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EDITORIAL GUIDE

## Network Test Strategies

Optical communications technologies are becoming increasingly complex. That means testing fiber-optic networks must become simpler and more efficient to meet operator needs. The articles in this Editorial Guide highlight the challenges network operators and technicians face and what strategies and technologies can help them keep pace.

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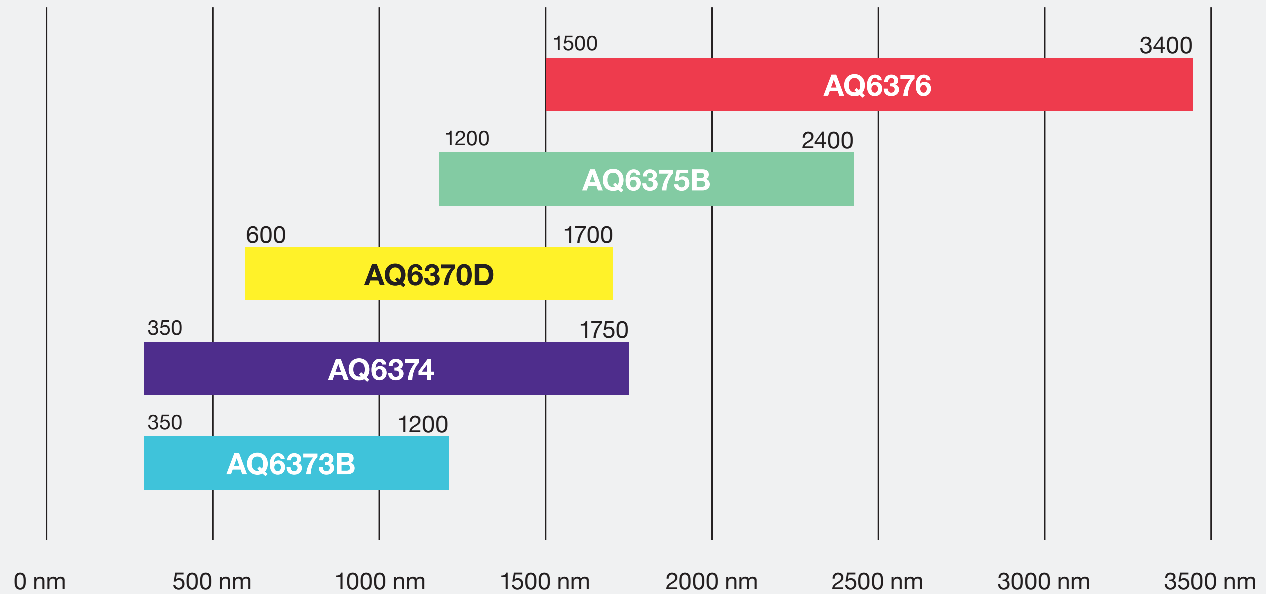


# Optical Spectrum Analyzer

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*Originally published June 29, 2017*

# Multi-platform Test Instruments for Successful SDN Migration

By **DANNY GONZALEZ,** Anritsu Co.

**OPERATORS ARE DRAWN** to software-defined networks (SDNs) because they simplify network management. As operators migrate from traditional environments to SDN, they must be aware of potential service disruptions, lower client quality of service (QoS), and other issues. Testing, while always important, takes on an even greater role during this transitionary stage, particularly at the data-plane level where operator revenue is generated.

While the tests – QoS, traffic generation, etc. – haven't changed, the technologies certainly have, and operators will be required to test a variety of client signals over the data plane. Circuit-based traffic common in legacy networks is now being encapsulated into next-generation transport technologies such as Optical Transport Network (OTN), Multiprotocol Label Switching (MPLS), and Generalized MPLS (GMPLS).

OTN has increasingly become the preferred method for high-speed networks for a number of reasons. It provides operators with better visibility and control closer

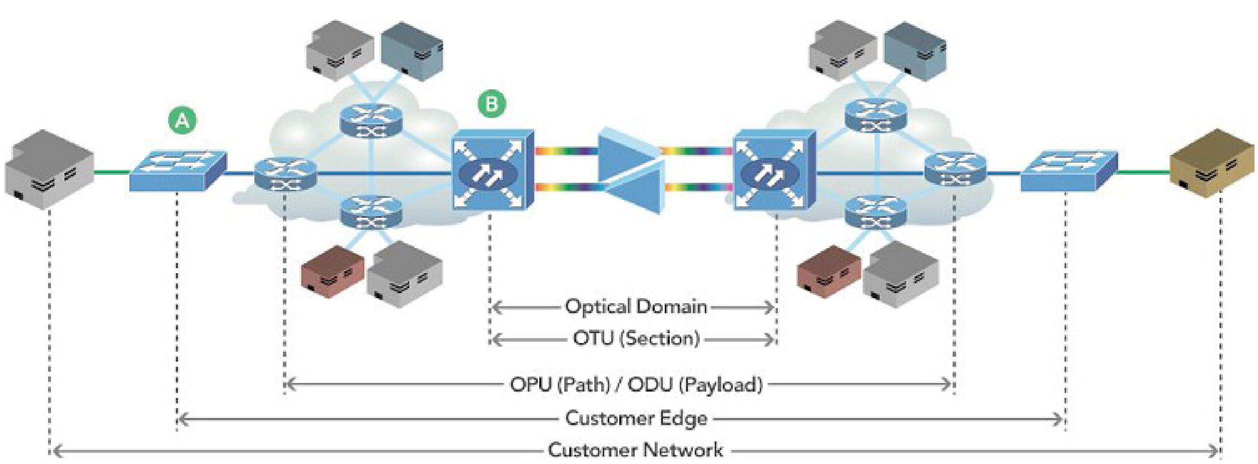


**FIGURE 1.** *OTN segmentation.*

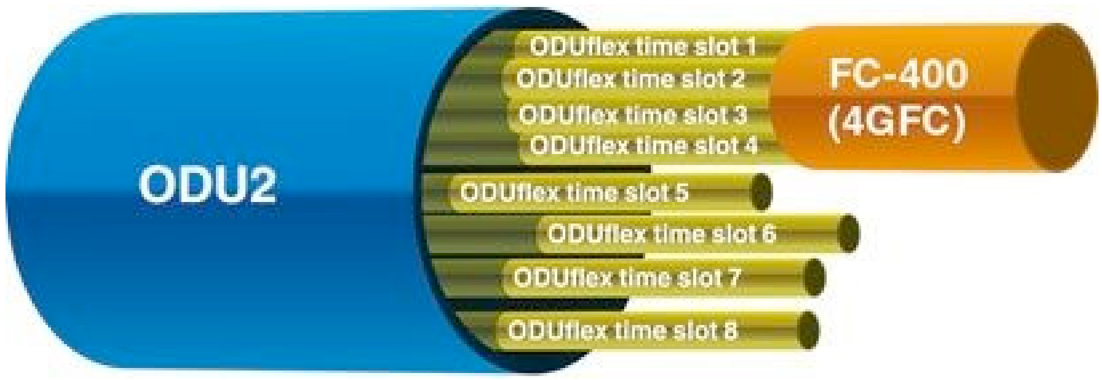


**FIGURE 2.** *ODUflex divides capacity to optimize OTN capacity.*

to the network edge. Network management becomes simplified, as OTN places user traffic at the core managed infrastructure earlier. OTN can also enable operators to better monitor and service large customers.

OTN uses Optical Data Unit (ODU) as digital wrapper to many technologies, such as Ethernet, SONET, and Fibre Channel (Figure 1). In essence, ODU is a transport container that carries client signals from network ingress to egress. It provides a payload area for client data along with overhead for performance monitoring and fault management. ODUflex (Figure 2) is a new feature that supports the flexible allocation of client-signal bandwidth to make the best use of OTN capacity.

The use of ODU reduces the number of technologies that need to be measured from many to one. The result is that test platforms must support ODU wrappers and be easily updated to keep pace with the constantly changing standards so they can generate any type of data to accurately measure the data plane.

## Appeal of SDN

OTN is only one change in the ever-evolving network. In the traditional approach to networking, most network functionality is implemented in a dedicated appliance, such as a switch, router, or application delivery controller. Within the respective appliance, most of the functionality is implemented in specific hardware such as an application-specific integrated circuit (ASIC). SDNs are viewed as a superior approach to this hardware-centric networking approach.

As described by the Open Networking Foundation (ONF), the SDN architecture (Figure 3) is dynamic, manageable, cost-effective, and adaptable. These attributes

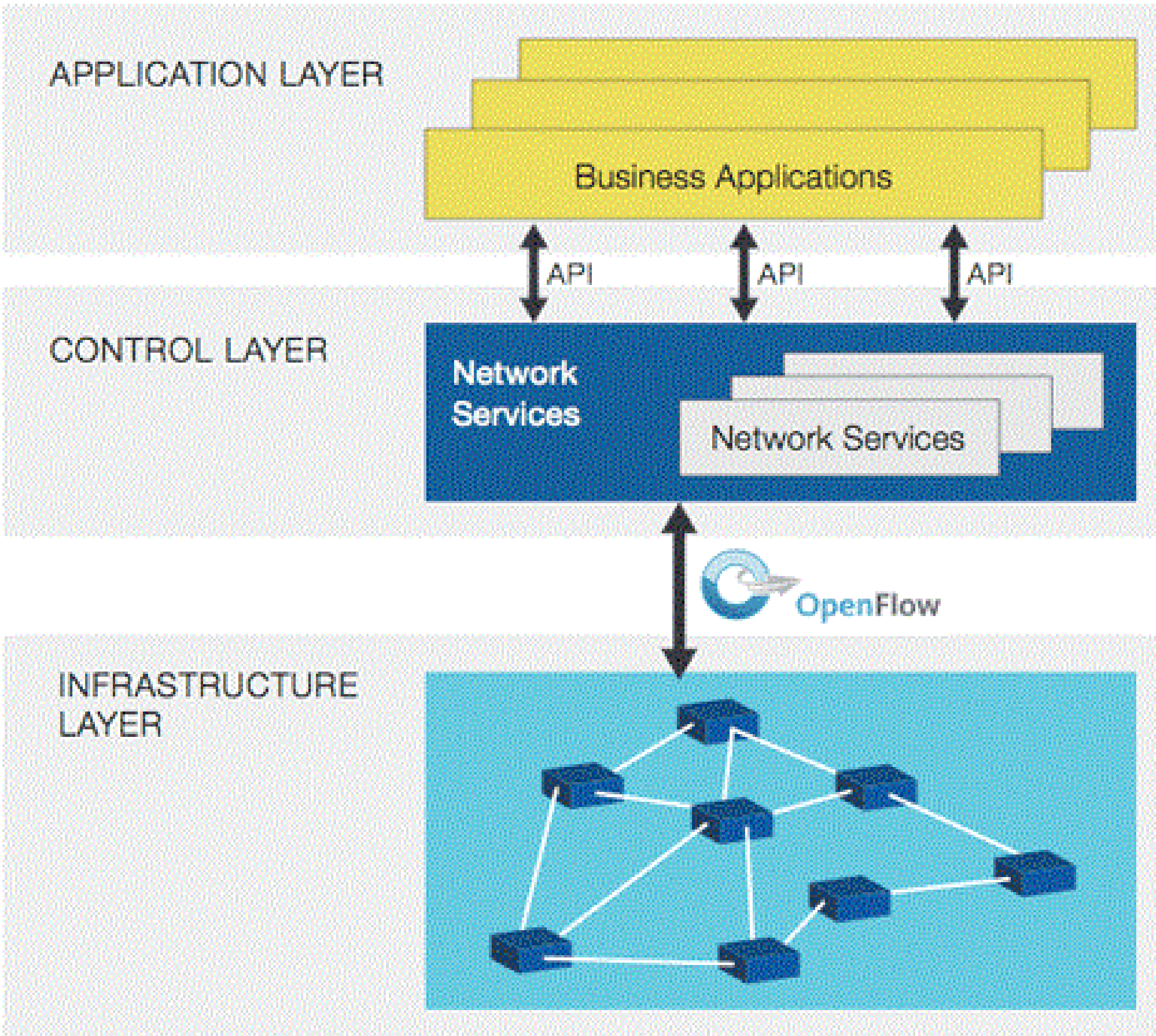


**FIGURE 3.** *SDN architecture. (Photo courtesy of OTN)*

make an SDN ideal for today's high-bandwidth networks. This architecture decouples the network control and forwarding functions, enabling the network control to become directly programmable and the underlying infrastructure to be abstracted for applications and network services.

Proponents of SDN point to five key benefits:

1. **Programmability:** Control of the network can be programmed directly because it is decoupled from forwarding functions.
2. Responsive: Administrators can dynamically adjust network-wide traffic flow to meet changing needs.

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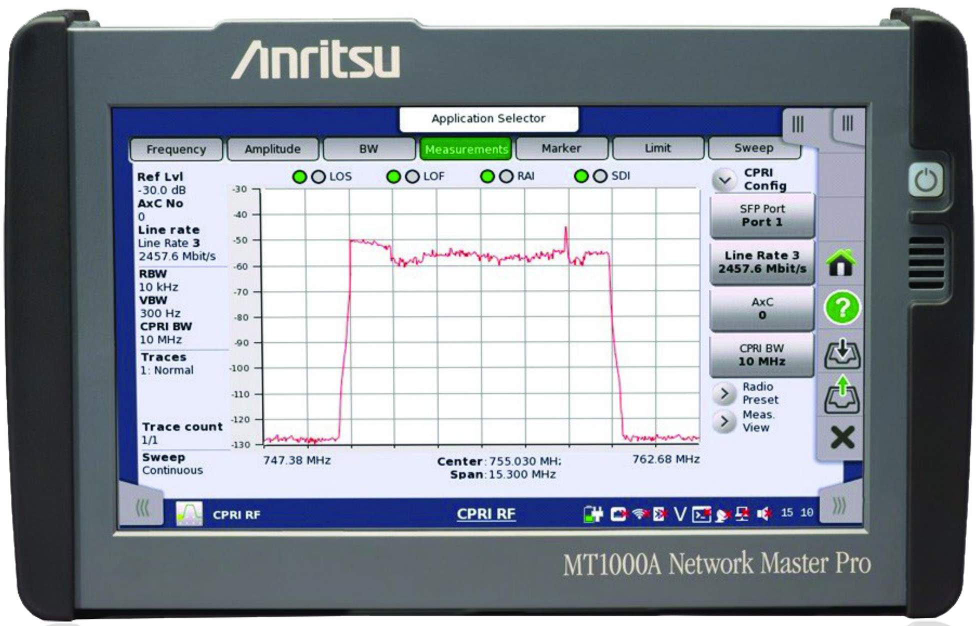


# Network Testing Simplified

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3. **Centrally managed:** Software-based SDN controllers centralize network intelligence to create a universal network appearance to applications and policy engines.
4. **Dynamic Configuration:** Network managers can configure, manage, secure, and optimize network resources very quickly via dynamic, automated SDN programs. Because the programs are open standards-based they can write themselves.
5. **Vendor-agnostic:** When implemented through open standards, network design and operation are simplified because instructions are provided by SDN controllers rather than multiple, vendor-specific devices and protocols.

### Network Testing

Many believe incorporating test software controlled by SDN into the network is another benefit and the best approach to maintain network performance. While this may be the most logical solution in a few years when standards and SDN technology have fully evolved, independent transport testers not integrated into SDN remain the best approach for today.

The reason test software integrated into the SDN is not currently optimal is that there is no reference when tests are conducted. For example, most networks use switches from multiple manufacturers. With SDN controlling the tests, there is no way to determine which results correlate to each switch. The incestuous nature of having the network element become the network tester by installing virtualized test capabilities creates additional points of failure. In this case, both the network element and optical modules raise questions when test results between interoperable devices yield inconclusive results.

A separate test instrument, such as the one shown in Figure 4, solves this problem because it has its own "golden" reference, so determining the results for each network element is easier and any issues can be located faster. For example, duplicating the same test environment and parameters taken from one network element can be achieved on different manufacturers' devices, regardless of control plane and management environment. In the event that one manufacturers' device yields opposing results, the independent test reference

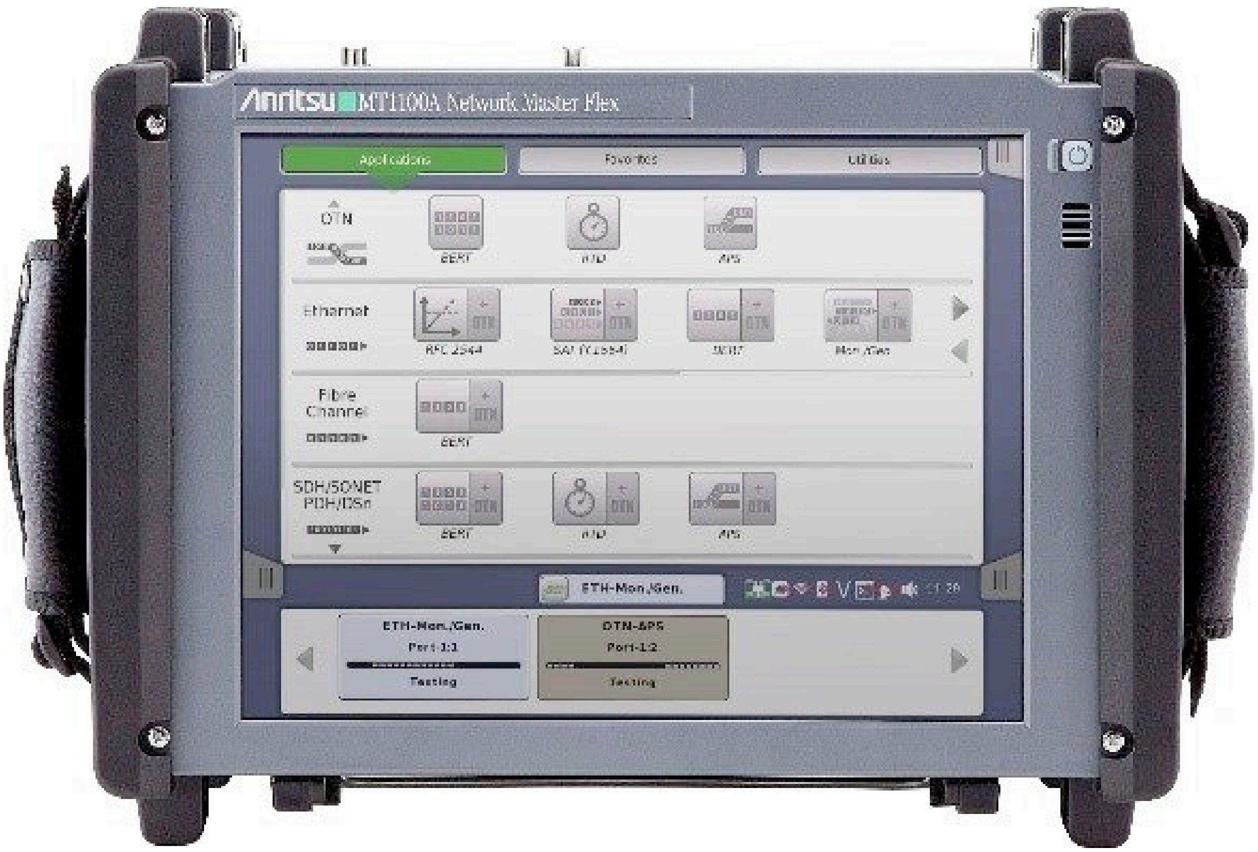


**FIGURE 4.** *Separate test instruments with a "golden" ratio more effectively test networks.*

can capture, troubleshoot, and report the results that can be duplicated without removing the network element nor virtual test instance.

Instrument flexibility is also critical, enabling operators to save time and money. Test sets need to support legacy and emerging transport technologies, as well as rates from DS1 to 100 Gbps, so they can conduct measurements anywhere in the network, including inside the metro, access, and core.

Virtualized tools for monitoring network performance, reliability, and dynamic traffic management that communicate through the control plane are significant reasons to migrate to SDN architecture. However, the need for independent testing and troubleshooting from reference is required in the data plane.

Not any separate test approach can be used to monitor networks during this migration to SDN networks. These environments require test instruments that support forward error correction (FEC) performance tests using Poisson distribution random errors. Adopted by ITU-T O.182, these tests are important because the FEC section is one of the most vital areas of the network frame. It allows for greater decibel range between equipment by correcting errors within the frame at the receiver end.

Reproducible, accurate FEC error correction tests are performed by generating truly random signal errors that can stress OTN FEC. This capability enables a much lower BERT measurement to ensure testing to the limit or beyond the switching equipment's ability. This is necessary to accurately measure the actual performance and threshold of an OTN.

**Network Monitoring**

To maintain network performance and efficiently troubleshoot issues, test platforms need to support section monitoring (SM) and path monitoring (PM) of an OTN, each of which has different alarms and error detections. These maintenance signals, as they are called, send feedback on issues that occur at the network far end and offer an indication of the layer in which they occurred. Among the indications are:

- Backward Defect Indication (BDI): indicates signal fail in the upstream
- Backward Error Indication (BEI): indicates the number of errors detected in the upstream
- Incoming Alignment Error (IAE): detects error by BIP-8 code in the OTU layer
- Backward Incoming Alignment Error (BIAE): counts the IAE errors in the upstream in the out.

Network engineers and technicians use these OTN maintenance signals to quickly and correctly locate an issue, so they know the position in the network where testing should begin. Use of these signals also enables issues to be prioritized. For example, Layer SM will have a higher priority because it is likely a core issue, whereas a PM problem is most likely a single customer issue.

Taking this Tandem Connection Monitoring (TCM) approach makes it easy to identify the customer or segment level affected. With this information, operators can ensure that issues affecting high-priority customers are corrected first.

Additionally, understanding the various TCM levels that are being analyzed or injecting errors identifies the section where there is a problem.

**Conclusion**

SDNs are evolving to enable networks to effectively and efficiently meet ever-growing bandwidth needs. The transition from traditional network environments to SDN is a complex process that poses many challenges to operators who must maintain high QoS and customer retention. The most effective way to ensure that this move will be done seamlessly is to use separate test instruments with a "golden" reference rather than integrating test software into the SDN.

**DANIEL GONZALEZ** is digital/optical business development manager for Anritsu Co. He has more than 16 years in application planning, development, digital and optical transport testing, training, and execution with knowledge in technologies including TDM, SONET, OTN, ATM, Carrier Ethernet, and physical layer signal integrity. He also is a member of IEEE.

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# 10G-PON Is around the Corner with New Test Challenges

By **NANCY LEE,** VeEX Inc.

**AS FIBER TO** the home (FTTH) deployments with GPON continue at an ever-increasing rate, the constantly growing demand for internet video streaming has service providers already conducting trials of 10G-PON, with plans for deployment imminent. Various standard bodies (ITU, FSAN, IEEE) have adopted their own PON standards. The International Telecommunications Union (ITU) published the GPON standards between 2003 to 2009 (ITU-T G.984.3) but, recognizing the continued demand for network speed would only continue to grow, added the 10G XG-PON standard (ITU-T G.987) in 2010. Existing GPON networks can usually be upgraded to overlay XG-PON transmission on the same physical plant; however, the system polarization-mode dispersion (PMD) limitation will ultimately define the maximum physical distance.

In an effort to further extend the reach for GPON beyond PON optical distribution network (ODN) limits, ITU G.984.6 approved the addition of reach extenders or RE (optical amplifiers or repeaters). An RE can be inserted mid-span between the optical line terminal (OLT) and ODN. The section between OLT and RE is called the optical trunk link (OTL), which extends the total physical plant between the OLT and optical network unit (ONU) to 60 km. Unfortunately, pre-existing GPON testers will not be able to test networks with 10G-PON transmission.

### What is PON?

A passive optical network (PON) is the section of a communication network that includes everything between two active elements: the OLT and the ONU/ONT. A PON uses optical wavelength-division multiplexing (WDM) so a single fiber can be used for both downstream and upstream transmission to support quad-play services: data, IPTV, voice, and security.

The OLT broadcasts the same data to all ONUs/ONTs. An ONU/ONT can recognize any data specifically targeted for it by filtering data using ONU-ID (Alloc-ID). Since all active ONU/ONT upstream signals transmit using a 1310 nm; a time-division multiplex (TDM) format must be used to manage and grant timeslots in which each ONU/ONT is allowed to transmit to the OLT. The OLT determines the distance and time delay of each subscriber. Then the total available bandwidth is divided between all ONUs so each user only gets a fraction. The upstream transmissions, via burst-mode operation, are allocated on an as-need basis by the OLT for each ONU/ONT that needs to send data. Because the TDM method involves multiple users on a single transmission, the actual upstream data rate is always less than the maximum available bandwidth due to sharing.

The typical split of a single fiber (PON port) is 1:32 or 1:64. A PON port therefore can service up to 32 or 64 subscribers. The maximum number of subscribers can be 16,384, which equates to 32 PON ports using a 1:64 split. On rare occasions, a split ratio of up to 1:128 is used. To provide service over a larger geographical area, the PON can also be deployed with a cascaded split (ex: 1x4 followed by 1x16 split).

**GPON**

GPON specifies downstream transmission at 1490 nm will be 2.488 Gbps and upstream transmission at 1310 nm will be 1.244 Gbps. IPTV can be transmitted using 1490 nm, but to minimize congestion, some service providers broadcast their video content using RF video (as in RF over Glass, or RFoG) at 1550 nm downstream. When interactive video is required, then a fourth wavelength must be used (1590 or 1610 nm, vendor dependent) for the video return path signal.

As for the data format, the original GPON packets can handle ATM packets directly. Recall that ATM packages everything in 53-byte packets with 48 bytes for data and 5 bytes for overhead. In 2008, the GPON standard removed direct ATM and only called for the use of a generic encapsulation method (GEM) frame to carry protocols. GEM can encapsulate Ethernet, IP, TCP, UDP, T1/E1, video, VoIP, or other protocols as called for by the data transmission.

The GPON network must be tested to verify levels and that reflectance does not exceed system limits:

1. Span length must be < 20 km (Class C+ < 60 km) and the span loss budget must be met.
2. A fiber scope must be used to inspect connectors and ensure they are free of contaminants, dents, and scratches. Use cleaning tools to clean contaminants. Dents or scratches can create insertion loss and reflectance.
3. Downstream and upstream launch power must meet specifications.
4. A PON meter must be used to confirm signal levels are acceptable per standards.

There are three primary classifications for GPON are Class A, B or C (see Table 1).

Table 1. GPON 2.48/1.244-Gbps Span Budget

| | Class A | Class B | Class B+ | Class C | Class C+ |
|---|---|---|---|---|---|
| Min. Span Loss Budget G.984.2 | 5 | 13 | | 15 | |
| Max Span Loss Budget G.984.2 | 20 | 28 | | 30 | |
| Min. Span Loss Budget G.984.2/Amd 2 Digital Only | 5 | 13 | 10 | 15 | |
| Max Span Loss Budget G.984.2/Amd 2 Digital Only | 20 | 28 | 28 | 30 | |
| Min. 1490nm Loss Budget G.984.2/Amd 2 Vid Overlay | 5 | 10 | 9 | 15 | 17 |
| Max 1490nm Loss Budget G.984.2/Amd 2 Vid Overlay | 20 | 28 | 27 | 30 | 32 |
| Min. 1310nm Loss Budget G.984.2/Amd 2 Vid Overlay | 5 | 10 | 13 | 15 | 17 |
| Max 1310nm Loss Budget G.984.2/Amd 2 Vid Overlay | 20 | 28 | 29 | 30 | 32 |

**10G-PON Upgrade Path**

10G-PON (also known as XG-PON G.987) may be the logical next-generation deployment strategy, but today one can choose XG-PON or XGS-PON (G.987.2 and IEEE 802.3 physical layer standards) as an intermediate step to reach multiwavelength NG-PON2 (G.989.3). The XG-PON network architecture can consist of a single passive optical distribution segment (ODS) or a group of passive ODSs interconnected with reach extenders (REs). The optical configuration for XG-PON enables the co-existence of GPON and 10G-PON transmissions using WDM filters and additional bandpass filters (Figure 1).

NG-PON2, developed by ITU in 2015, defines a PON architecture capable of supporting total network throughput of 40 Gbps using four symmetric upstream/downstream wavelengths available to each subscriber. The NG-PON2 standard is unique in its use of active tunable filters and a tunable laser in the ONU. XGS-PON is a subset of the NG-PON2 standard; for TWDM-PON within NG-PON2, the

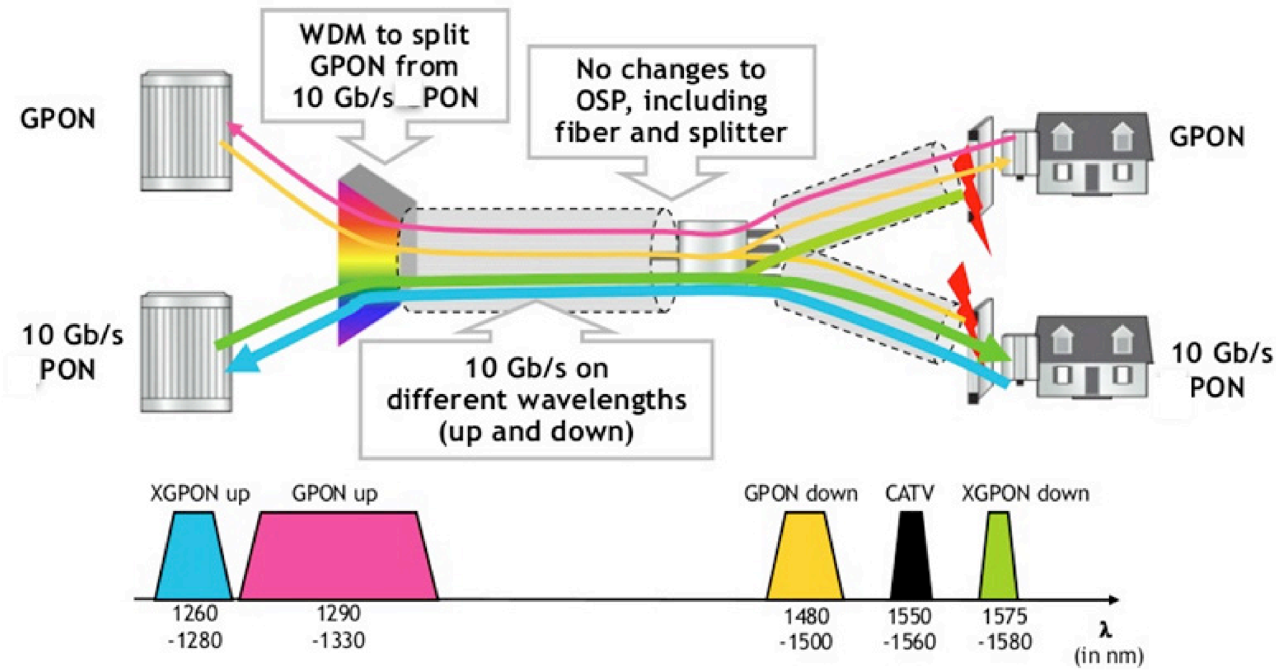


**FIGURE 1.** *Upgrade for 10G-PON wavelength overlay in both uplink and downlink.*

eight-channel wavelengths are defined. The table below highlights some of the unique aspects of the PON networks.

**Table 2. Unique Aspects of Three PON Approaches**

| | GPON | XG-PON (10G) | XGS-PON (40G) |
|---|---|---|---|
| Downstream 2.48 Gbps | 1490 nm | 1490 nm | 1596–1603 nm |
| Downstream 10 Gbps | | 1577 nm | 1596–1603 nm |
| Max DS # channels | | 2 | 4-8 @ 100GHz channel spacing |
| 10G DS In-band crosstalk tolerance | | | 35.3 dB |
| RF Overlay Downstream | 1550 nm | 1550 nm | 1550 nm |
| Upstream 1.24 Gbps | 1310 nm | 1310 nm | 1310 nm |
| Upstream 2.48 or 9.95328 Gbps | | 1270 nm | 1524-1544 (wide band) |
| | | | 1528-1540 (reduced band) |
| | | | 1532-1540 (narrow band) |
| Upstream channel spacing | | | 50-200 GHz |
| US crosstalk tolerance | | | 31.9 (Type A link) |
| | | | 27.9 (Type B link) |
| Max. fiber length ODN | ≤ 20 km | ≤ 20 km | ≤ 20km (DD20) |
| Max TC layer fiber distance | | ≤ 20 km | ≤ 40 km (DD20) |
| Max Differential fiber step | | 20 km | 20 km |
| Max differential optical path loss | | | 15 dB |
| Min ORL of ODN at R/S | | | 32 dB |
| Max single element Reflectance | | | -35 dB |
| Dispersion delay limit | | 10 ps | 10 ps |

The debate over the best architecture to deploy for 10G-PON remains ongoing, but for the U.S. market, it appears that XGS-PON may be winning the battle at the moment.

## PON Testing

In the past, some companies installed GPON networks using pre-existing construction tools such as OTDRs, light sources, and traditional broadband power meter. GPON infrastructures are less forgiving than 10G-PON, so this practice is not recommended for the following reasons:

1. upstream traffic is "bursty in nature" and cannot not be tested unless the ONU is authorized by the OLT downstream traffic
2. broadband meters (InGaAS) are not pass-through meters and do not contain filters to isolate specific transmissions. On a WDM network, total transmission span power will be measured regardless of user wavelength settings.

In Figure 2 below, we illustrate how a broadband optical power meter (OPM) differs from a GPON and XG-PON meter:

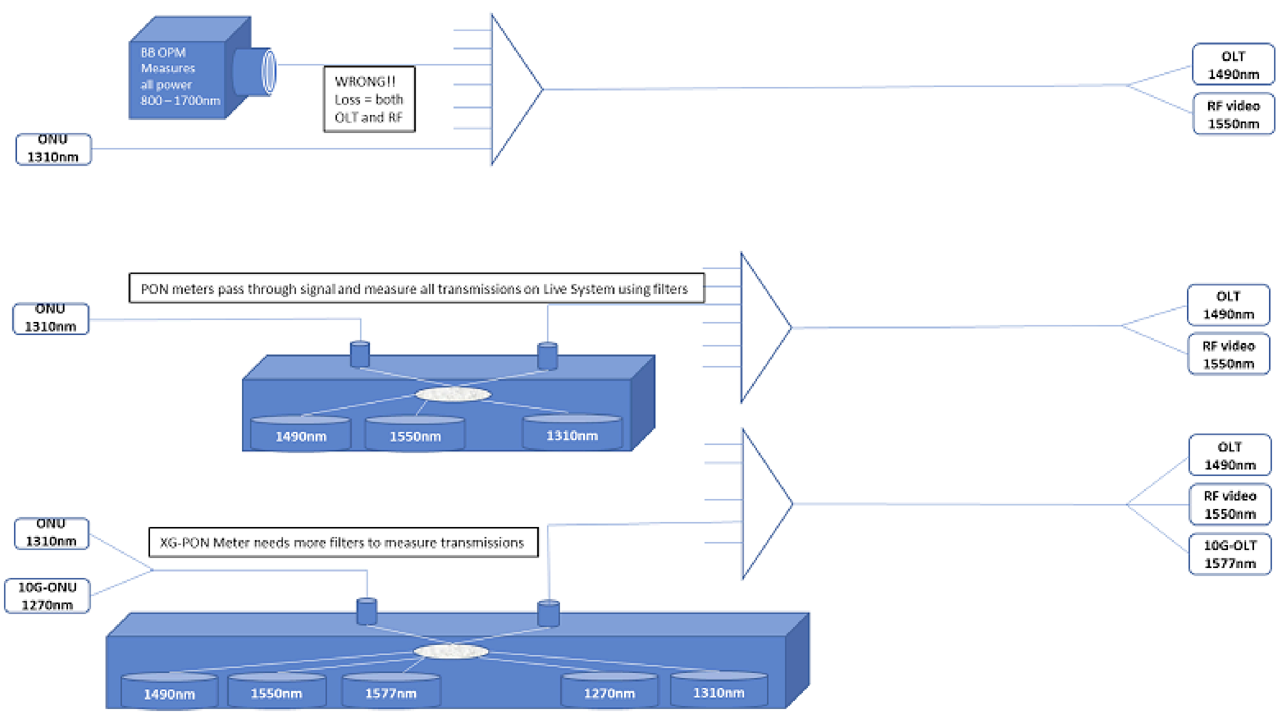


**FIGURE 2.** *How operation of a broadband optical power meter (OPM) differs from a GPON and XG-PON meter.*

As you can see, broadband OPMs are useful during the construction of a PON network, but once the network is in service, this type of basic meter is not practical. A GPON meter is a pass-through meter that has WDM/filters and dedicated receivers for each transmission wavelength. Using this type of meter, a technician is able to check all transmission levels (1310/1490 and optionally 1550 nm) prior to new service activation. For GPON networks that have RF overlay and need a return-path wavelength checked, one could use a broadband OPM provided you check the set-top box signal before it is merged into the ONU. To test 10G-PON, not only must we add additional receivers, to ensure no crosstalk exists, we must also incorporate band-pass filters, not just WDM to provide the necessary isolation for 1550- and 1577-nm transmission.

PON test tools are categorized as physical layer or higher-layer tools. The following test tools are recommended to diagnose faults between the OLT and ONU/ONT:

Physical Layer Field Tools (see Figure 3)

- Optical time-domain reflectometer (OTDR) with 1625- or 1650-nm filtered testing, to diagnose faults without disrupting service.
- Optical power meter (broadband or PON) and light source to measure span budget and OLT/ONT transmission power.
- Optical return loss (ORL) meter to test span return loss.

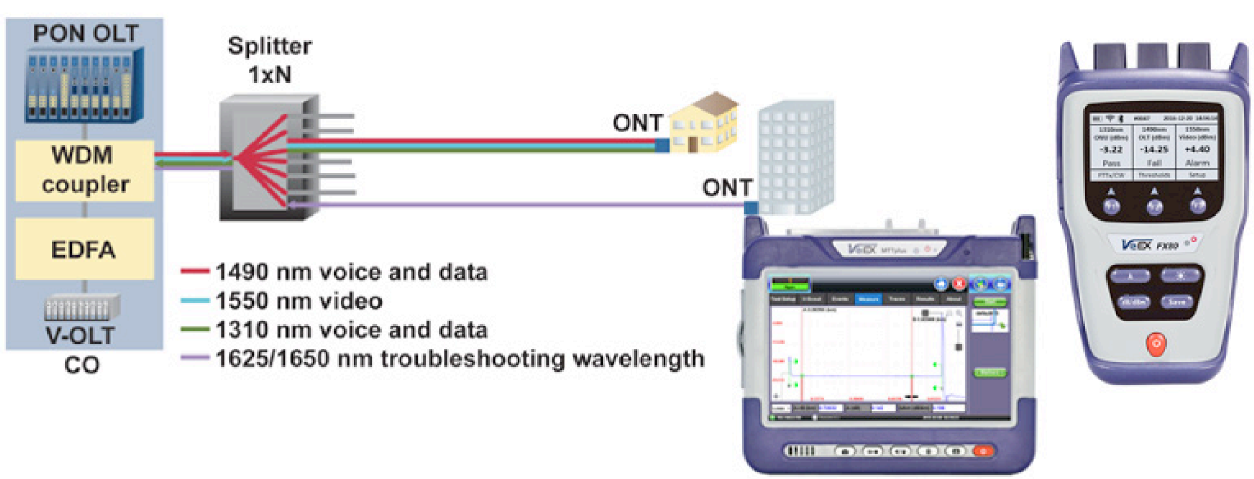


**FIGURE 3.** *Physical Layer field tools.*

Higher Layer Tools (Figure 4)

- Polarization mode dispersion (PMD) tester to verify dispersion is within system limits.
- PON Analyzer to troubleshoot alarms/errors at the customer premises and monitor PLOAM and OMCI messages between the OLT and ONU.
- Optical channel analyzer to verify co-existence of GPON and XG-PON downstream signals and identify potential crosstalk issues.

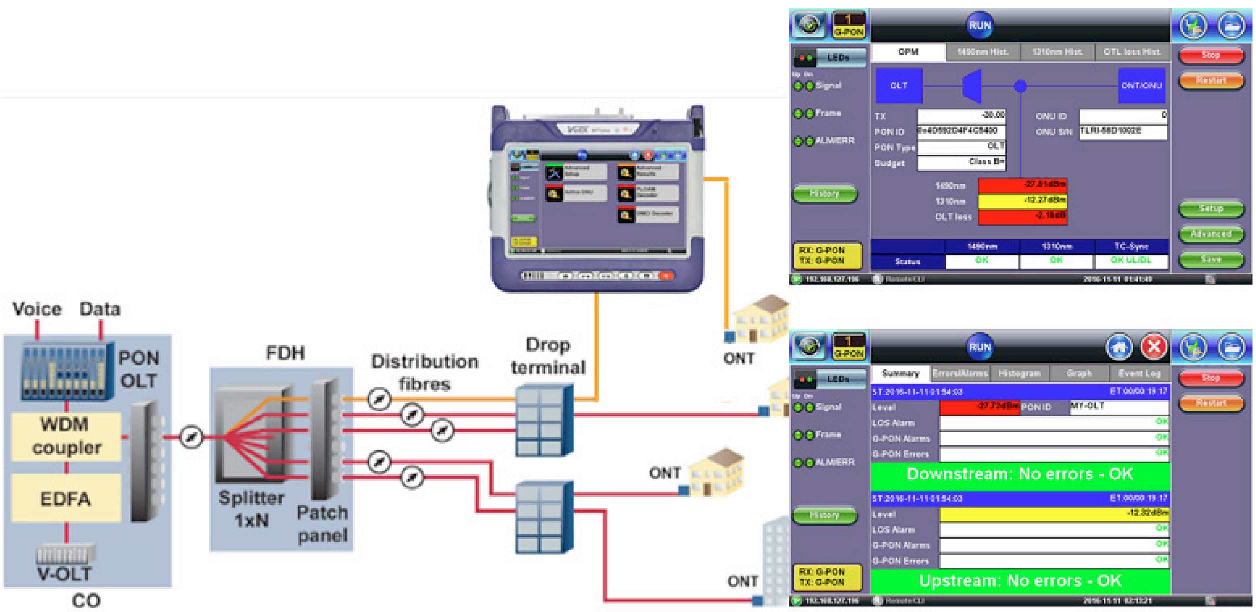


**FIGURE 4.** *Higher layer field tools.*

The table below summarizes the difference in tools recommended to ensure successful upgrade from GPON to 10G GPON.

While one can certainly argue about the cost/benefit of outfitting fields technicians with all the tools shown above, one cannot argue with the fact that 10G-PON will eventually make GPON test sets obsolete. So when budgeting for a 10G-PON upgrade, don't forget to budget for new tools to support your 10G upgrade endeavors.

| Table 3. Recommended PON Tools | | | | |
|---|---|---|---|---|
| | | NG-PON | NG-PON2 | |
| | GPON | XG-PON1/2 | XGS-PON | Purpose |
| OTDR | Yes | Yes, 1650 nm(F) | Yes, 1650 nm(F) | If 1610-nm return path used, use 1650-nm(F). Locate breaks/microbends/event reflectance |
| LS + BB OPM | Yes | Yes | Yes | Verify span loss during construction |
| ORL Meter | Optional | Yes | Yes | Reflections will interfere with 10G transmission more than 1G |
| PON meter | Yes, GPON | Yes, 1/10G GPON | Yes, 1/10G GPON | Verify In-service signal levels |
| PMD Tester | No | Yes | Yes | Verify dispersion does not exceed system limits |
| PON Analyzer | Yes, GPON | Yes, 1/10G GPON | Yes, 1/10G GPON | Verify In-service signal levels and physical layer protocol analyzer |
| 50GHz Optical Channel Analyzer | Optional | Optional | Yes | Verify co-existence of channels and no crosstalk issues |

**References:**

1. ITU-T G.984.2 (03/2003) Gigabit-capable Passive Optical Networks: Physical Media Dependent layer specification
2. ITU-T G.984.2 Amendment 1(02/2006) New Appendix III – Industry best practice for 2.488 Gbit/s downstream, 1.244 Gbit/s upstream GPON
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# Challenges in Next-Gen PON Deployment

By **WOLFGANG MOENCH** and **DOUGLAS CLAGUE**, Viavi Solutions

**PASSIVE OPTICAL NETWORKS** (PONs) are increasingly viewed as a crucial element of current and future broadband access networks. The massive deployment of PONs is driven by growing bandwidth demand, primarily fuelled by high-speed internet traffic. This evolution is driving a need for higher bandwidth in the downstream. Adding to that, growing services such as online gaming, file sharing, and cloud computing will generate more symmetrical traffic. It's apparent that in the long-term, optical access will have to evolve towards symmetrical traffic transport.

For next-generation passive optical networks (NG-PONs), service providers expect improved bandwidth and service support capabilities over their existing PONs. While NG-PON2 networks are considered the most promising approach, service providers do have to deal with evolving standards.

### Evolving Standards

As with any network, the equipment used with PON must adhere to standards for operation. These are set by the ITU and IEEE groups and, in the case of the ITU, will address GPON (Gigabit PON), XGS-PON (10-Gbps PON), and NG-PON2 standards. For the most part, GPON is what we see in use today. But current GPON and IEEE EPON standards do not enable further scaling of subscriber count or capacity to reach end-user bandwidth requirements.

The next steps will be to increase service capacity and become symmetrical. The table below illustrates the standards and rates and how next-generation PON will increase capacity (and revenue). Current GPON delivers data rates of 2.4 Gbps downstream and 1.2 Gbps upstream. For satisfying high-bandwidth demands NG-PON2 standard G.689 was established by ITU-T. A time- and wavelength-division multiplexing approach (TWDM) was selected, bundling multiple wavelengths in the downstream and upstream directions. The overall bandwidth can therefore be increased to 40 Gbps downstream/10 Gbps upstream using four channel/wavelengths at 10/2.5 Gbps rates.

**TABLE: PON STANDARDS AND TRANSMISSION RATES**

| | GPON | XGS-PON (sym) | NG-PON2 | GE-PON | 10G-EPON | 100G-EPON |
|---|---|---|---|---|---|---|
| Standards | ITU-T G.984 (2003) | ITU-T G.9807.1 (2016) | ITU-T G.989 (2015) | IEEE 802.3ah (2004) | IEEE 802.3av (2009) | IEEE 802.3ca (2019 TBD) |
| Downstream/Upstream Data Rates | 2.4 / 1.2 Gbps | 10 / 10 Gbps | 40 / 10 Gbps | 1.25/1.25 Gbps | 10 / 10 Gbps | Up to 100 /100 |
| Splitting Ratio | up to 1:64 (128) | up to 1:128 (256) | | up to 1:64 | up to 1:128 | TBD |
| Coexistence | N/A | Yes, with G-PON | | N/A | Yes, with GE-PON | |

The optical distribution networks (ODNs) account for 70% of the total investments in deploying PONs. Therefore, it is crucial for the NG-PON evolution to be compatible with the deployed networks such as GPON. With NG-PON2 using multiple wavelengths, there is a need for tunable transceivers in the optical network terminals (ONTs) at the customer premises. Currently, low-cost tunable receivers are not yet available; therefore, many operators envision an intermediate step using XGS-PON before migrating to NG-PON2. XGS-PON uses less expensive fixed lasers and receivers in the C-Band and therefore provides a better business case.

Today's GPON systems use 1490 nm as a downstream channel and 1310 nm as the upstream. XGS-PON uses 1578 nm downstream and 1270 nm upstream, which means you can overlay the XGS-PON service on the same plant as the GPON service. NG-PON2 uses the G.989 standard, which is a multi-wavelength access standard that supports TWDM technologies (see Figure 1).

To physically implement the migration or activation of newer PON services requires network changes, especially in the central office. For leveraging existing ODNs, a coexistence element is needed. This can have different configurations depending on the technologies that the service provider wants to deliver. Essentially, it's a passive optical coupler to combine GPON, XGS-PON, and NG-PON2 services up and downstream.

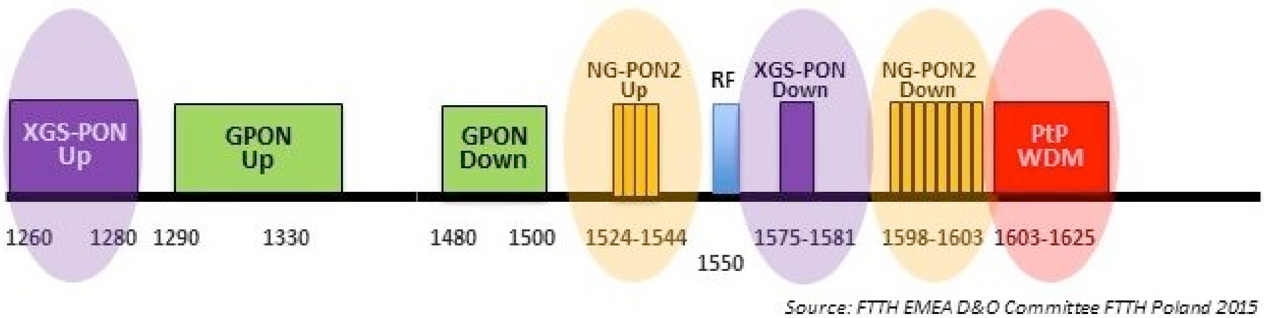


**FIGURE 1.** *The various PON standards have been developed to promote backwards compatibility, enabling the same fiber to support multiple PONs.*

The new NG-PON2 transmissions enable service providers to increase the FTTH networks' bandwidth capacities and reduce deployment costs by sharing the same fiber with more connected customers, or even by sharing networks with multiple operators. The new NG-PON2 standard, using transmission wavelengths in the 1535-nm region for upstream transmission and in the 1600-nm region for downstream transmission, employs more of the same fiber deployed and allows seamless overlays of new services to existing GPONs.

### New Challenges

No matter where you are in the ODN, connector cleanliness and condition is critical. Fiber is often installed in harsh environments (e.g. dirty cellars) and damaged or dirty connectors can severely degrade service performance. Despite this, service providers or their contractors might opt not to test completely. One of the rationales is time—time per job, per inspection, and per number of connectors. Without testing, the risk is poor-quality installations and therefore poor service. Simply put, the impact of faulty installations will be customer churn.

There are several failure risks that can affect the success of roll out plans, migration timelines, service quality, and churn rates (see Figure 2). Here are some of the vulnerabilities exposed with all variants of PON services/standards:

:: Dirty connectors, bad splices, and microbends that add loss, which means the total ODN loss no longer meets the standards; such conditions lead to intermittent or poor service (or no service)

:: Splitter elements can be faulty

:: Transposed fibers caused by human error when connecting a fiber to a wrong splitter port

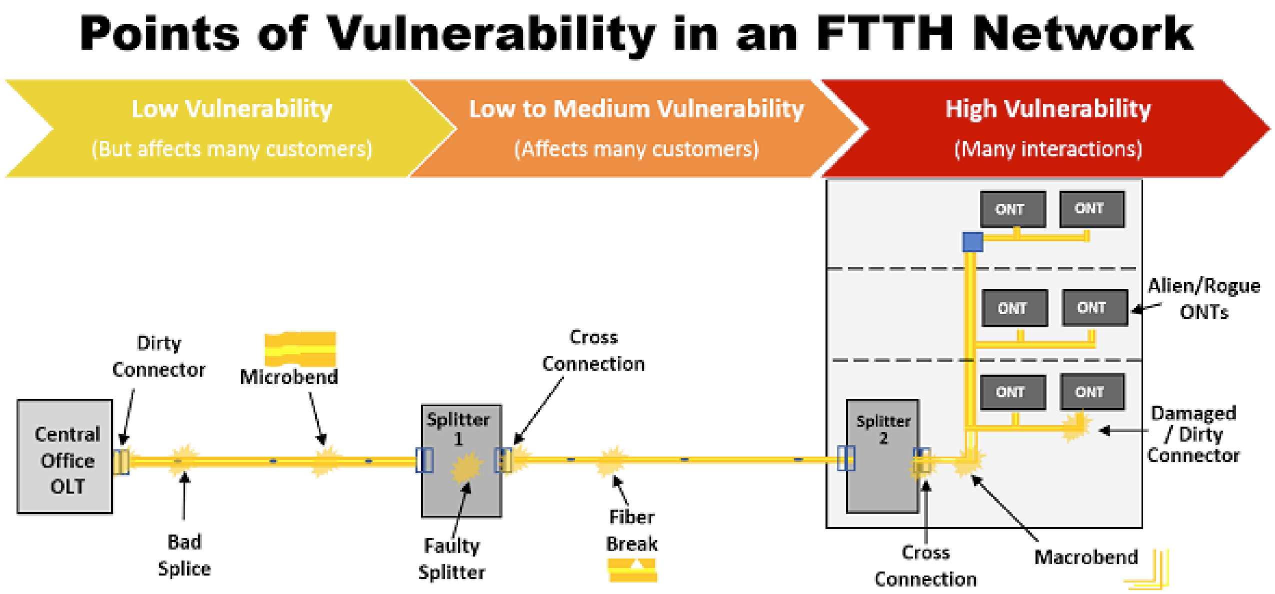


**FIGURE 2.** *There are several points on a typical PON where trouble might arise.*

- Rogue ONTs that transmit outside of their allocated upstream time slot, which results in upstream clashes with other ONTs and service disruption
- Alien devices, where a subscriber has accidentally installed other devices than an ONT (e.g., a media converter). These devices may send continuous upstream traffic that interferes with other ONTs in the PON and degrades or interrupts the service.

Even greater vulnerabilities exist around in-house cabling. As with any fiber connection, making sure end faces are clean and free from any damage is key. Macrobends due to bad cable installation practices are a key issue to be aware of for XGS- and NG-PON2 deployments. Those services are using higher wavelength bands (>1550 nm) that are more sensitive to bending loss. Installers, contractors, and subscribers may simply not be aware of the issue that small bending radius in indoor cable installation will cause excessive loss and degrade service performance. Even when using new bend-insensitive G.657B fibers, bending loss may reach more than 1 dB when cabling radius reaches values <7.5 mm (e.g., around corners). Having an installer perform this check as part of an install is relatively easy to implement, but subscriber self-installs remove that assurance. In fact, self-install may not be the best approach for higher-speed, higher-revenue services like XGS-PON and NG-PON2.

While evolving networks and standards mean things are getting more complicated, test equipment should remain simple to use to ensure job and workflow efficiency. Testing does take time, but bad installations result in re-work, repeat truck rolls, and delays in activation. Installers need to inspect every time they make a connection. Proper qualification during construction means doing testing not only at 1310/1550 nm but also at 1625 for NG-PON2, storing of test results, and for contractors, easy submission of results (to get paid quicker).

For service activation, power levels of all downstream and upstream services must be verified. With the use of new wavelengths for XGS-PON as well as for NG-PON2, there is a need for new PON power meters, like Viavi's OLP instruments, that enable wavelength-selective, through-mode power measurements.

Support for on-going operations requires troubleshooting tools that won't disrupt those existing services, in order to be used in-service and be future proofed avoiding those XGS-PON and NG-PON2 wavelengths means using 1650nm.

There is also a case to be made for centralized PON monitoring to reduce service outage time and mean time to repair (MTTR) and guarantee high quality of service for high-speed access networks.

Next-generation PONs will help service providers launch and sell in-demand, on-demand services to their customers. However, as we know, innovative technologies can bring new challenges – especially during the time of evolution from one standard to another. While NG-PON2 is a very promising approach, it does come with new considerations that are best mitigated with consistent, basic testing during construction, installation, and deployment. After all, higher capacities mean more services are riding on their networks—which means more reward, but also more risk.

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Anritsu Company is the United States subsidiary of Anritsu Corporation, a global provider of innovative communications test and measurement solutions for 120 years. Anritsu's "2020 VISION" philosophy engages customers as true partners to help develop wireless, optical, microwave/RF, and digital instruments, as well as operation support systems for R&D, manufacturing, installation, and maintenance applications. Anritsu also provides precision microwave/RF components, optical devices, and high-speed electrical devices for communication products and systems. The company develops advanced solutions for 5G, M2M, IoT, as well as other emerging and legacy wireline and wireless communication markets. With offices throughout the world, Anritsu has approximately 4,000 employees in over 90 countries.

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**LINKS:**

- Industry's Smallest-in-class 100G Tester
- Network Master™ Pro Product Page
- CPRI RF on the Network Master Pro – video

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**LINKS:**

- Main Website
- OFC 2017 Exhibitor Video
- FX150 Handheld OTDR Video
- RXT-4111 DWDM OTDR Module Video
- Fiber Experts page

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**LINKS:**

- White Paper: Qualifying FTTH Networks before Equipment Installation
- Video: FiberChek Probe
- Poster: Do you Inspect Before You Connect?
- Web Page: Market's Lightest, Most Portable DWDM OTDR
- White Paper: Important Factors for Choosing an OTDR

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**LINKS:**

- Events
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