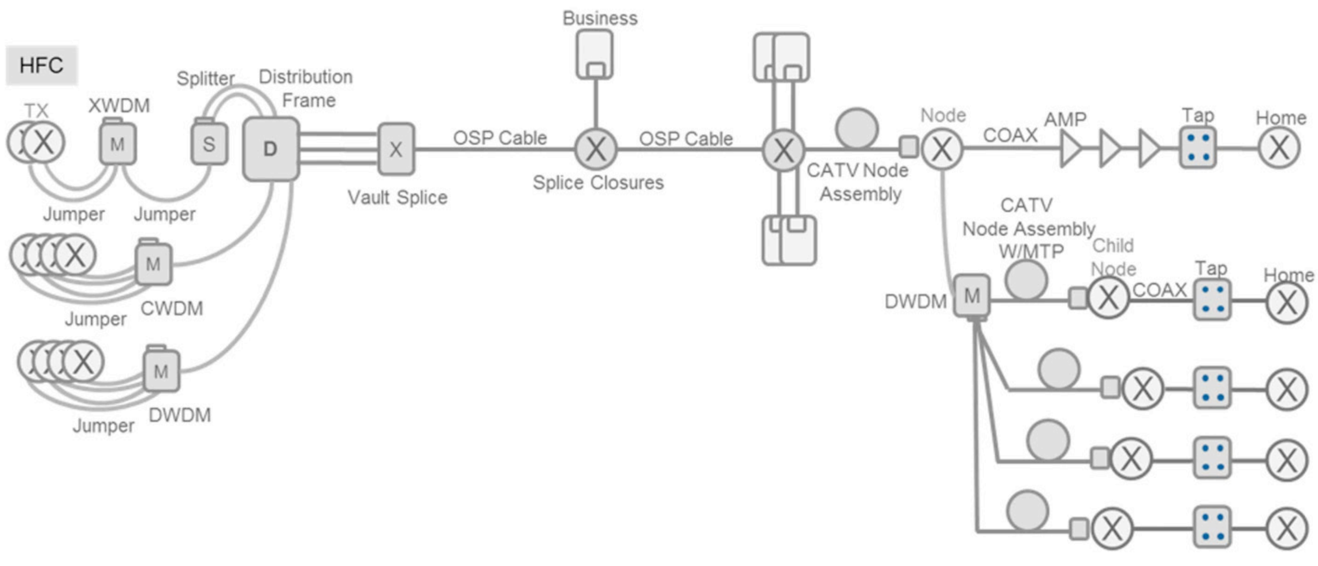


Figure 3. HFC with DWDM fiber deep.

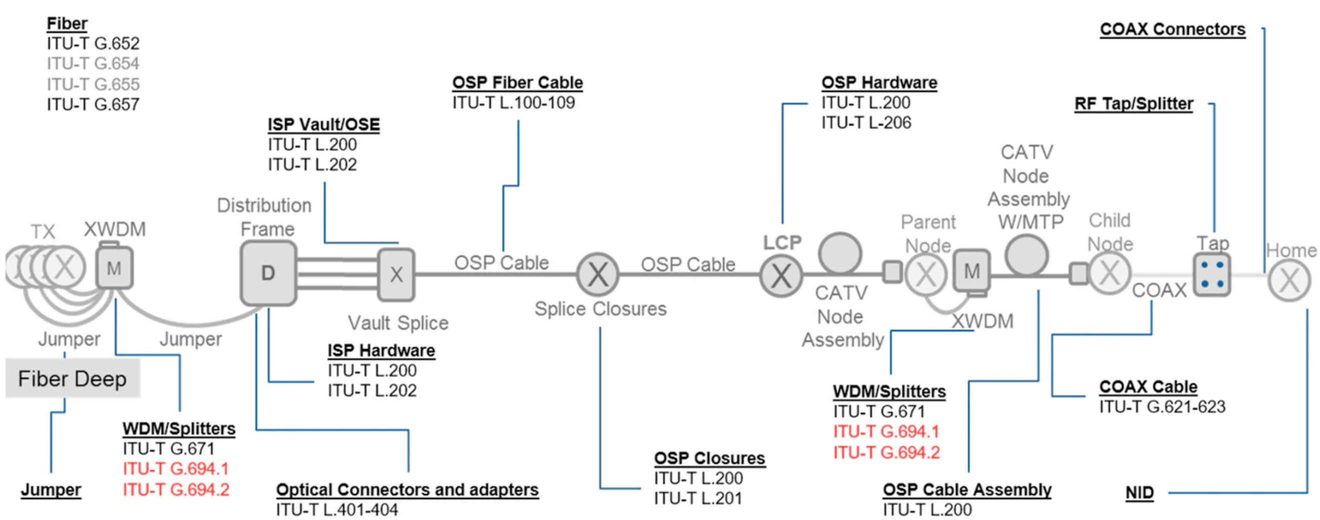


Figure 4. ITU-T standards.

standards for telecommunications. See Figure 4 for a look across some of the standards the ITU-T covers for an HFC network.

The first areas that the ITU-T defines are the operational bands where CWDM and DWDM are deployed. The bands are defined as O-band (original), E-band (extended), S-band (short), C-band (conventional) and L-band (long).

Single-mode fiber transmission began in the O-band and was developed to take advantage of the transmission performance of the glass fiber at 1310 nm.

To take advantage of the lower loss at 1550 nm, fiber was developed for the C-band. As links became longer and fiber amplifiers began being used instead of optical-to-electronic-to-optical repeaters, the C-band became more important.

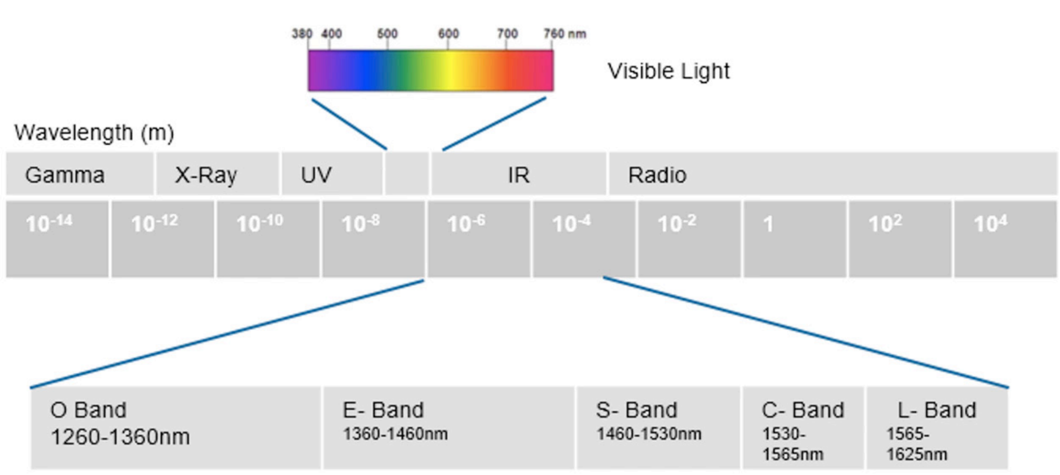


Figure 5. ITU-T wavelength operational bands.

With the adoption of DWDM systems, use of this band was expanded. Development of new fiber amplifiers continued to expand DWDM upward to the L-band.

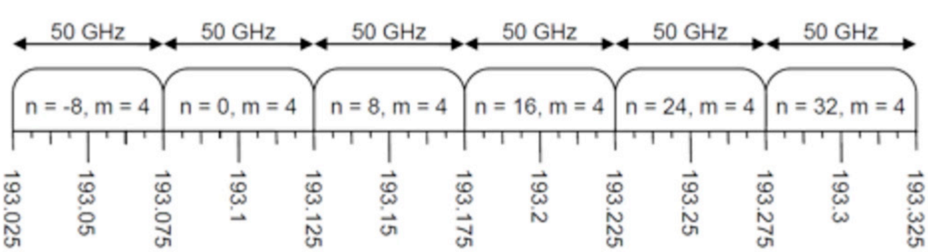
Figure 5 illustrates these bands. The complete electromagnetic (EM) spectrum is used as a reference.

ITU-T G.694.1 and G.694.2 are the standards that cover DWDM and CWDM. ITU-T G.694.1 (DWDM) provides information including:

- Definitions of frequency grid: slot and width
- Center frequencies, including the nominal central frequencies within the C-band and L-band

Nominal central frequencies (THz) for spacings of:				Approximate nominal central wavelengths (nm) (Note)
12.5 GHz	25 GHz	50 GHz	100 GHz and above	
•	•	•	•	•
•	•	•	•	•
•	•	•	•	•
195.9375	–	–	–	1530.0413
195.9250	195.925	–	–	1530.1389
195.9125	–	–	–	1530.2365
195.9000	195.900	195.90	195.9	1530.3341

Example: Center Frequencies



Example: Flexible Grid

Figure 6. ITU-T G.694.1 center frequencies and flexible grid examples.

- Frequency grid, including recommended support for a variety of fixed channel spacings ranging from 12.5 to 100 GHz.

Figure 6 shows an example of a frequency grid.

ITU-T G.694.2 (CWDM) defines key information on:

- Definitions on wavelength grid: spacing and width
- Nominal central wavelengths; the grid wavelengths are within the range 1271 to 1611 nm
- Central wavelength spacing and wavelength variation. Effective CWDM with uncooled lasers and wide passband filters require a nominal central wavelength spacing of not less than 20 nm.

Figure 7 shows an example of a wavelength grid.

Applying ITU-T G.694.1 and G.694.2 grids across the bands is shown in Figure 8.

The CWDM channel lineup runs across all bands (O-L), while DWDM remains in the C-band. MSOs have used multiple bands and still use

Nominal central wavelengths (nm) for spacing of 20 nm
1271
1291
1311
1331
1351
1371
1391
1411
1431
1451
1471
1491
1511
1531
1551
1571
1591
1611
NOTE – The endpoints of this table are illustrative only.

Example: CWDM Grid

Figure 7. CWDM wavelength grid

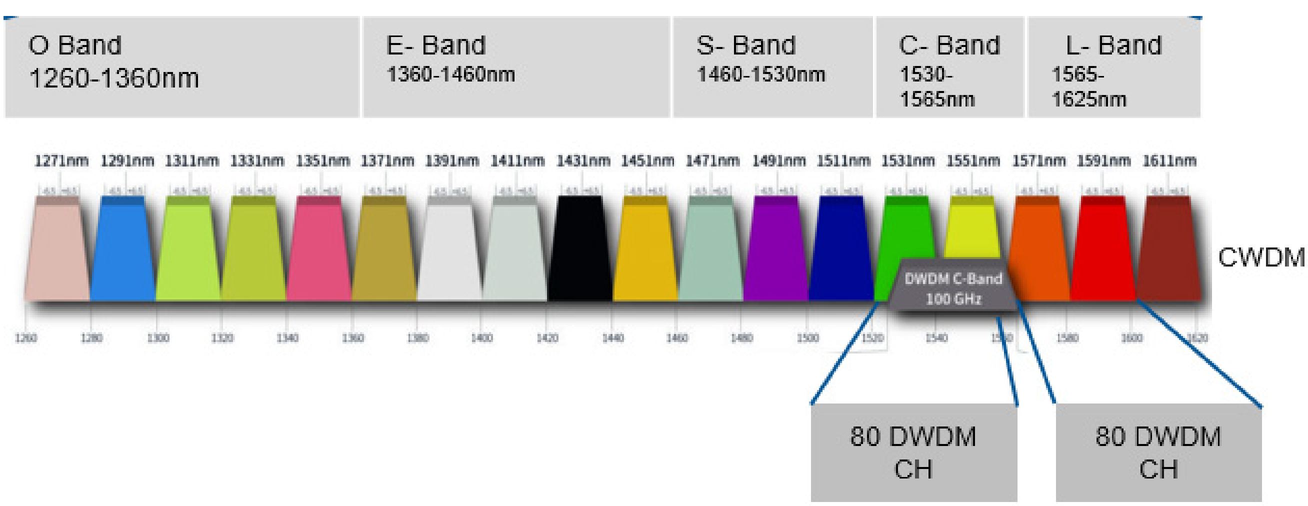


Figure 8. DWDM and CWDM spectrum allocation.

1310, 1550 and 1490 nm for HFC networks today. Fiber deep architectures like Node+0 will use the more of the C-band to deliver 40 or more wavelengths.

The advantages and challenges of using more DWDM include:

Advantages

- Maximum capacity systems available; up to 160 channels across the C+L bands
- Maximum distance with optical amplifiers; extended distances can ease headend consolidation
- Amplification vs. regeneration; no optical-to-electrical-to-optical signal processing

Challenges

- Optical amplified systems can bring nonliner transmission effects
- Requires higher-performance lasers and optical components
- Needs more power per wavelength.

With this background information in hand, you're now ready to consider WDM component technology and specification parameters, multiwavelength transmission choices and impairment factors, and network architecture and cabling strategies.

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VIAVI is a global provider of network test, monitoring and assurance solutions to communications service providers, enterprises, network equipment manufacturers, government and avionics. VIAVI delivers end-to-end visibility across physical, virtual and hybrid networks, enabling customers to optimize connectivity, quality of experience and profitability.

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White Paper

Test Guide to DAA Planning, Deployment, & Maintenance

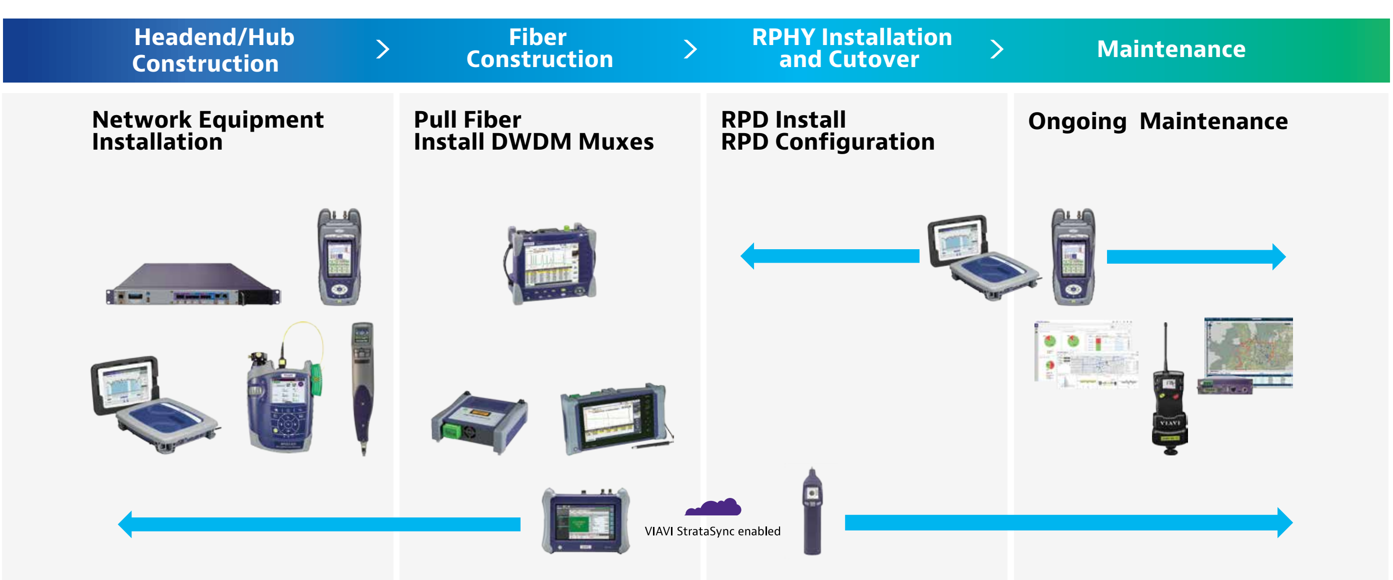
Simplifying DAA deployment complexities with easy-to-use fiber, Ethernet and RF solutions

Introduction

The race is on for service providers to deliver Gigabit speeds with unprecedented service reliability. Cable operators are well-positioned today to compete with freshly-upgraded DOCSIS 3.1 networks, but as subscribers insatiable thirst for increased bandwidth continues to grow it is clear that significant architectural changes will be needed to keep up. Distributed access architectures (DAA) like Remote PHY hold the promise of cost-effectively enabling the smaller service group sizes needed meet future demands while holding the line on hub space/power requirements. DAA deployment will not come without significant technical, organizational, and logistical challenges as early adopters have learned. This app note focuses on the network test, monitoring, and maintenance aspects of DAA deployments and was collected from discussions and partnerships with leading cable operators from around the globe.

Framework for Efficiently Operationalizing DAA

The diagram below provides a general framework to guide thoughts around planning for, deploying, and maintaining DAA nodes in your network. It should be looked at more as a menu than a recipe – not all items will apply in all cases but regardless it is a good starting point for planning your specific rollout. This framework was created and refined through close interaction with early-adopter MSO's of all sizes from around the globe and leading DAA network equipment vendors. While there is inevitably some variation from provider to provider, many of the general themes were quite similar across the board.



Note that the DAA deployment lifecycle above is broken into four distinct phases:

- Headend/Hub Construction – In this initial phase the service provision equipment and portions of the transport network are prepared to support primarily the inside plant segment of the DAA network.
- Fiber Construction – This phase generally occurs either after or in parallel with Headend/Hub construction. The focus here is characterizing existing fiber and deploying/testing/characterizing new fiber, muxes, and other optical components as needed to support the new network architecture.
- DAA Node Installation and Cutover – This phase is where the actual DAA node is physically installed, configured, tested, and services cutover.
- Maintenance – This includes activities that are needed to monitor, maintain, and troubleshoot DAA nodes after cutover. Note that this list may also include most of the tests included in previous sections as different types of problems emerge in normal network operation.

Headend and Hub Construction

This phase is all about ensuring that service provision equipment and supporting network infrastructure are prepared to support DAA nodes once deployed.

Ethernet & Transport
Validate proper network config - no packet loss/latency issues for traffic through headend & hub

MPO & AOC
Inspect connectors and ensure optical cabling is not degrading services

GPS Antenna
Required for proper timing functionality

Network Equipment Installation
· Know that headend/hub are ready to support DAA

Characterize RF
Ensure proper PHY layer performance

DOCSIS Service
Verify DOCSIS service performance

Video
Validate combining is correct, no dropped channels

Voice
Ensure voice services properly integrated

Shelf RPD Verification
· Pre-check headend setup before RPD's fielded

This phase can be divided into two primary sections:

- Network Equipment Installation
- Shelf RPD Verification

Network Equipment Installation can include physical installation and configuration of new CMTS/CCAP chassis. Some operators will take this opportunity to consolidate CCAP's and migrate them upstream into headends, with the ultimate longer-term goal of virtualizing them within data centers. This is also the point where leaf/spine architectures are sometimes introduced enhancing network efficiency and resiliency but also introducing new complexities. Besides testing the CCAP's themselves for proper functionality, the network interconnecting them must be tested to ensure no packet loss or latency issues.

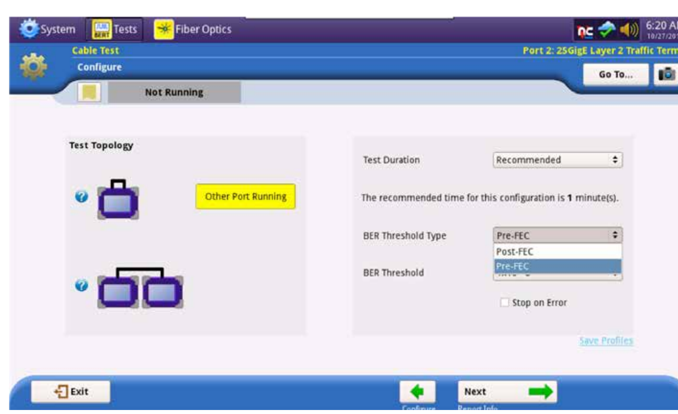
- Basic Layer 3 Testing:
  - Connectivity
    - Ensure DHCP functionality, devices able to get IP addresses
    - Successful Ping
  - Quality
    - No frame loss at maximum throughput (typically 10G) – adequate to support DOCSIS/Video services at node
    - Characterize latency at turn-up state
      - Compare later to help detect congestion, PTP, other issues

As these changes occur and network functions virtualize and migrate upstream, headends start looking more like datacenters. This trend drove the adaptation of the telco CORD acronym (Central Office Rearchitected as a Datacenter) into HERD (Headend Rearchitected as a Datacenter) for cable. Two common datacenter technologies that have begun migrating into Cable are MPO (Multiple Push-On) connectors and AOC (Active Optical Cables). Direct-attach copper cables (DAC) are the copper equivalent in that they have an active component to them.

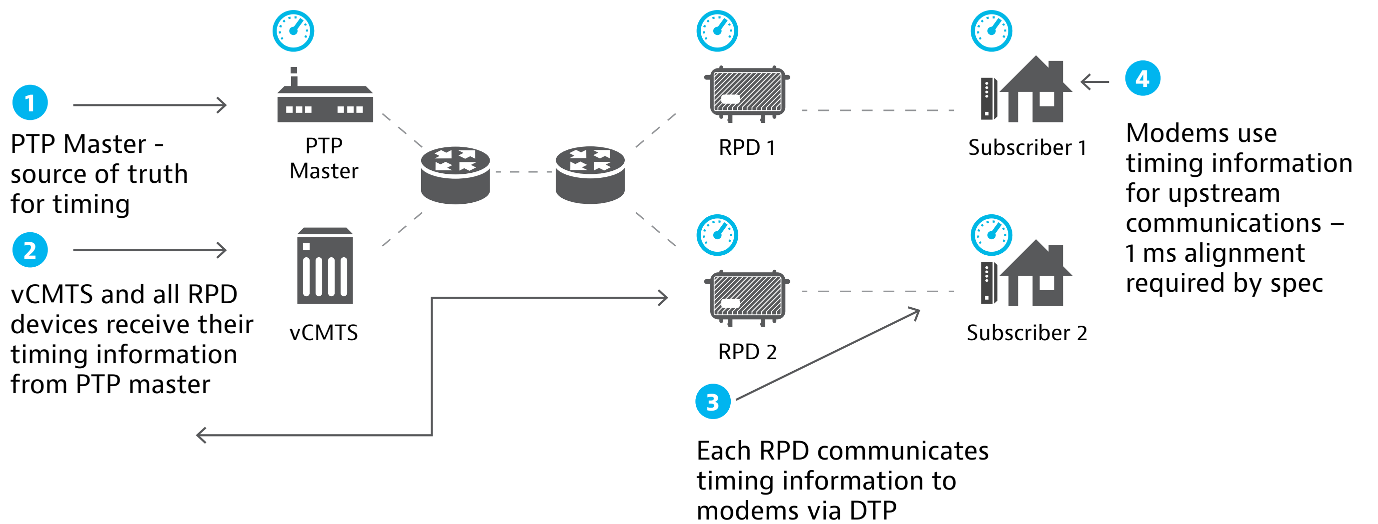
Both allow operators to increase density primarily in headends but also improve efficiency. On the flip side both new-to-cable technologies also introduce testing challenges. MPO connectors are cumbersome to inspect without the right tools, and a single contaminant can take out multiple fibers due to their proximity within the connectors. With AOC's, cables now become active components and must be tested for performance/bit errors in addition to basic connectivity.

MPO inspection is critical to ensure cleanliness of bulkhead and the patch cord connectors, which can impact ORL/IL on all fiber paths. It is also important to test polarity of all links, adaptors, and patch cords to ensure no crossover issues. Application testing is also critical. MPO inspection is performed most efficiently using the FiberCheck Sidewinder, while polarity and application testing are best performed with the MPO-LX test set.

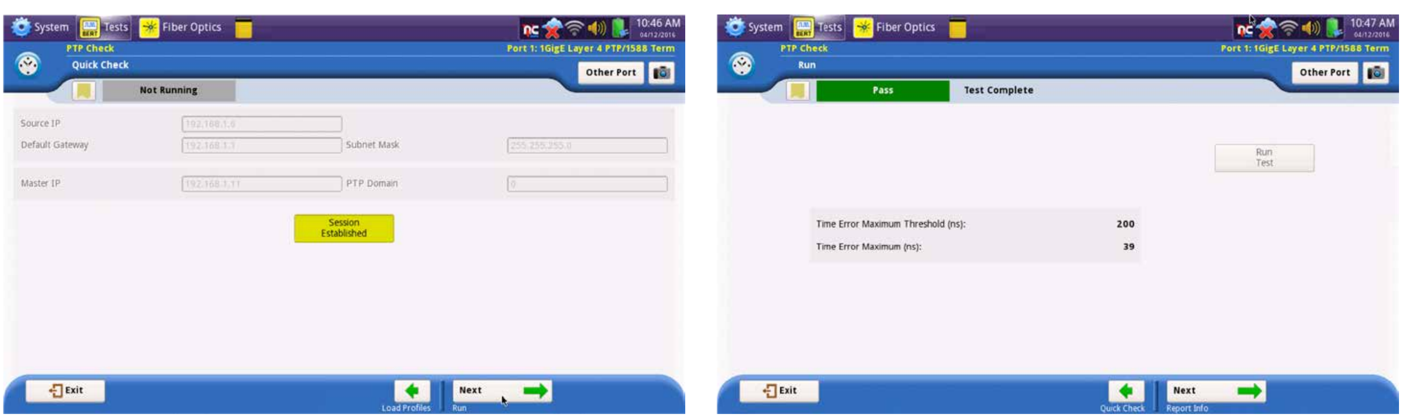
AOC/DAC testing is very similar to testing any other Ethernet link. Typical tests looking for BER and packet loss can be performed using a TB-5800 for AOC/DAC cables. They should not create BER above the 10-9 level. Single cables can be tested in a single pass, and breakout cables can be cycled through to cover all legs.



Network timing is critical to maintaining synchronization between RPD's and CMTS, especially for Remote PHY nodes which split the MAC and PHY layers sometimes at distance of 10's of km. PTP (Precision Timing Protocol) is the most common method used to maintain network sync for R-PHY nodes, but it can also be used for video/audio sync in R-MACPHY nodes. Complete loss of PTP services are catastrophic especially for Remote PHY nodes as they will cease to operate but as a result are relatively easy to detect with the correct test gear. Less obvious are subtle shifts in PTP timing, networks may still function but will begin to experience BER. Without proper training and test capabilities these situations are impossible to diagnose for maintenance technicians and will likely result on excessive time chasing false symptoms and customer frustration.

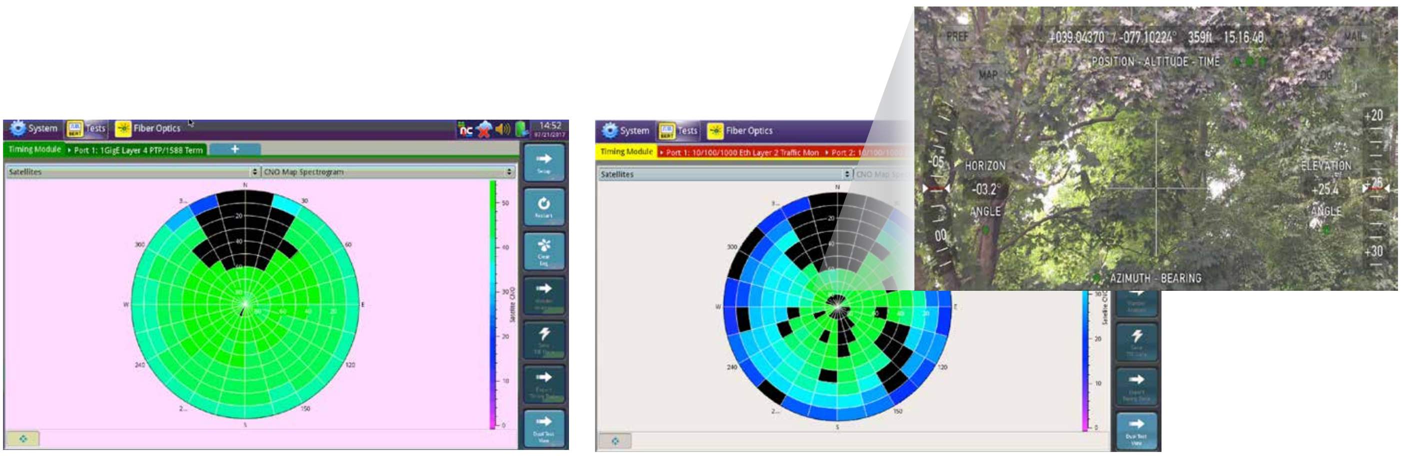


PTP Use in R-PHY



Test recovered clock accuracy based on the network path – critical for upstream DOCSIS spectrum

PTP timing relies on the GNSS satellite constellation as the ultimate source of truth, so a robust GPS antenna setup is critical to reliable operation. It is critical that the setup is tested to ensure that it is cabled properly, has a clear view of the satellites across time, and has a high carrier to noise ratio across the entire sky. Typically, a value of 40dBmV is adequate for reliable GPS operation. The VIAVI TB-5800 can automate these measurements, simplifying their execution for Tech's less familiar with how they work.



Shelf RPD Testing is sometimes used as a pre-check to verify that everything is ready from hub/headend/network standpoint to support future DAA node cutover. By turning up a sample DAA node within the headend, headend-based functionalities can be tested long before the first DAA node is sent out to the field for deployment. Video is a great example of a functionality that can't be thoroughly tested before turning up the first DAA node. When headend/hub changes are made in traditional networks a common verification practice is to connect a set top box at the output of the combining network and flip through the channels to verify that all are present and working. This is not possible with DAA because there is no RF present in the headend/hub to connect a set top box. Even if RF were available there would be nothing present to test—the video signal itself is created for the first time at the DAA node. Turning up a sample shelf DAA node allows verification of headend support for DOCSIS, video, and voice capabilities before calling the headend/hub construction phase complete.

- DOCSIS:

  DOCSIS service/throughput testing at this point in the process should closely mimic what Tech's are doing in the field. The OneCheck Expert in the One Expert (ONX) CATV field meter is a simple method to check all necessary parameters in a single scripted test routine. Deep knowledge of the field meter is not required, with just a couple of clicks the ONX will set up and run predefined tests including full-lineup physical and service layer tests.

  - Recommended tests
    - SC-QAM: Level, hum, MER, BER, Echo, group delay, in-channel frequency response, tilt, transmit level, throughput, DQI over time
    - OFDM: MER/subcarrier, signal level variation, ingress under QAM, PLC lock status/level/MER/CWE, NCP lock status/CWE, throughput
    - Combined SC-QAM + OFDM: Bonding verification, combined throughput, packet loss/round trip delay/jitter

- Video:

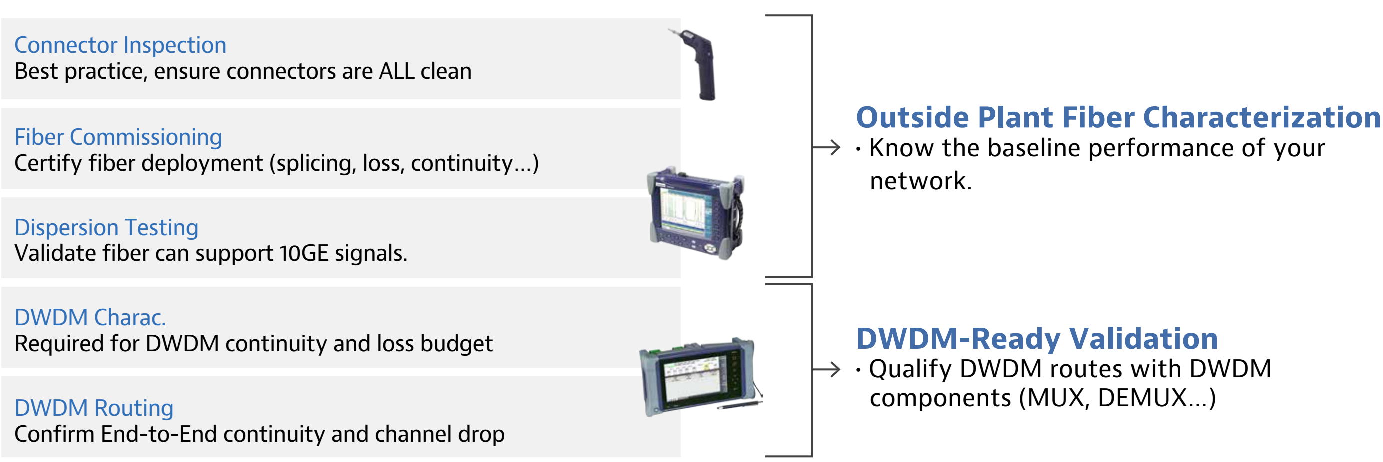
  DAA also significantly impacts video as in most cases the final video output is created on the DAA device itself and can't be tested farther upstream in the process. Ideally a field meter can be used to check for presence of all video carriers, ensure no BER, and validate correct program content by comparing MPEG PID's vs DSG program information. If an operator does not have field meters with this capability a set top box and TV can be used to spot check a few channels for shelf RPD verification, but this method will not scale well for field use as DAA deployments accelerate going forward. Alternatively, the VSE-1100 can be used to scan the entire downstream and display RF characteristics of video carriers, MPEG metrics, and validate program content per-channel.

- Voice:

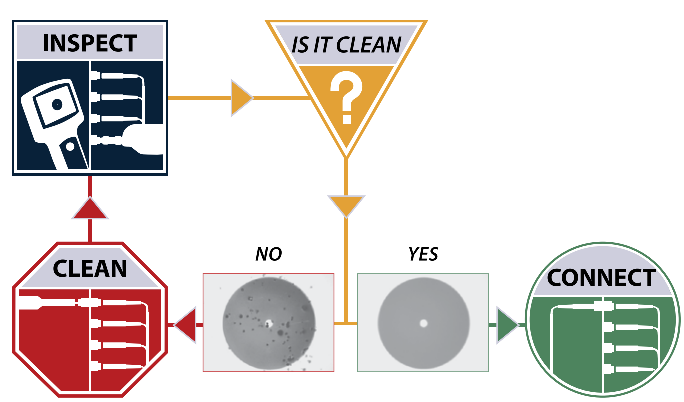
  It is also to confirm that VoIP services have been properly integrated during shelf-RPD verification, the simplest was to do this is to hook up a provisioned MTA and simply make a voice call. While this will not provide a MOS score or similar it will at least confirm that the service is present and functional. Additionally, VoIP SIP can be tested with an ONX field meter for deeper test capability if desired.

Fiber Construction Workflow

This phase focuses on ensuring that the fiber portion of the network is ready for DAA node installation and turnup. This phase naturally separates into the outside plant fiber characterization and DWDM-ready validation sections.



Anytime that fiber connectors are being connected cleanliness is of the utmost importance, multiple studies have shown that contaminated or damaged fiber end faces cause 80% or more of fiber-related networking issues. A single particle mated into the core of a fiber can cause significant back reflection, insertion loss, and even equipment damage. Operators should follow the "Inspect Before You Connect" process to ensure fiber end faces are clean prior to mating connectors.



Outside Plant Fiber Characterization includes baselining optical characteristics for both new fiber being deployed and existing fiber. Just because fiber deployed 20 years ago has performed well with legacy low-speed analog signaling does not mean that it is capable of supporting services needed to support 5G and other higher-speed use models.

Full fiber characterization cannot be performed without taking a network out of service, and DAA deployment provides the perfect opportunity while the network is already being taken down to ensure that deployed fiber assets can deliver advanced services when needed in the future.

Typical Fiber Characterization tests may include:

Test Parameters	Measurement
Connector Inspection	Inspection Scope
Bi-directional Insertion Loss	Loss Test Set
Bi-directional Optical Return Loss (ORL)	Loss Test Set or FiberComplete
Bi-directional connectors/splice measurements	OTDR or FiberComplete
Distance Measurement	OTDR or FiberComplete
Reflectance Measurements	OTDR or FiberComplete
Polarization Mode Dispersion (PMD)	PMD Analyzer
Chromatic Dispersion (CD) measurement	CD Analyzer
Attenuation Profile (AP) measurements	Spectral Analyzer

Some of the testing may seem obvious (Insertion loss, optical return loss, reflectance), but the tighter Chromatic Dispersion (CD) and Polarization Mode Dispersion (PMD) specifications to support 10GE signaling reintroduces the need for dispersion testing. While counterintuitive, dispersion is generally not a problem for faster 100GE links as they often use coherent optics which are more robust to this problem. Min/Max for typical systems are listed below but can vary.

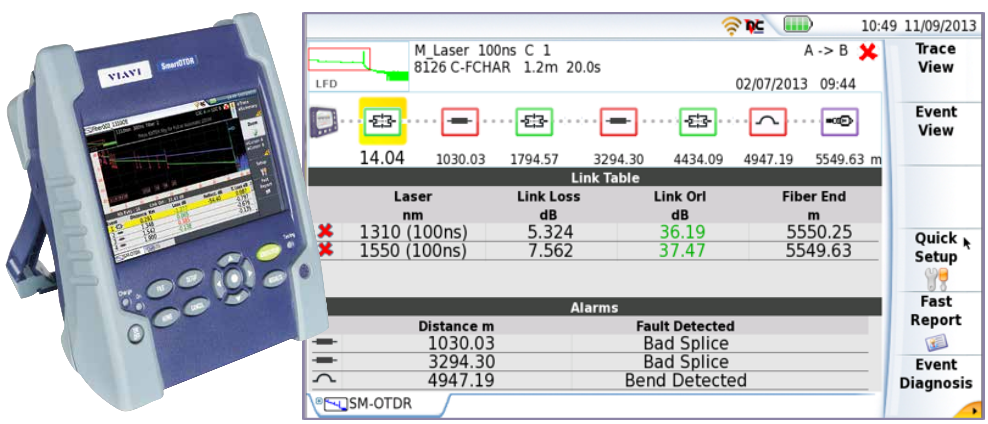
Transmission Type	Transport Speed	PMD Max	CD Max
SONET	OC-192/STM-64	10 picoseconds	1176 ps/nm
Ethernet	10 Gb/s	5 picoseconds	738 ps/nm
SONET	OC-768/STM-256	2.5 picoseconds	64 ps/nm
Ethernet Coherent	100Gb/s	25 picoseconds	30000 ps/nm
Ethernet Non Coherent	100Gb/s (4x25 Gb/s)	1.0 picoseconds	500 ps/nm

OTDR Test:

An optical time-domain reflectometer (OTDR) allows technicians to detect, locate, and measure events on fiber links such as mated connectors, splices, bends, ends and breaks, and the following properties can be measured by having access to only one end of the fiber (unidirectional testing):

- Attenuation – The optical power or signal loss or the rate of loss between two points along the fiber span.
- Event Loss – The difference in the optical power level before and after an event.
- Reflectance – The ratio of reflected power to incident power of an event.
- Optical Return Loss (ORL) – The ratio of the reflected power to the incident power for an optical link.

The VIAVI SmartOTDR allows technicians at any skill level to perform all essential fiber tests. The Smart Link Mapper (SLM) application displays each event as an icon, giving technicians a schematic view of the entire link, helping them use an OTDR more effectively, without the need to be able to interpret and understand OTDR trace based results.

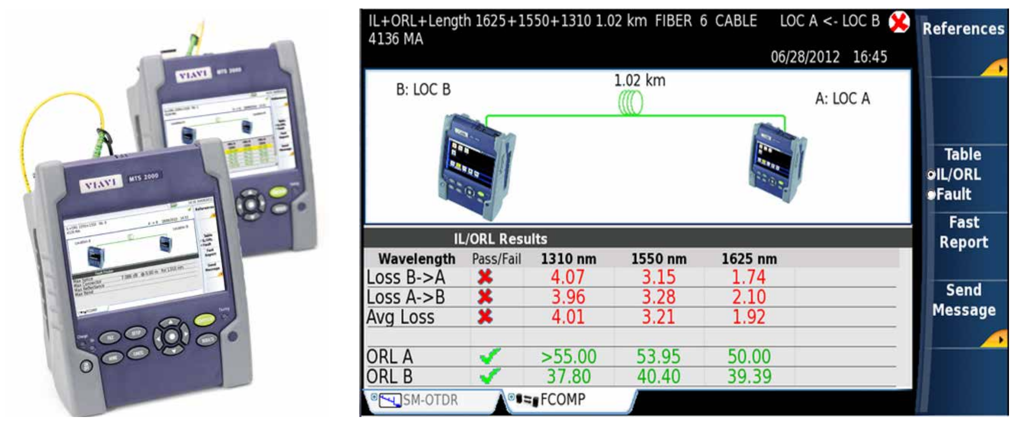


SmartOTDR and SmartLinkMapper application

In order to more accurately characterize fiber links and individual events, and to try to uncover additional events that may have been concealed by an OTDR's own dead zone performance when testing unidirectionally, dark fiber providers or the fiber owner/operator can perform bi-directional tests. This allows for more accurate measurement of events (losses and reflections, etc.), and to confirm they are the same in both directions, there are situations due to fiber tolerances, mismatches or splicing that can result in excessive or differing optical losses (or apparent gains) when viewed from different directions.

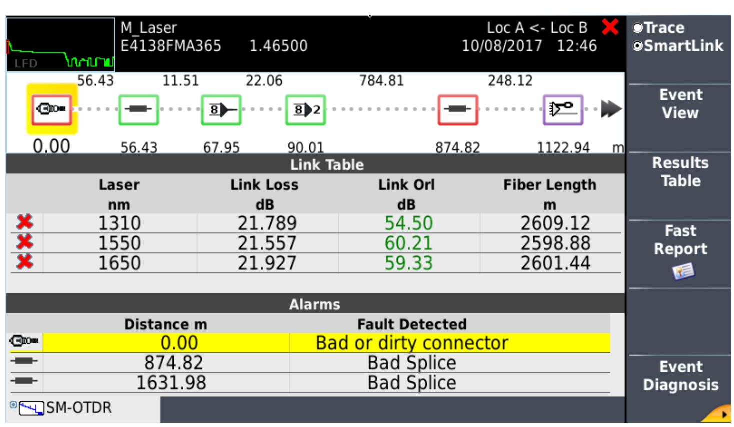
Keep in mind you can never be 100% sure what direction of service a fiber will be used for when it is installed. A lot of applications are dual fiber with one Tx and one Rx fiber, but there are also single fiber implementations with different wavelengths being used for Tx and Rx on the same fiber in opposite directions.

For improved accuracy of OTDR results, it is highly recommended to perform bi-directional tests. This allows technicians to identify potential faults that might be hidden by OTDR dead zones. Bi-directional tests will certify fiber performance in both directions (remember PON fibers carry light in 2 directions, up and downstream). Automation of the bi-directional testing and reporting process, presenting results in an easier to read format (Smart Link Mapper), along with performing tests via a single test port will significantly reduce test time, improve test workflow and reduce complexity (i.e. the risk of mistakes and re-test). VIAVI FiberComplete solution automates bi-directional IL, ORL and OTDR fiber certification.



FiberComplete for T-BERD/MTS-2000, -4000 V2, -5800 V2

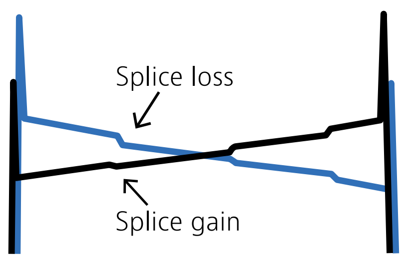
The Smart Link Mapper (SLM) application displays each event as an icon, giving technicians a schematic view of the entire link, helping them use an OTDR more effectively, without the need to be able to interpret and understand OTDR trace based results.



FTTH-SLM

VIAVI FiberComplete™ is an all-in-one, automated and single test port solution that tests bi-directional insertion loss (IL), optical return loss (ORL), and OTDR.

Bidirectional Analysis



Fiber backscatter coefficient mismatches can cause a splice to appear as a gain or as a loss, depending upon the test direction.

Bidirectional analysis is used to minimize possible mismatches by measuring the splice loss in both directions and averaging the result to obtain the true splice loss.

FiberComplete application

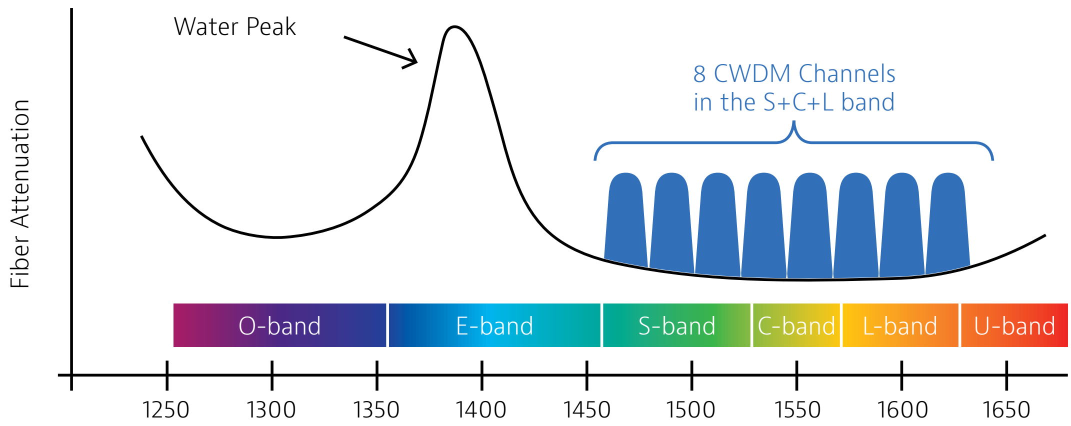
The second portion of the Fiber Construction Workflow focuses on DWDM functionality. DWDM is frequently used in DAA deployments to better leverage existing deployed fiber as well enabling future revenue opportunities. Once individual fiber links have been characterized, end-to-end DWDM route validation is needed to ensure complete routes are within specification. DWDM OTDR's are required to test for end to end continuity, loss, etc through the MUX's/DEMUX's present across individual routes as well as full-channel testing across each MUX/DEMUX pair.

Link Qualification

WDM (Wavelength Division Multiplexing)

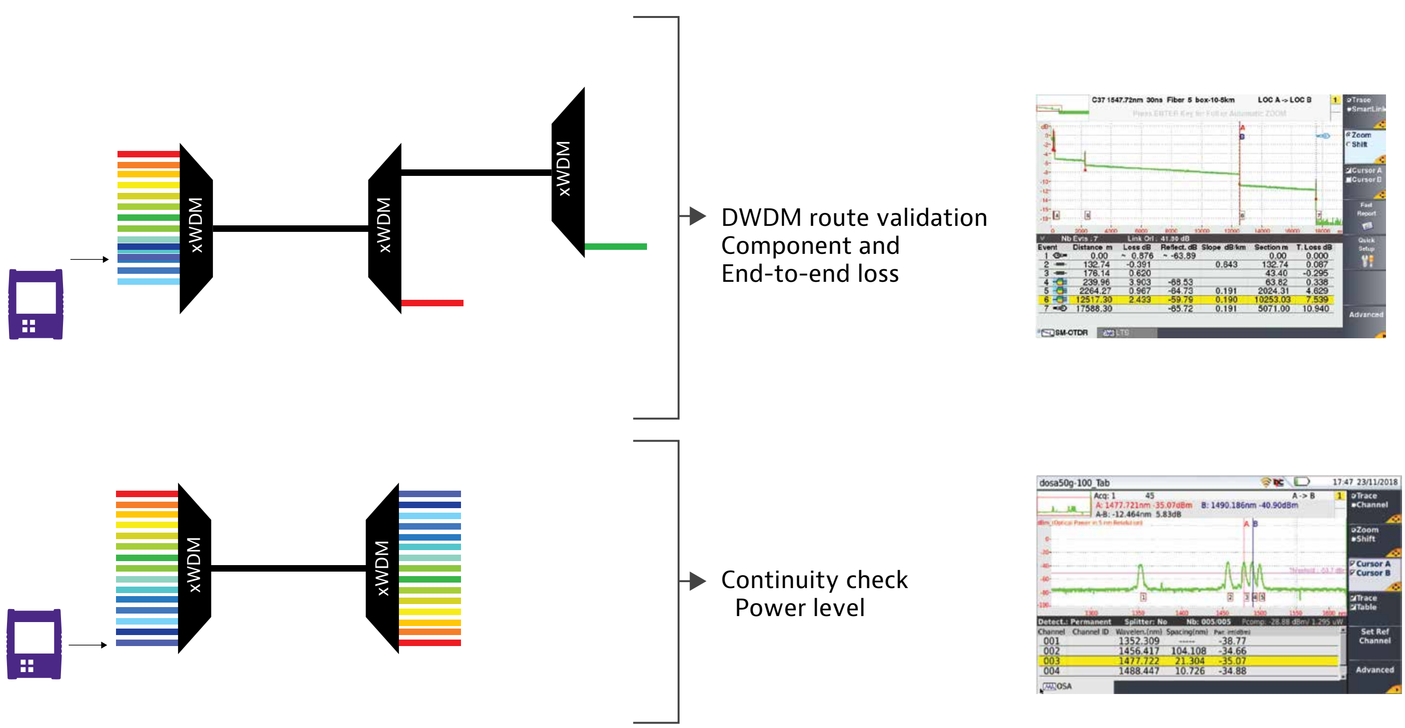
WDM allows service providers to increase capacity by adding new equipment at either end of a fiber strand and combine multiple wavelength/channels on a single fiber strand. Multiplexers are used to combine wavelengths onto a single fiber, and demultiplexers are used to separate the wavelengths are the other end. DWDM is most prevalent for modern DAA deployments but you may still see some of the legacy technologies in certain cases.

1. **Coarse Wave Division Multiplexing (CWDM),** provides up to 18 channels (or wavelengths) on a single fiber to allow for higher capacity. CWDM networks are typically passive with no active amplifiers in order to save cost and complexity and due to the wider channel spacings it can utilize cheaper components (SPF transceiver Tx/Rx, MUX/DeMUX and filters) which again makes it cheaper to deploy. Keep in mind that a key driver for access networks is price/cost. In addition, with only 18 channels it's easier to manage and maintain (there are only 18 variations of SFP to manage during deployment and maintenance). Passive CWDM is typically only used for distances up to 80km, however, for distances between 40 to 80km there can be a reduction in the number of usable channels to only the upper 8, this is because of the fiber's attenuation of wavelengths below 1470nm due to things like water peaks. The losses per wavelength across all the transmission bands are known as the fiber's attenuation profile (AP). The AP varies between fibers and fiber types and will partially dictate the number of useable channels which will have an impact on capacity scalability. Low water peak fiber has been available for some time but unless you are certain about the fiber in the ducts it is best to check. Ultimately for passive links the optical budget of the transceivers, passive element losses, splice/connector losses and the fiber's AP (i.e. optical loss per wavelength per km) will define the max link length achievable.

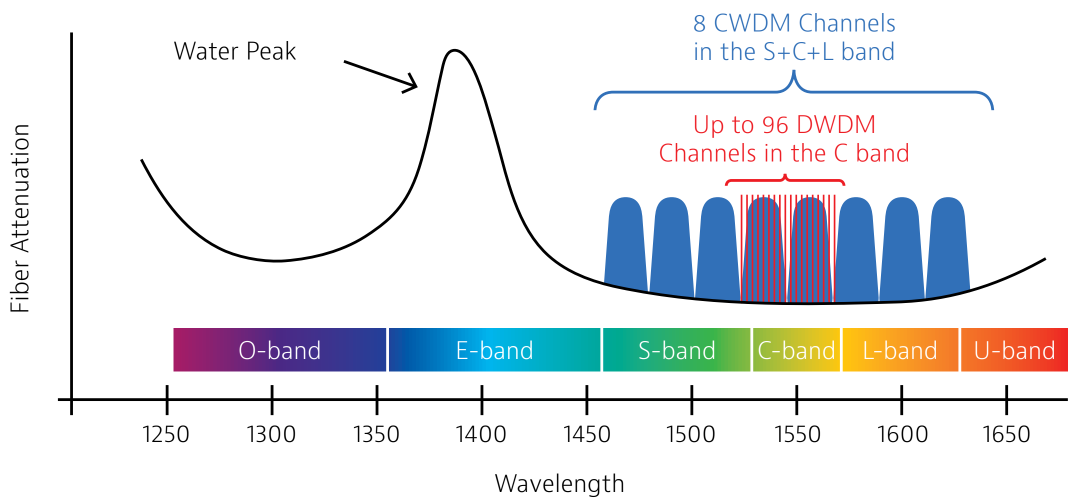


CDWM channels in the S +C +L band

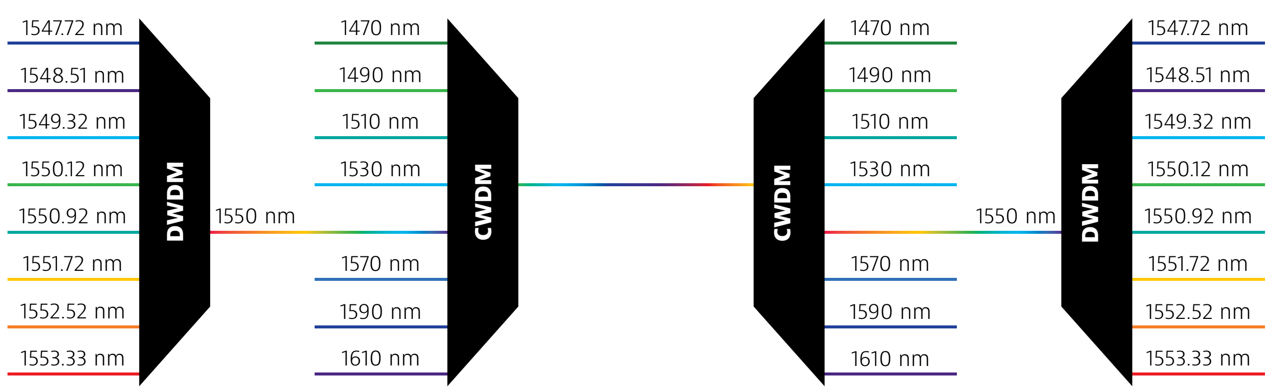
2. Dense Wave Division Multiplexing (DWDM), provides up to 96 channels per fiber depending on the spacing used. Spacing of 100 GHz is still the most common, but today's DWDM systems can support 50 GHz (0.4 nm) and even 25 GHz spacing with up to 160 channels is possible. To put this in perspective, WDM has a spacing of 20 nm per channel. DWDM networks can be passive or active, which approach is used will depend mostly on the distances involved, current data requirements and future capacity need. As for passive WDM the maximum distance for passive DWDM will depend on the transceiver's optical budget and the fiber loss per km for each wavelength (its AP).



3. Hybrid CWDM & DWDM (xWDM), provides the possibility to expand the capacity of CWDM infrastructure by using an appropriate CWDM channel to accommodate multiple DWDM wavelengths. In this hybrid environment, the DWDM wavelengths typically use 100GHz spacing, this is for two reasons, firstly to allow for small drifts in transmitted wavelengths so filtering doesn't impact other services and secondly to keep the cost of transceivers, filters, and MUX/DeMUX to a minimum allowing for the utilization of cheaper components with wider tolerances.



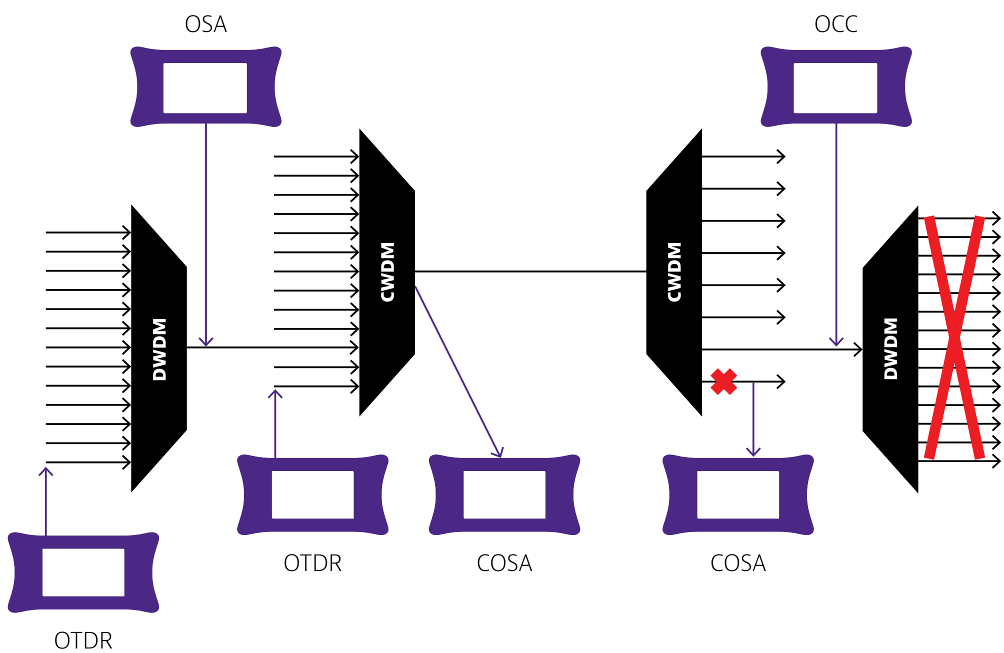
Hybrid CWDM and DWDM



Example of 8 DWDM channels (100GHz spacing) added to an existing 8-channel CWDM network

xWDM-specific test challenges

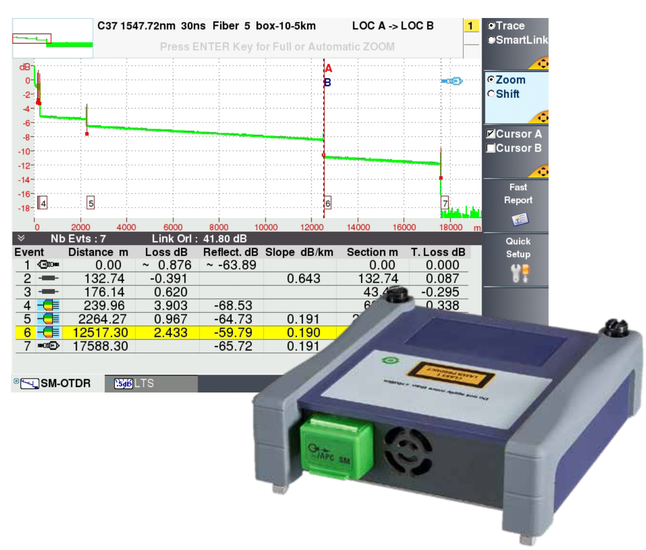
It is expected that most of the fiber network infrastructure will be upgraded to take advantage of higher multiplexing technologies to offer higher throughput. However, testing xWDM networks is not so trivial, especially since DWDM channels are so close, DWDM transmitters require precise temperature control to maintain wavelength stability and operate properly, and wavelength filters must do their job of passing the correct wavelength while blocking others. This means that an issue with one channel could easily create issues with the channels on either side, making testing and maintaining DWDM networks more complex. DWDM networks must be tested for loss, connector cleanliness, and spectral quality. The following tests are essential for xWDM networks.



xDWDM testing

WDM OTDR Test

A CWDM or DWDM OTDR such as the VIAVI 4100 series CWDM and DWDM OTDR modules, for the T-BERD/MTS-2000, 4000, 4000 V2, and 5800 V2 mainframes, can be used to validate a core fibers ability to transport all the xWDM wavelengths during build certification and prior to the connection of the WDM MUX/De-MUX. They can also be used after MUX/De-MUX connection to validate the end to end wavelength routing and losses for specific wavelengths or for maintenance and troubleshooting to expose and locate any bends, breaks, bad connectors or splices. Standard OTDRs using traditional 1310/1550nm wavelengths for test can't be used for this second level of testing due to the wavelength filtering implemented in the MUX/DeMUX devices.

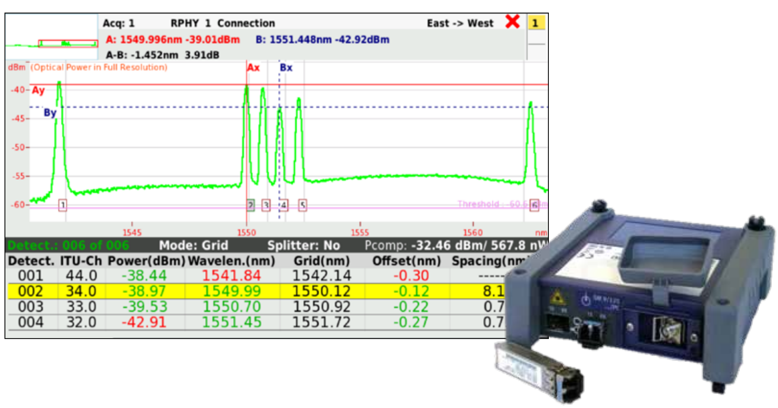


DWDM OTDR Module

Channel check

A CWDM or DWDM power meter (aka Optical Channel Checker (OCC)) can be used to perform basic checks for wavelength presence and power levels to validate correct wavelength routing.

A small form factor CWDM or DWDM optical spectrum analyzer/ optical channel checker, COSA (CWDM) and OCC-4056C (DWDM) 4100 series module for the T-BERD/MTS-2000, 4000, 4000 V2, and 5800 V2 mainframes, can also be used to perform the same wavelength presence and power level checks. However, with the added capability to report ITU-T channel numbers, technicians can quickly measure actual wavelength to check for drift or offset and report actual channel spacing (particularly important for DWDM). While dual integrated SFP bays allows technicians to verify wavelength/channel of colored and tunable SFPs which also provides the option to become a tunable light source which can be used for link routing/insertion loss test.



OCC-4056C DWDM Optical Channel Checker Module

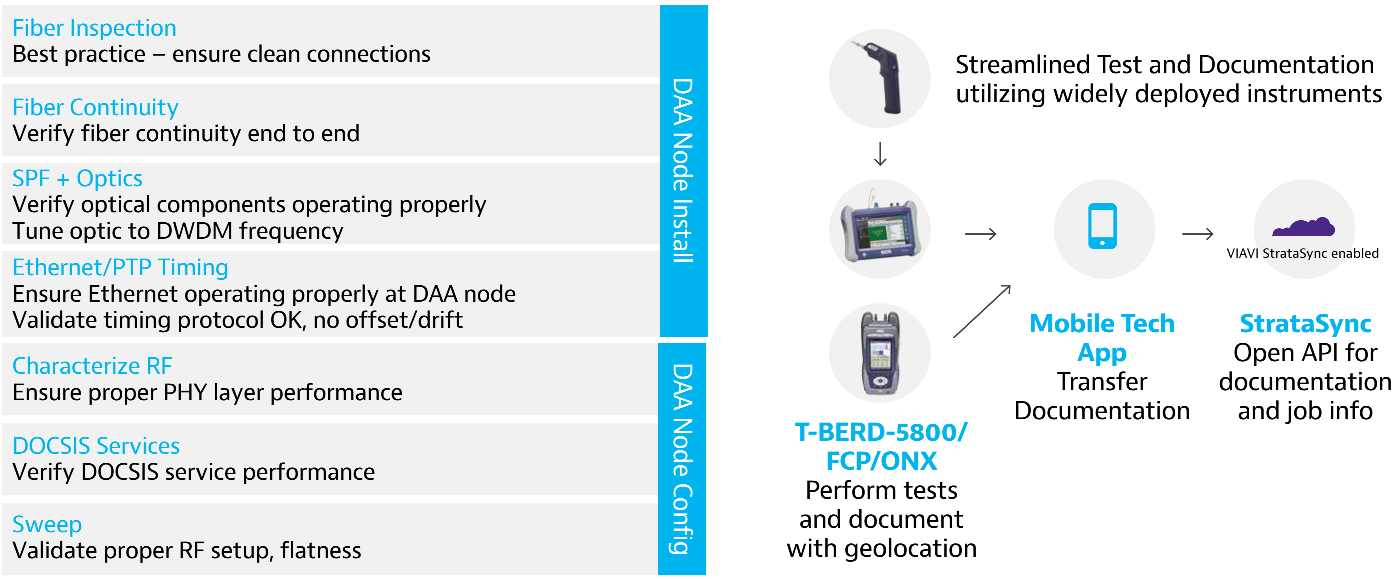
Optical power measurement if splitting a PON network from DAA Node

As part of PON network activation technicians must validate that downstream and upstream optical power levels are within expected ranges prior to final connection of end devices. For G-PON and XGS-PON or NG-PON2 the OLP-87 PON power meter can perform wavelength selective power level measurement. It also supports through mode operation and upstream burst mode measurement enabling both upstream and downstream power level measurements. It also helps in validating the ONT/ONU device by checking if the device is active and responding to the PON network equipment (OLT (Optical Line Terminal)).

OLP-87 G & XGS-PON
or NG-PON2 Selective PON power meter

DAA Installation and Cutover Workflow

As its name implies, this section is split between testing required during the actual DAA node installation and testing required during the configuration and cutover.



DAA Installation and Cutover Considerations

DAA Node Installation testing begins with fiber inspection and cleaning (if necessary) and end to end continuity check – nothing else matters if signal is not present on the fiber. It is worth adding a reminder here that not all test gear is capable of testing through DWDM muxes, keep this in mind when selecting appropriate instruments for this test need.

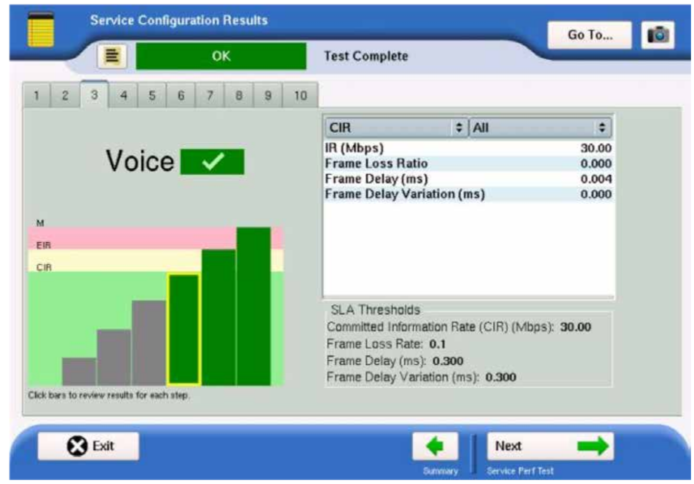
Next steps include verifying that the optical components including the SFP are working properly. If tunable SFP's are being used they must be tuned to correct wavelength at this point. Tunable SFP's are gaining in popularity despite their higher cost/unit vs fixed wavelength units. The ability to stock just one SKU in each truck capable of covering all wavelengths vs 16 or more different SKU's makes them an attractive option for an increasing number of operators.

Basic steps for SFP Tuning and Verification

- Tune optic to appropriate frequency (if tunable) – VIAVI OCC 4056 or TB-5800
- Verify SFP is operating on correct frequency, not drifting, appropriate power – VIAVI OCC 4056
- Ensure no BER – VIAVI T-BERD 5800
- Repeat tests included in HE/Hub Construction

Once the optics are up and running it is important to run Ethernet validation tests including PTP timing tests. Ethernet connectivity to CCAP and end to end throughput testing ensures the performance and stability of the Ethernet link feeding the node.

Newer industry standard for single and multiple service Ethernet and IP service activation test.



Measure Key Performance Indicators and Bandwidth Profile.

- CIR, EIR (Throughput)
- Frame Delay – FD (Latency)
- Frame Delay Variation – FDV (Jitter)
- Frame Loss Rate – FLR
- Committed Burst Size – CBS
- Policing
- Fully automated with report generation

For DAA Node Config and Cutover, the focus is on ensuring that the services provided by the node are operating properly. Standard DOCSIS service testing at the node output validates that specified services levels can be met, and RF testing including sweep ensure that the RF setup/alignment is solid and won't be the cause of intermittent problems later. It is recommended to repeat the DOCSIS, Video, and Voice tests recommended in the Headend Hub Construction Verification section above

DAA Maintenance and Troubleshooting Workflow

Once the entire DAA value stream is operational and nodes are cut over, they will still need to be monitored and maintained. While many operators will drive fiber deeper into their plant via DAA deployment, most of the drivers of plant maintenance remain as very few operators are pushing to N+0 with cascade depths typically remaining at N+3 or higher. In a DAA plant squirrels will still feast on cables, cars will still run into poles, and most importantly homes/drops will continue to drive ingress remediation truck rolls. The need for plant maintenance does not change, but how it is performed must change as DAA transforms networks.

Leakage
Efficiently find/fix plant integrity issues

Ingress Suppression
Continue to address the "85% problem"

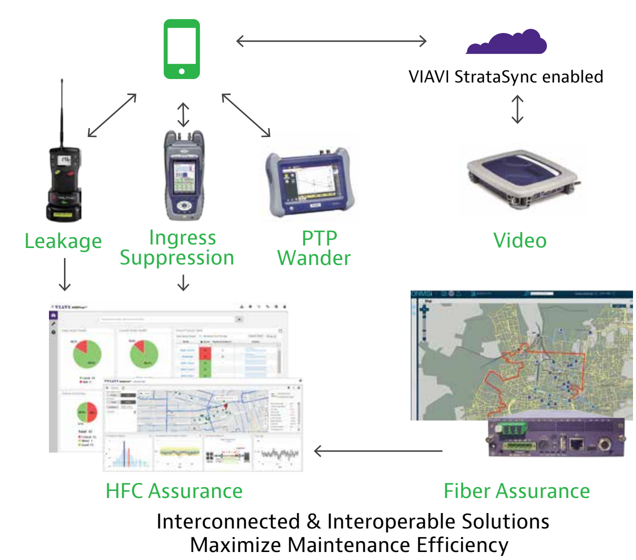
PTP Wander
Ensure timing issues don't cause BER

PTP Wander
Verify correct channels present and in-spec

Fiber Assurance
Find breaks faster proactively address bends

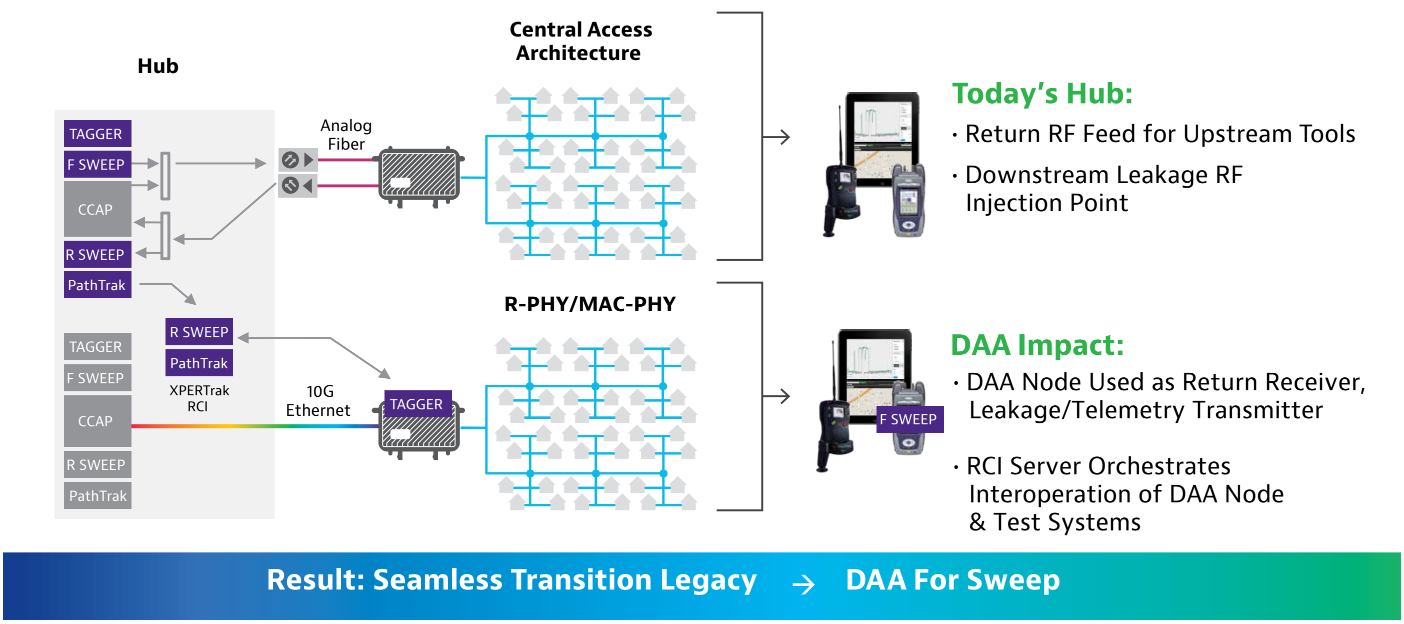
HFC Assurance
Detect and localize QoE-impacting plant issues

Ethernet Assurance
Validate end to end performance to detect issues before customers complain



DAA Maintenance & Troubleshooting Considerations

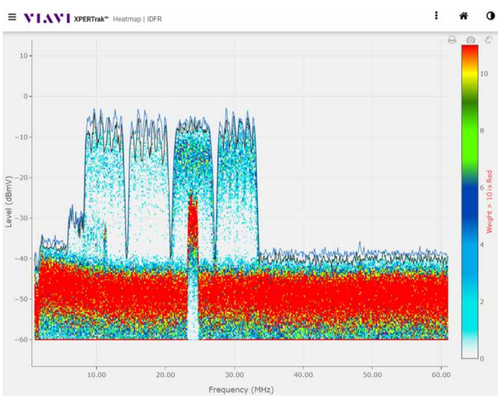
It is well understood by now that all DAA variants eliminate RF test points from hubs, disallowing the use of traditional rack-mounted return path monitoring, forward/return sweep, and leakage taggers. With ingress remediation commanding 85+% of maintenance tech time, it is critical that operators retain essential capabilities like return path monitoring and leakage to address it. Return sweep is also still considered mandatory by operators globally for amp alignment, critical troubleshooting use, and as a companion to PNM tools. Fortunately, a solution has been developed in cooperation between the leading test vendor and all major DAA infrastructure vendors that enables reuse of existing field meters and technician workflows for return sweep, and upstream ingress monitoring and remediation. Based on CableLabs standards, this solution is applicable to networks deploying DAA systems from any vendor with CableLabs compliant NDF/NDR implementations. Use of DAA nodes to transmit leakage tags was an early request from operators to DAA vendors and is also now generally available.

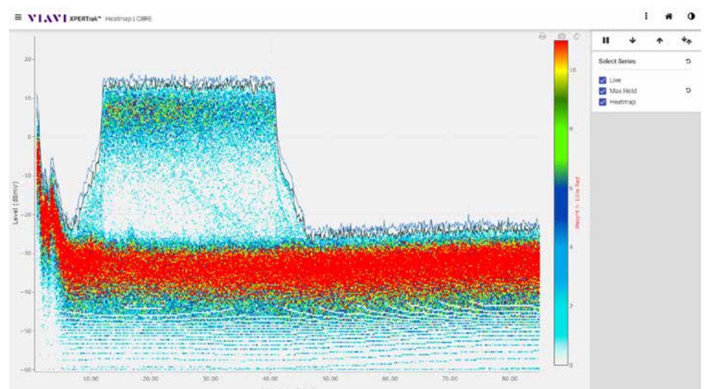


Virtualization Enables Test Capability Continuity

Leakage: Proactive driveout leakage management processes are still recommended post-DAA implementation. Thresholds will vary and should be reduced as the network is tightened up over time, targeting all leaks over 20uV/m for remediation should be achievable by most systems. Ideally four frequencies will be monitored across the downstream spectrum band to ensure complete coverage and not miss frequency-specific shielding weaknesses. Wide OFDM downstream carriers can create blind spots for systems relying exclusively on signal tags, it is recommended that OFDM detection be used in these regions to enable full coverage.

Ingress suppression: Even as fiber pushes deeper into networks, ingress suppression remains the single largest consumer of maintenance tech time. A robust leakage management program will reduce the frequency of ingress runs, but when they are required high performance spectrum analysis in the hands of maintenance tech's is still absolutely critical for efficient find and fix processes. The wide OFDM-A upstream carriers introduced by DOCSIS 3.1 create challenges for traditional spectrum analyzers, it is recommended to pursue a maintenance solution enabling variable persistence heatmap analysis from the RPD to address these challenges.





Beyond the field activities listed above, assurance systems are still critical to ensure that operators can:

- Quickly be alerted to issues impacting subscriber QoE
- Trend network performance to spot emerging issues before they become customer impacting
- Maximize maintenance ROI by focusing work on issues that matter most

While historically Assurance solutions have been somewhat siloed between Fiber, Ethernet, and HFC systems. As the lines between these technologies/mediums blur (think 10G optical Ethernet link going to DAA nodes for example) Assurance solutions are undergoing a similar convergence. Fiber monitoring data is now being overlaid on HFC Assurance system maps, and automation of service-level testing is leveraging test probes from all three technology areas.

HFC Assurance

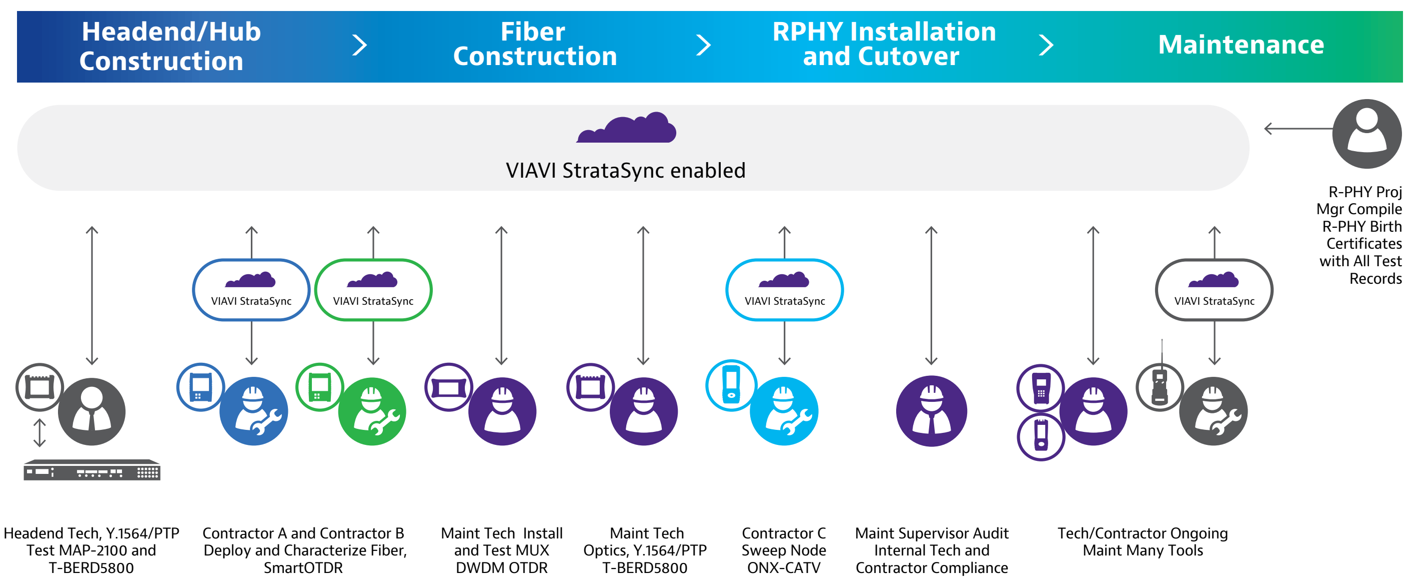
Once the DAA network is operational, the role of HFC assurance systems is to continue to provide all the same visibility that Tech Ops and NOC folks had before the DAA transition, plus more. Upstream monitoring data previously provide by hub-based measurement hardware must now come from virtual sources such as the RPD or CCAP. Test vendors must walk a tightrope to ensure that this data can be collected at a rate necessary to provide meaningful insight and on-demand troubleshooting capabilities while not impacting service provision capabilities of these devices. The secret sauce in these systems lies more in data collection and analysis than in the data itself.

Monitoring considerations:

- Monitor network performance from the subscriber level up – ensure pockets of heavily impacted subscribers don't get lost in node-level averaging.
- Monitor both physical layer and service layer data. PHY data can be a critical early indicator of impending service issues and is helpful in determining/locating root cause issues
- Use all your data sources. Combining PNM, QoE, plant leakage data, and past field meter measurement data on a single map can illuminate issues and speed their resolution

DAA Deployment Project and Data Management

By now you should have a good understanding of the types of tests that need to be considered at each stage of a DAA deployment lifecycle, why they are needed, and some of the challenges presented at each stage. The bigger challenge comes in when the overall lifecycle is viewed in its entirety from a program management standpoint including the interdependencies between stages. There are many different workgroups involved including both direct and contractors, a wide variety of test equipment, and a ton of test data to be collected, analyzed, and stored. Knowing when all prerequisite tests have been completed and passed before proceeding with the next step in the process is tedious, time-consuming, and error-prone unless the process is centralized and automated. Creation of a birth certificate upon DAA node cutover including all test data relevant to its performance can be invaluable when trending performance over time and troubleshooting issues but is not feasible using manual methods. For these reasons and others it is recommended that a cloud-based workflow management system be used to ensure correct tests are being deployed to test gear per task, data is being centrally collected and analyzed including from contractors, and is made available on-demand via dashboards or for export via API. Below is an example deployment of a cloud-based workflow system and how it is used across the DAA lifecycle.



DAA Deployment Project and Data Management WorkFlow

Conclusion

There is no doubt that DAA is a key element that will allow HFC networks to remain the most cost-effective medium for delivering data, voice, and video services well into the future. Many early adopters are well into their deployments, proving that it can be done but not without some challenges along the way. Hopefully the overall DAA deployment framework and test details provided in this document will help you to plan for your own transition and achieve a more problem-free experience.

Solution Guide

Solution	Description	DAA Test Activities
VIAVI FiberChek Probe	Handheld device for fiber inspection and analysis	Fiber inspection
VIAVI FiberChek Sidewinder	"All-in-one" handheld inspection and analysis solution for multifiber connectors such as MPO	Fiber inspection (multifiber)
VIAVI SmartOTDR	Single device with optical time domain reflectometry measurement, fiber end face analysis, optical loss testing and visual fault locator	OTDR test
VIAVI FiberComplete	Automatic bi-directional insertion loss (IL), bi-directional optical return loss (ORL using OCWR method), distance and bi-directional OTDR or fault finder	Bi-directional testing to improve fiber link characterization
VIAVI T-BERD 2000/4000	Test platform for OTDR and OCC modules	OTDR and channel check testing
VIAVI COSA-4055 (CWDM) and OCC-4056C (DWDM)	CWDM optical spectrum analyzer/DWDM optical channel checker	Channel checking for presence and power. Measure actual wavelength, offset and drift, and channel spacing. SFP tuning for OCC-4056C
VIAVI OLP-87 PON power meter	FTTx/PON power meter for use in activating and troubleshooting B-PON, E-PON and G-PON and next generation high speed XGS-PON and NG-PON2	Optic power measurement during network activation
VIAVI OTU-5000/SmartOTU	Small form-factor remote fiber monitoring unit, integrated with XPERTrak HFC Assurance System	· Monitor fiber links between hub and parent R-PHY node · Notification of fiber break or fiber stress issues
VIAVI T-BERD/MTS-5800 (100G)	Handheld dual-port 100G instrument for testing, service activation, troubleshooting, and maintenance	· GPS test · PTP test (PTP timing error test) · Ethernet test (backhaul)
VIAVI ONX-CATV	Handheld HFC/DOCSIS meter...	· RF characterization and conformance test · DOCSIS service-level testing · Sweep test · Live field spectrum analysis
VIAVI XPERTrak	DAA-ready Assurance solution enabling continuity of critical test capabilities during and after DAA transition plus identification if the most critical network issues to address first.	· HFC service assurance · PNM analysis · RPD support for sweep and live spectrum · Integrated fiber alarming and remote on-demand OTDR test
VIAVI Seeker X	DAA-ready plant leakage solution useful to find network integrity issues	· Validate tight plant after construction/repair · Proactively find shielding weaknesses reducing ingress opportunities

VIAVI **VSE-1100**	High-performance integrated field spectrum and video analyzer. Features Spectrum, QAM, and MPEG video analysis for headend/hub sites ruggedized for outside plant use	· Verify presence/absence/quality of all video carriers · Validate channels/streams on each carrier?
VIAVI **StrataSync**	Cloud-enabled platform for asset management, configuration management, and test-data management of VIAVI instruments as well as asset tracking of non-VIAVI instruments	Management of vendors, employees and subcontractors as one team during all DAA network deployment activities

VIAVI Solutions

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