

Exploring a New and Innovative FTTH Testing Approach

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INTRODUCTION

With bandwidth demand growing much faster than revenue, providers must find innovative ways to connect more homes to their FTTH network in order to market their services as quickly as possible. To do so, they not only have to hire a significant number of new technicians, they also have to shift their current copper technicians to fiber, which leads to many new challenges.

First, new technicians lack expertise, which increases training time. Second, very few experienced copper technicians will be able to efficiently test and troubleshoot fiber from day one. Given the massive quantity of fibers to test, the chances of misdiagnoses and incorrect characterizations by untrained technicians are high. This will ultimately result in turn-up failures and construction-phase errors requiring one or more truck rolls, which will have a direct impact on OPEX. Is there an innovative link-validation test that allows us to use fewer, not-necessarily-trained technicians and less test equipment? Is it possible to certify part of or an entire link when testing from the central office?

Managing test data is also part of the FTTH testing challenge. At the moment, optical layer test data are fragmented and dispersed, as well as product-oriented. We believe operators could use a unique, open solution that would be easily parsed by any system or application, offering more automated processes and continuous network performance evaluations.

BACKGROUND INFORMATION AND TERMINOLOGY

For clarity, a "link" is any fiber span between an ONT and an OLT network and a "line" is any link terminating at a single OLT.

The solution detailed herein is an "intelligent" OTDR. Essentially, it's a software application that runs on a test unit that is able to set and take multiple and valuable acquisitions and analyze them to generate detailed information about every element on a link. It does this in a single-button operation, providing maximum simplicity for expert-level link characterization. This new test method makes every technician a fiber-optics expert, whether they are testing in the field or from the central office. Plus, it doesn't require the parameter settings used in traditional OTDR testing, which means no distance, no pulse width, no averaging time setting and no detection threshold setting required.

This technique, which is the natural evolution in reflectometry, is designed to automate and simplify the OTDR test process. It stems from the need to create optimal testing technology for PON networks. Everyone will agree that this is the most challenging network to test because of its short links and many closely spaced elements, such as splices, connectors and splitters.

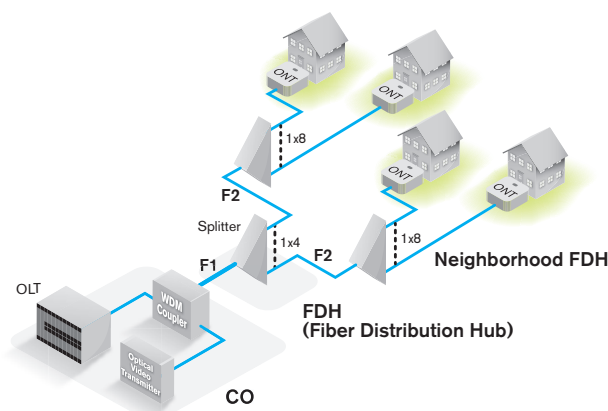


Figure 1. This standard double-stage PON network is very challenging for a technician without experience to test using an OTDR.

Although using an optical loss test set (OLTS) to characterize a link may be easier, it has one major limitation: it cannot locate the problems on the link. Furthermore, an OLTS requires two units and two technicians, thus increasing OPEX.

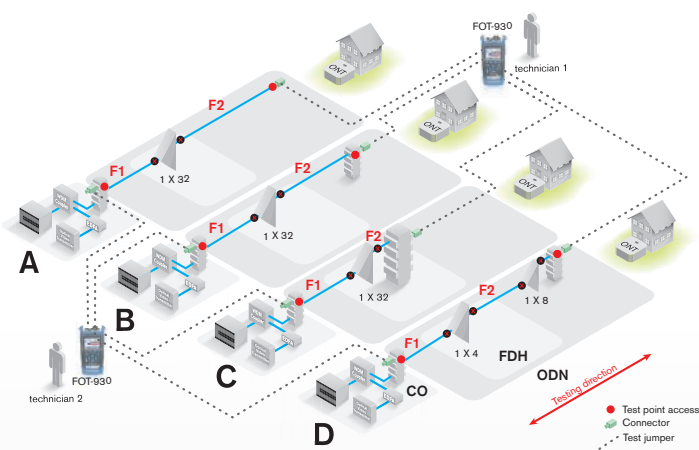


Figure 2. An end-to-end test with a pair of OLTS units is fast, but fails to locate the problem.

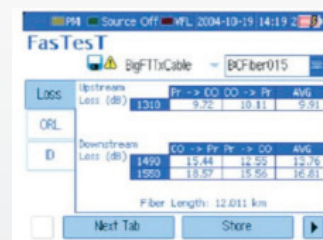


Figure 3. Example of OLTS test results: loss, fiber length and ORL.

The second option is OTDR. Any well-trained OTDR technician will be able to identify and locate problems on a link. However, the shift from copper to fiber and the increased number of deployments is diluting the number of experienced technicians. Combine this with budget compression and reduced training, and the result is an increased risk of improper testing, misdiagnoses, unusable OTDR results and repeat truck rolls.

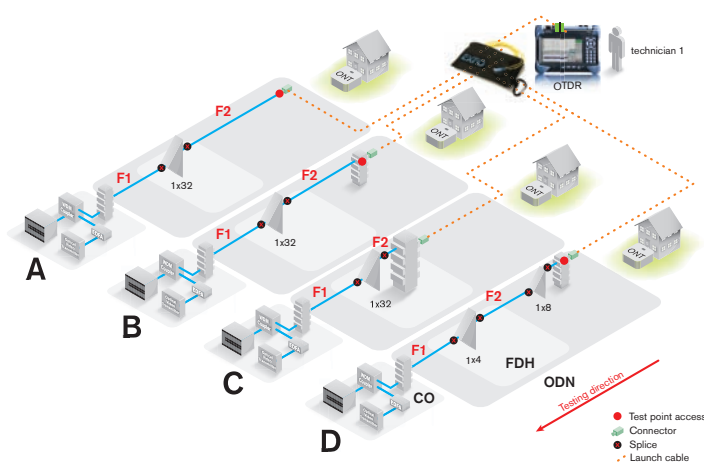


Figure 4. An OTDR test on a PON network.

The complexity of a PON link will require skilled technicians to set different parameters to get as much information as they can from a single OTDR measurement. They will also have to perform other acquisitions with other parameters to fully characterize the link.

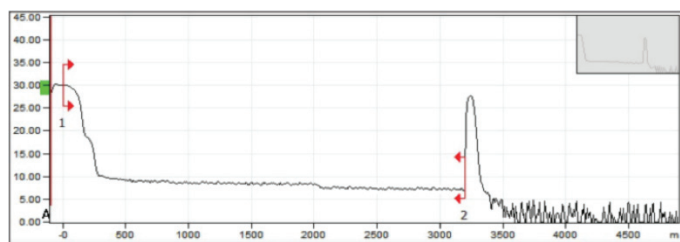


Figure 6. Incomplete OTDR test results on a 1x32 PON due to improper testing parameters.

PORTABLE APPLICATIONS

The goal is to make sure the link or line complies with the specifications: total loss, total ORL, splice loss, connector loss and reflectance as well as no macrobends.

The technique is to use a series of different pulse widths to fully characterize the many elements on a link or line (i.e., fibers installed from the CO to all splitters). In order to measure total loss and ORL, launch and receive fibers are needed. In a PON network, where the splitting ratio can be as high as 1 to 128, the recommended length of the receive fiber is at least 2 km (1.25 mi) and that of the launch fiber is 50 m (167 ft), which is enough to fully characterize the first connector. Launch and receive fibers must be of the same type (e.g., G652 to G652) so that the Rayleigh backscattering and mode-field diameter will be similar.

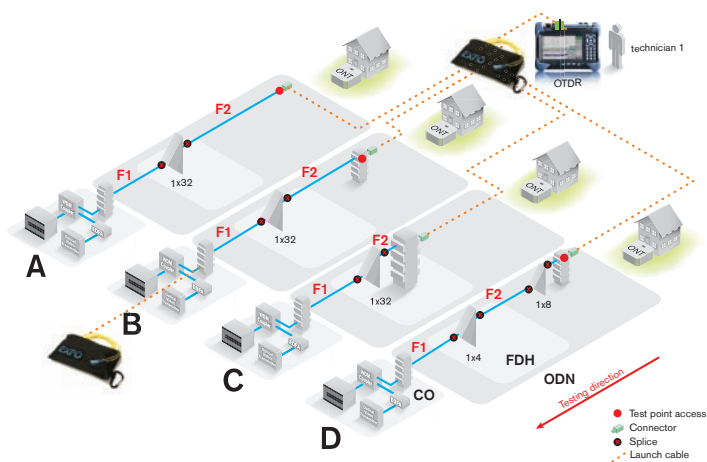


Figure 7. A portable test setup with launch and receive fibers for a PON-line certification with a 1x32 splitter.

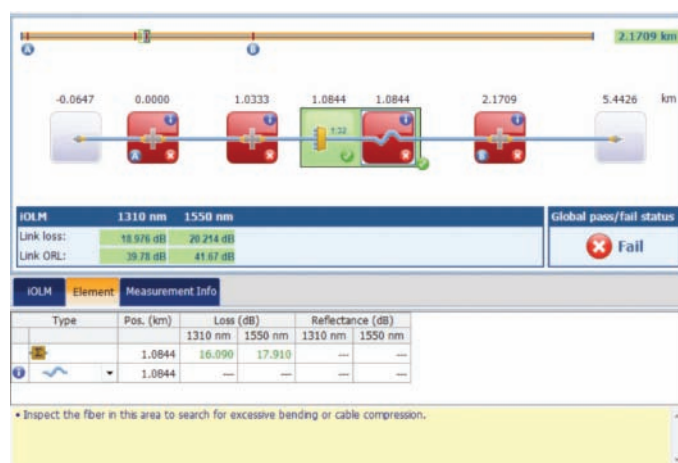


Figure 8. Example of test results. All the information, including diagnostics, is provided in a single view.

The same measurements as shown in the previous example were performed on a PON network using a light source and a power meter with a one-jumper reference, OLTS with a side-by-side reference and an ORL meter. The reference method for the loss is the power meter and the reference measurement for the ORL is the ORL meter.

IL	ONT to OLT		OLT to ONT	
New Test Method	1310 nm	1550 nm	1310 nm	1550 nm
IL (dB)	18.98	20.21	18.85	20.46
Δ IL with PM/LS (dB)	-0.14	-0.22	-0.64	-0.25
PM/LS				
IL (dB)	19.12	20.44	19.49	20.72
OLTS				
IL (dB)	18.76	20.24	18.76	20.82
Δ IL with PM/LS (dB)	-0.36	-0.20	-0.73	0.10

Figure 9. Table of IL test results from the different methods.

As shown in the table in Figure 9, the maximum IL difference between new test method and the reference method (PM/LS) is 0.64 dB, which compares favorably to the OLTS method. Based on the PM/LS and the OLTS results, an experienced technician could have suspected a macrobend on the line because the difference in loss is more than 1 dB between 1310 and 1550 nm. However, he would have no clue as to the location of the macrobend. He could therefore use an OTDR and a different combination of pulse widths to find the macrobend himself. With this new technique, all technicians will be able to clearly see that there is a macrobend immediately after the splitter (see image below of a test conducted from ONT to OLT).



Figure 10. The position of a macrobend analyzed by a portable OTDR with multi-pulse acquisition and analysis capabilities.

This is a one-end, single-unit testing method that provides clear diagnostics and discovered elements in a single view.

IL	ONT to OLT		OLT to ONT	
New Test Method	1310 nm	1550 nm	1310 nm	1550 nm
ORL (dB)	39.78	41.67	39.96	42.83
Δ ORL with ORL meter (dB)	0.84	0.57	-0.02	-0.15
PM/LS				
ORL (dB)	38.94	41.1	39.98	42.98
OLTS				
ORL (dB)	39.14	41.26	40.00	43.20
Δ ORL with ORL meter (dB)	0.20	0.16	0.02	0.22

Figure 11. Table showing the different ORL test results.

Based on the ORL measurements, the maximum difference between the ORL meter and our new test method is 0.84 dB, which is small enough to locate any ORL issue. So what is causing an ORL issue on the line? It's connector reflectance, but according to the ORL results, we are below the 32 dB threshold. Now, if we look at the results below, we can see that there is one high reflective connector that needs to be fixed (exceeds the -55 dB threshold). This is what we are looking for when testing with an ORL meter (or OLTS) in both directions. We want to know the direction of the high ORL because that's where the high reflective connector is. Obviously, we would have missed it with the ORL meter or the OLTS.

Type	Pos. (km)	Loss (dB)		Reflectance (dB)	
		1310 nm	1550 nm	1310 nm	1550 nm
	1.0319	0.374	0.352	-51.4	-52.1

Figure 12. Results showing a connector exceeding the reflectance limit of -55 dB.

In this case, placing a receive fiber at the CO allows the technician to validate the entire line (32 subscribers). Unlike an OLTS, the tech will not only know that he has a problem, he will also see where the problem is and obtain diagnostics on how to fix it. The ultimate goal is to accelerate deployment and minimize truck rolls. Can the same method be used with a traditional OTDR? Yes it can, but the technician will also have to use multiple pulse widths to characterize each element as well as a long pulse width for end-to-end loss. As mentioned at the beginning of this paper, the test results will depend on the technician's skillset. Can the same measurement uncertainty be obtained using a traditional OTDR? Again, depending on the technician's skillset and because it's not a fully automated process, the results will vary from one tech to another. How much testing time will an experienced technician using a traditional OTDR need? With this fully automated test method, measuring one branch at two lambdas takes less than 2 minutes (depending on link complexity), according to an internal study conducted with experienced OTDR technicians. On the same link, it took 10 minutes to find all errors.

One problem that was revealed in this study concerns the management of all OTDR traces required to certify one line. Technicians tend to record key results on paper and save traces without consolidating the results. Many tests are performed but most of the time, the results are archived, where they are abandoned and forgotten. These problems can now be resolved because all results can be consolidated in one report and all the testing parameters and results can be stored in a single data block, for example in an XML format. The goal is to have an open and fully documented way to describe what is found and measured, and provide it in a format where all the details can be extracted for future use. Pairing this useful data with an automated process like a repair ticketing system, inventory management system and a fault management system, allows decisions to be based on the most pertinent information. For example, comparing the measurement at the time of construction (n years ago) to the new measurement will save significant problem-solving time.

We will now examine how to troubleshoot a line using this new type of test unit. In this case, the PON network is live but one subscriber is experiencing service problems. The preliminary diagnostic reveals a physical problem with the fiber and since only one subscriber is down, we suspect the problem is after the splitter. A technician is sent to the premises and without disconnecting from the splitter, he will be able, at the ONT, to measure the incoming power at 1490 nm. In this case, the power is too low.

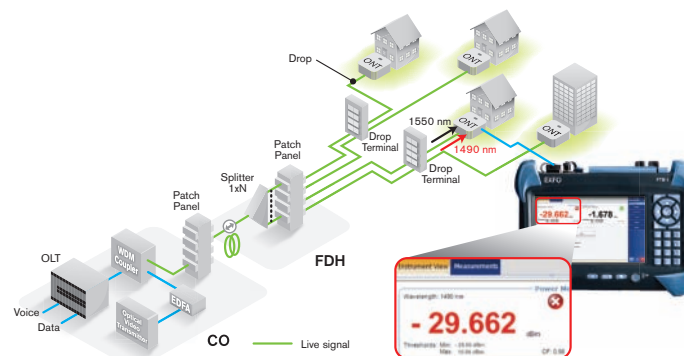


Figure 13. Example of a power measurement when troubleshooting a link.

Next, a measurement using an out-of-band test wavelength (e.g., 1625 or 1650 nm) can be taken without disrupting traffic. The technician doesn't need the receive fiber, because he is trying to locate the faults, not the end-to-end loss. If he had access to the test results from the time of construction, he could compare the before and after measurements to quickly spot the difference.

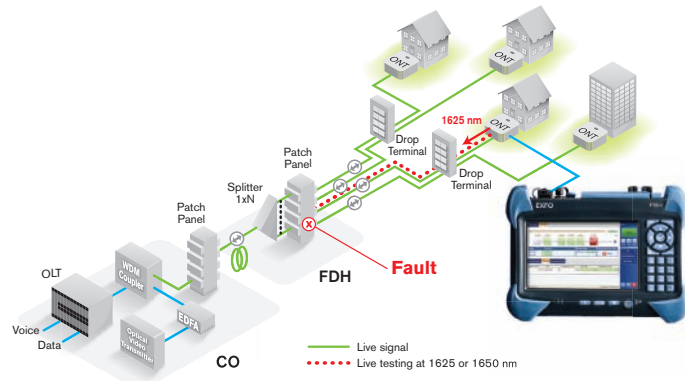


Figure 14. Typical test set-up for locating faults on a live network.

FIXED, REMOTELY OPERATED APPLICATIONS

In this section, we will discuss a well-known and well-documented approach for line certification from the OLT side that uses a passive, reflective filter at one or multiple ends of a PON line. In current deployments, this method is used to distinguish a branch, verify continuity and detect any possible degradation with respect to the standard reflectance level (i.e., to monitor the optical line independently from ONT-active equipment). One key improvement that is now commercially available is the ability to measure absolute end-to-end loss on each optical path between the CO and the endpoint using a specialized filter called a high-reflectance demarcation filter. This allows full-line certification to be done with test equipment placed on the OLT side. Obviously, the purpose is to continue to provide post-activation support and maintenance with the same test equipment by creating a birth certificate that can then be trended and used for subsequent maintenance. These enhancements were made possible by the same technology, which provides the technician or system with consistent, easy-to-interpret results.

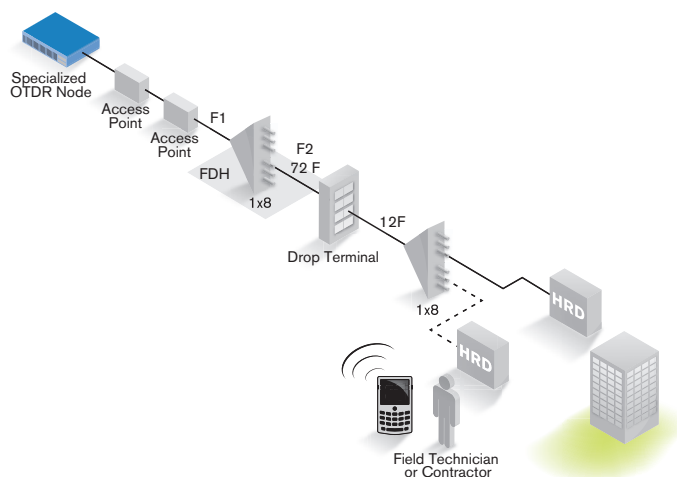


Figure 15. Highly reflective, passive filters, such as Fiber Bragg gratings also called high-reflection demarcation (HRD) filters, placed at each termination to allow tablets/PDAs with wireless connectivity to run a certification test from the node.

A HISTORY OF OTDR TESTING WITH REFLECTIVE TERMINATION FILTERS

In the mid-2000s, NTT developed and deployed a test method that allowed them to verify link integrity from the central office to the subscriber end. The measurement is obtained through an in-service PON using a standard 1650-nm OTDR at the node. In the early days of FTTH, ONUs were placed outside the house and were therefore more readily accessible. Today, most service providers opt for equipment inside the home, placing a 1650-nm highly reflective filter in the termination box inside the ONU where a jumper connects to the unit transceiver optical port. The filter is used to remotely verify that an ONT is connected to the network as well as isolate the transceiver unit from the OTDR test signal. The termination filters provide a distance-based discrimination of each PON branch when tested from the exchange site. This gives NTT added value, allowing a link-down situation to be analyzed and diagnosed with an OTDR test, when the problem is distribution-fiber or equipment related. This also allows them to dispatch the appropriate team with proper instructions and tools to quickly fix the problem. These filters typically add 1 dB to the line budget. The network design must therefore consider this additional loss if the filter is permanently affixed to the line.

USE OF REFLECTIVE FILTERS FOR LINE CERTIFICATION FROM THE NODE

In addition to the basic demarcation function offered by mass-produced Fiber Bragg grating (FBG) filters, this new approach takes advantage of key filter characteristics:

- High, uniform filter reflectance ensures the reliable and repeatable measurement of end-to-end attenuation at 1650 nm. This measurement can be traced to a standard reference. The high-reflectance (-0.5 dB at 1650 nm) means that end-to-end attenuation can be measured in excess of 30 dB, with a spatial resolution under 50 cm, in a relatively short period of time.
- The spectral selectivity of FBG filters produces strong reflection at 1650 nm, but at 1625 nm, it is nearly identical to the reflection produced by a mated UPC connection. The detection or activation of a filter on the line can be reliably achieved by looking at the differential reflectance response of every interface at both 1625 and 1650 nm.

Although initially designed for troubleshooting and monitoring applications, the above method supports operators in the construction phase; specifically, the certification process. This makes it possible to verify the work done by contractors, audit their work or ensure a more stringent and rigorous quality control over newly installed home-passes. This method has the following key advantages and benefits:

Centralized	From the CO side, a single test instrument that can be shared by a group of technicians or contractors. Results are immediately available online, making process automation possible and easier to implement.
Automated	When operated with an optical switch unit, it can automatically test hundreds of fibers.
Time-saving	It can help validate that the connectivity from CO to endpoint is proper and well-documented.
Efficient	It can test a PON, end to end, in just a few minutes, requiring very little experience and manipulation.
Valuable	It can provide length information on each test point in order to audit the amount of cable installed. Since it tests at 1650 nm, it can provide a go/no-go result because it will typically show higher loss when excessive bending is present, but roughly the same loss as at 1550 nm when fibers are properly lain.

RECOMMENDED CERTIFICATION PROCESS

We can expect a single technician to be able to execute the following link-certification process in real-world conditions.

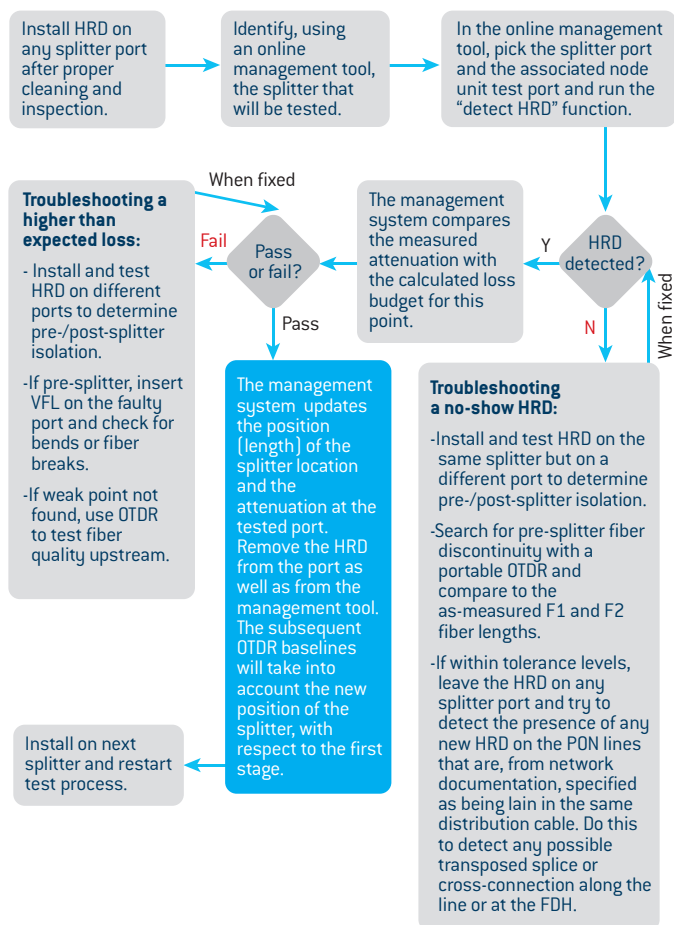


Figure 16. The suggested line-certification method and procedure based on node OTDR and HRD testing.

FROM CERTIFICATION TO ACTIVATION

Assuming that HRDs can be placed on each leg at a demarcation point close to the subscriber's premises during activation, a test can therefore be performed to confirm that the situation has not changed since the initial commissioning stage.

If no change is detected, the technician can install the drop cable and once this is done, he can redo the test. In addition to drop fiber insertion loss, the test can provide the exact length of the installed cable, ensuring a better control of the inventory and its cost.

TROUBLESHOOTING AND MONITORING FROM THE OLT SIDE

In addition to simplifying the field-testing process with this new technique, we believe there is also a high demand for an optical

testing tool that allows better decisions to be made in various network conditions, whether locally or over a larger area. The fact is most operators rely exclusively on equipment-reported parameters to make decisions on network outage and performance degradation. There seems to be little concern for the long-term performance of FTTX networks. However, cost pressure is going to force support and maintenance teams to use better, more efficient tools to be able to handle larger, rapidly expanding networks.

We believe the following factors will increase the demand for a centralized optical test solution regardless of network equipment:

- › Multi-operator model operation is growing and so is the need for responsibility borders
- › Interoperability in terms of transport equipment is necessary, but having one standard way of supporting FTTX network is very complicated
- › CPE equipment is no longer affixed to the network for its entire lifespan, which means it cannot be used for the long-term evaluation of network quality
- › Reducing the number of times the subscriber environment is accessed for on-site troubleshooting is key to saving significant support costs and shortening TTR delays
- › Subscriber participation, such as online DIY testing of link quality up to a known, accessible point, has the potential to generate considerable savings for operators who cannot afford a large, support fleet

A SOLUTION THAT USES REFLECTIVE FILTERS AS DEMARICATION DEVICES

In the ideal situation where, on day one of a line/drop port installation, a reflective filter (i.e., HRD) is installed for the certification process, this test point will become an inherent part of the network. It will be used for troubleshooting as well as for the preventive maintenance or centralized trending of optical network performance. Since the measurement is obtained with an OTDR, the equipment can also be used to locate faults, thus providing support to the fault management process.

Depending on the ODN architecture, an HRD would ideally be placed in an easy-to-access, connectorized terminal. From this access point, a technician is able to test upstream and downstream without impacting the end user, as well as minimize the risk of disconnecting the wrong port at the FDH or upstream cabinet. Based on the above:

- › If the fault is before the demarcation point, it will be quickly confirmed by the node-side test equipment and there is no need to bother the end user; immediate repair is possible. Several impacted subscribers can also be quickly confirmed.
- › If the fault is after the demarcation point, including the equipment, then an appointment is required. If the HRD is a removal-adaptor jack (see commercial types available below), it can be moved from the jumper output inside the home to verify continuity and end-to-end loss, like during certification. If a jumper cable is damaged, it can be changed without requiring additional testing. All these measurements are time-stamped and can be recorded as they are executed.

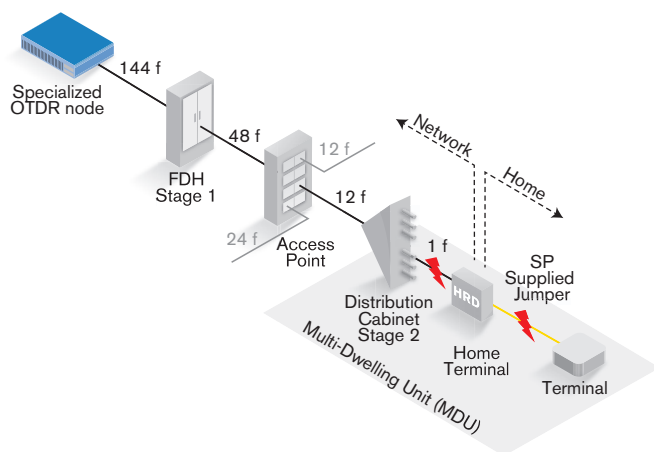


Figure 16. An HRD spliced (pigtail type) or inserted (plug-jack type) into a technician-accessible terminal.

As for an end-to-end spliced network, the HRD can be placed at the ONT input, so that connectivity and attenuation can be checked up to the actual delivery point. In this architecture, the main benefit of using an HRD-based test method is the capacity to always know whether or not the ONT is physically connected to the network as well as the actual attenuation. Since all HRD components are identical and passive, replacing an ONT should have no impact on the ability to test the link since the reflectance level is within a few tenths of a decibel of the nominal -0.5 dB at 1650 nm and the length is exactly the same.

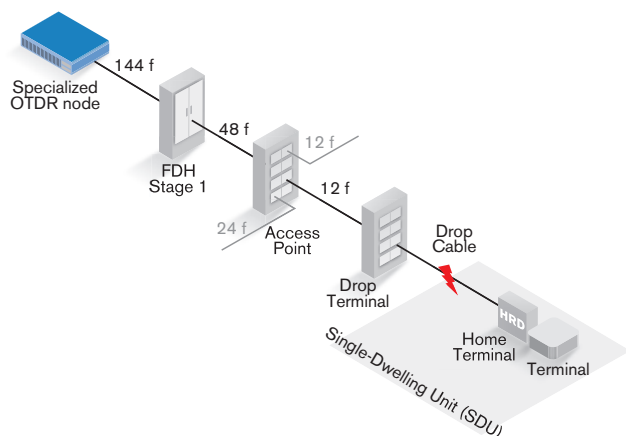
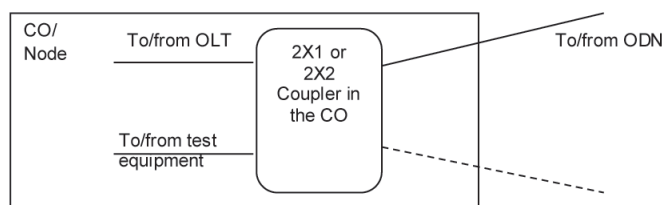


Figure 17. An HRD hardened to an ONT input port.

Testing a live network from the OLT is possible if it was designed with an extra coupler port at the CO, on the OLT side, thus enabling the test signal to be inserted at this port for both unscheduled or permanent testing or monitoring.



Placing an HRD filter on a single branch of a 32- or 64-split PON line creates an additional test point that can be used for troubleshooting and preventive maintenance, while newer, more green-field areas could get larger HRD coverage. If the installed network doesn't allow any extra components to be added to the line, then the most efficient, automated and easy-to-use portable test solutions will be required to service it, as discussed in the previous section.

TODAY'S MINIMUM 50-CM SPACING LIMIT AND SOLUTIONS

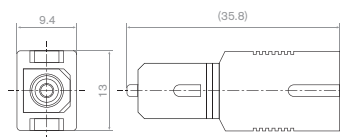
The main limitation of this test method is the fact that an optical spacing of 50 cm is typically required between filters, when two or more filters are simultaneously installed on different branches of the same PON. The test solution provides intelligence and insight on the situation and proposes close dark spots, in case of a very dense situation.

If an operator wants to use more than one HRD at a splitter location or at the end of factory-preset, standard-length drop cables, a 50-cm separation (minimum) is recommended between the last stage splitters (one or multiple stages) in the internal fiber spool length. That way, field management can be totally, or almost totally, eliminated.

HRD PACKAGING

Filters used for this application are mass-produced and commercially available. Various packages are also available, but since the FBG filter is placed in a fiber core, which is then inserted into a standard connector ferrule, it can be provided in any format. At the moment, standard products are available in the packages described below:

- › Pigtail with bare fiber at one end and any connector type at the other (1.5 m max.). It can also be terminated at the other end and transformed into a jumper cable (1.5 m max.).
- › Male-to-female adapter



- › Mechanically spliced to a drop-fiber cable or drop fiber



SYNERGY BETWEEN BOTH FIXED (NODE) AND PORTABLE (FIELD) APPLICATIONS

The format of the test result for this solution is a combination of the line structure, definition and description along with the measured parameters, presented in a single data block and written in XML. Point to multipoint can be seen as an extension of a basic point-to-point dataset. Since systems cannot talk to each other in OTDR language, or via binaries or text files, this creates a need to generate an open and fully documented way to allow the automated processes (e.g., repair ticketing system, inventory management and fault management system) to share and understand the OTDR measurement. This will put more valuable information in the hands of the technicians.

CompletionStatus	Completed
ID	Line1
InternalReference	
LineResults	
LinkResult	
LinkElements	
LinkElement	
LinkElement	
LinkElement	
LinkElement	
LinkElement	
LinkType	MultiLinkElement
Changed	false
Comment	
CultureDependent	
Hrd	
ID	S1
LinkReports	
PhysicalEvents	
Position	3545.0844346421366
PreviousFiberSection	
SplitterRatio	64
Status	None
Type	Splitter
SubLinkElements	
Links	
LinkElements	
LinkElements	
LinkElements	
LinkElements	
LinkElements	
LinkReports	

Figure 18. Example of a readable, open, easy-to-parse test result. This is an XML dataset with editable/augmentable line description designed to work with the test engine.

The ability for test and measurement vendors to go one step further in the support system stack is key to enabling more efficient workflows as well as more valuable connections between the test results and other physical and logistical information available from other systems. Using a common line XML dataset, whether generated from a node or from field test equipment, is very promising. This will ensure the consistent and highly productive management of test results, which can otherwise be tedious and difficult.

CONCLUSION

In this white paper, we demonstrated cases where a new OTDR test method based on increased automation and intelligence can be used in the field as a construction or troubleshooting tool to save time and speed up deployment without compromising on network quality. We also reviewed its application from the node. This innovative technology will reduce, if not totally eliminate, repeat truck rolls, thus improve OPEX. In all cases, a common XML format is the key to documenting the network and will allow a better use of the data gathered during network construction and maintenance. The key methods described herein have moved beyond the concept phase, they have been field-tested and proven.