Application Note

Maintenance and Troubleshooting of a PON Network with an OTDR

Troubleshooting a faulty passive optical point-to-multipoint network (PON) can be more complex than a point-to-point network. This application note looks at the use of non-intrusive or active fiber testing for troubleshooting PON networks.

Point-to-Point FTTx Network

When a failure occurs on a point-to-point FTTx network, the network completely shuts down. It is then easy to disconnect the fiber without further affecting the customer issue.

To troubleshoot and fix FTTx network problems, an optical time domain reflectometry (OTDR) test can be performed with any test wavelength, such as 1310 or 1550 nm as the transmission signals are shut down.

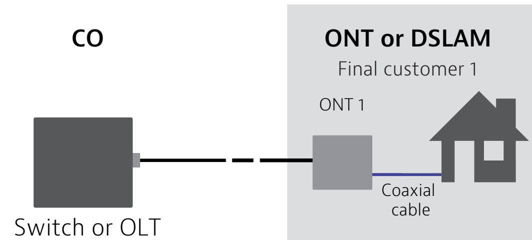

Figure 1. FTTx Case = Point-to-Point FTTH Network

Point-to-Multipoint FTTH Network (PON) Topology

Troubleshooting a point-to-multipoint fiber-to-the-home (FTTH) network (also defined as a PON network) differs significantly.

The International Telecommunications Union (ITU-T) and Institute of Electrical and Electronic Engineers (IEEE) have created several standards for optical access systems based on PON architecture (G.982, G.983 or G.984 for ITU and 802.3ah or 802.3av for IEEE). As Figure 2 shows, a PON network consists of one optical line terminal (OLT) connected via a splitter to multiple optical network terminals (ONTs) (one for each subscriber, up to 64 subscribers). Sometimes, a second splitter can be connected in cascade to the first splitter (as Figure 3 shows) to dispatch services to buildings or residential areas.

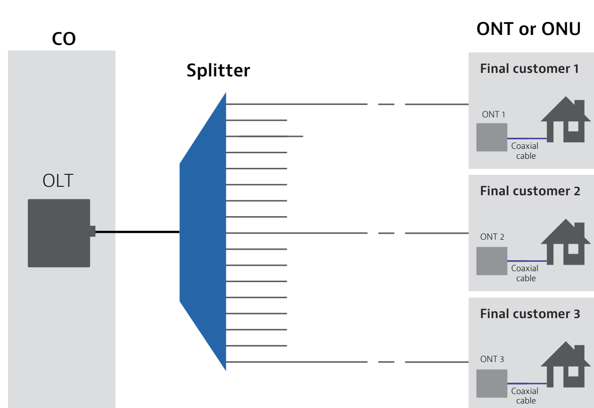

Figure 2. Simple PON Network Topology

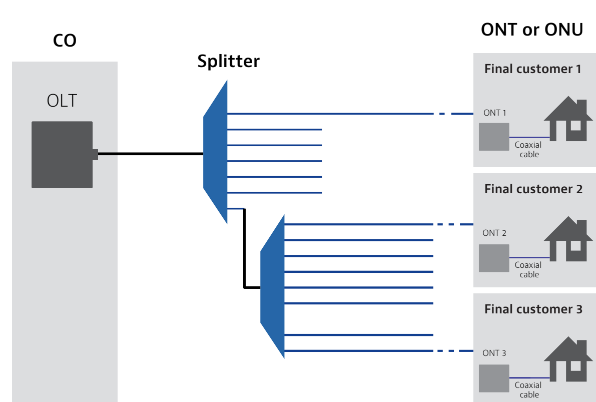

Figure 3. Cascaded PON Topology

Using the network monitoring system at the Network Operation Center (NOC), operators can easily determine which subscribers are affected. They can also identify possible fault elements such as how many customers are affected and whether the PON is cascaded.

The cases below describe each possible scenario:

PON Case 1: Simple PON - Only One Customer is Affected

When only one subscriber cannot receive service, three potential faults are probable, see Figure 4:

1. Fault in the distribution fiber between the customer and the closest splitter
2. Fault in the ONT equipment
3. Fault in the customer's home wiring

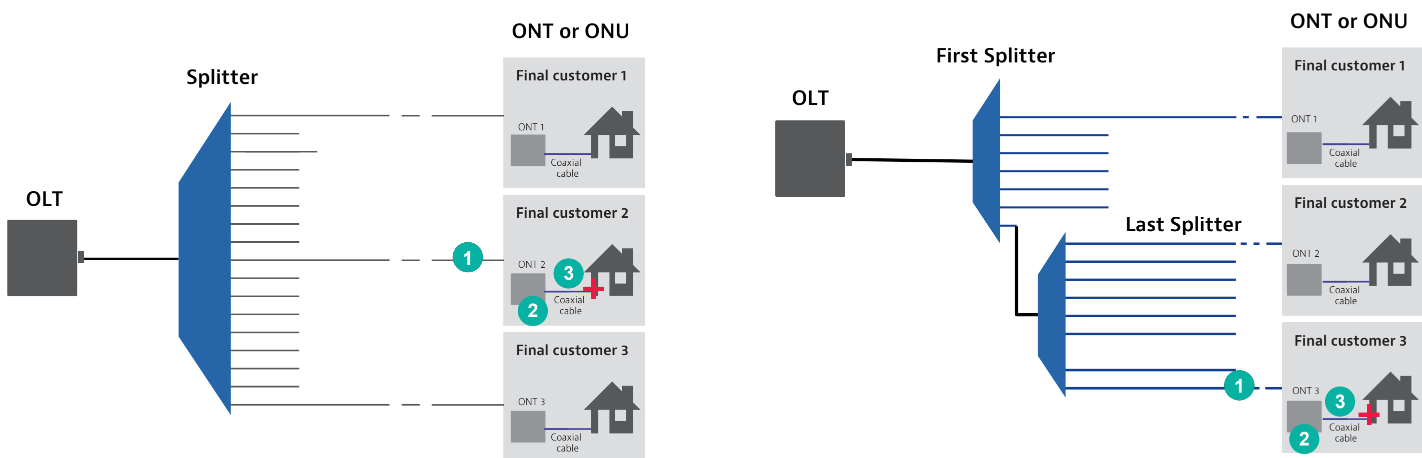

Figure 4. PON Case 1—Possible Faults When Only One Subscriber is Affected

PON Case 2: Cascaded PON and all Affected Customers are Connected to the Same Splitter

When all customers connected to the same splitter cannot receive service, but others connected to the same OLT can, the cause may be because of one of the following (see Figure 5):

1. Fault at the last splitter
2. Fault in the fiber link between the cascaded splitters

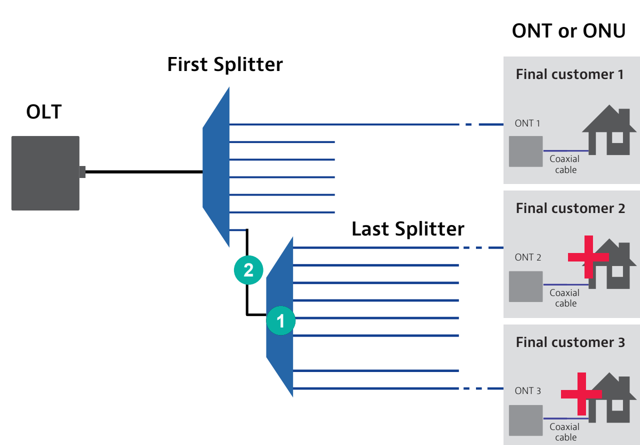

Figure 5. PON Case 2—Cascaded PON with Affected Subscribers Connected to Last Splitter

PON Case 3: All Customers are Affected (at the OLT level)

Whether or not the PON is cascaded, all customers dependent on the same OLT may be affected. If all customers are affected, the cause may be from of the following:

1. Fault in the splitter closest to the OLT
2. Fault in the feeder fiber/cable of the fiber network
3. Fault in the OLT equipment

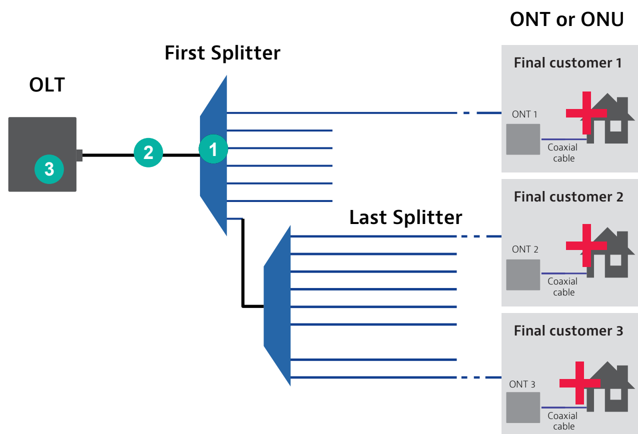

Figure 6. PON Case 3—All Subscribers are Affected (All Connected to the First Splitter)

Other Variable: Splices or Connectors at Strategic Places

If connectors are available at the splitters, terminals, or drops, isolating part of the faulty network easier. Inspecting connectors and taking OTDR measurements using 1310/1550 nm wavelengths are often performed on network sections that are out of service.

In-service testing (test on a network carrying traffic) is needed mostly when the entire network is spliced and when some but not all customers are affected.

Constraints of In-service Testing Measurements

In order to troubleshoot PON networks in service, two dedicated tools are available:

- PON power meter
- In-service 1625 or 1650 nm OTDR

Traffic wavelengths are typically 1310/1490 or 1310/1490/1550 nm. A PON power meter is normally employed to verify that the signal is transmitted correctly to and from the ONT. A PON meter measures the power levels of all the signals and can then discriminate whether the issue comes from the customer's ONT or from the network.

The use of a classical OTDR with 1310 or 1550 nm test wavelengths would interfere with the traffic signals and disturb the traffic. At the same time, the traffic signals could also disturb the receiver of the OTDR, making it difficult to interpret OTDR traces. Because of these mutual disturbances, classical OTDRs cannot be used, and specific in-service OTDRs are required (see section on Specific In-service Portable OTDR Device).

Recommended Steps for Locating Faults

Despite the fact companies with diverse fiber networks have their own methods and procedures, most of them optimize their fault location process to reduce the number of truck rolls.

The schematic in Figure 7 offers a complete view of:

- All of the possible fault locations, depending on how many customers are affected
- The best location to shoot an OTDR while minimizing truck rolls
- Whether or not a specific in-service OTDR device should be used

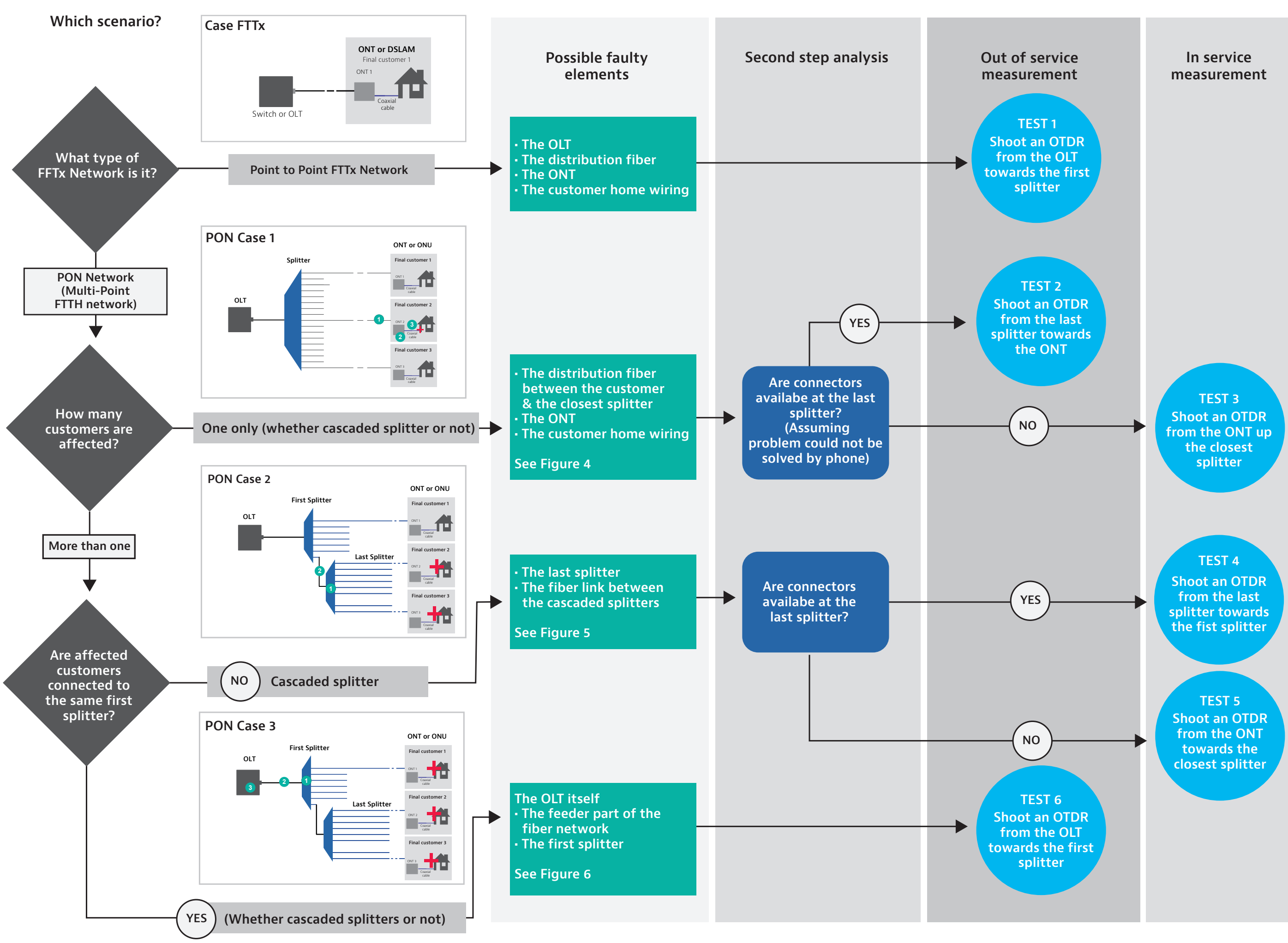

Figure 7. Schematic Summary

Specific In-service Portable OTDR Device

The in-service OTDR was designed specifically for testing live fiber networks. This dedicated device uses an out-of band wavelength (test wavelength far away from traffic wavelength) to enable OTDR testing without disturbing either the network transmitters or the receivers.

VIAVI first developed this particular OTDR a few years ago, allowing dark fiber providers to perform in-service monitoring on metropolitan and long-distance networks. In this case, a wavelength dense multiplexer (WDM) is required to connect the OTDR to the network itself while the traffic remains active.

In the case of a PON network, this WDM is no longer needed, except for monitoring purposes (using a remote fiber test system). The PON network is a point-to-multipoint configuration and the troubleshooting test is performed directly from an accessible element (ONT or splitter). The operator can disconnect the element because service is already off downstream toward the customer.

First, the in-service OTDR must not disturb the other customers while shooting the OTDR test wavelength upstream toward the OLT, which is most likely the case, as OLTs reject signals above 1625 nm, based on ITU-T recommendations.

Second, the traffic signals that the OTDR receives will be rejected to obtain accurate OTDR traces. The specific long-pass filter used to protect the OTDR diode can be added either via a jumper between the OTDR and the network or built into the OTDR.

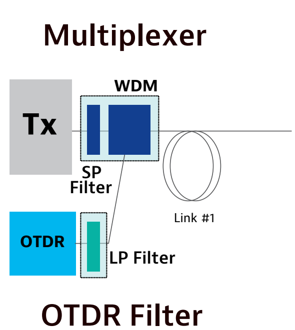

Figure 8. OTDR Insertion for In-service Monitoring

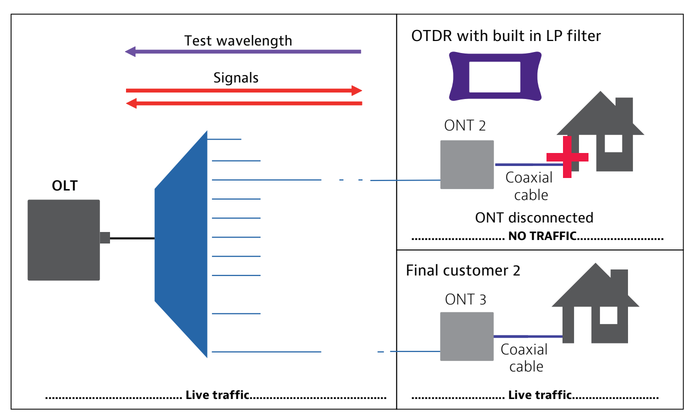

Figure 9. OTDR Insertion for FTTH Troubleshooting at a Customer Location (ONT is disconnected)

Most equipment providers enable the use of the 1625 nm wavelength for safe testing. Some countries, such as Japan, are nevertheless pushing the 1650 nm wavelength as reflected in the ITU-T L.41 recommendation, which provides maintenance wavelengths on fiber-carrying signals. The 1650 nm wavelength is preferred based on the design of the filters and also because it is further away from the traffic signals (current and future PON technologies).

Making the Right Testing Decisions

To optimize maintenance costs and time, it is essential to select the right OTDR tool, the correct pulse width, and the best location to start troubleshooting. OTDR configuration should be set according to the equipment being qualified and the distance to cover.

Consider each case from the scenarios presented in Figure 7. To avoid complexity, this document only analyzes the cases where connectors are only available at the ONT/OLTs.

Case 1: Troubleshooting of the Distribution Fiber

Simple PON—Only one subscriber affected.

Consider that no connectors are available at the splitter (see Figure 7, Test 3)

Case	Test Location	OTDR Direction	What Must be Seen	Comment	Pulse Width to use	Specific OTDR
Case 1 One customer down	**Customer's Home** Disconnect the ONT	**Up**stream	**Distribution fiber** up to the closest splitter	Testing through the splitter is not required, as the issue is only on the distribution fiber side.	**Short pulse** 3 to 30 ns	**In-service OTDR**

1 Fault in the distribution fiber between the customer and the closest splitter

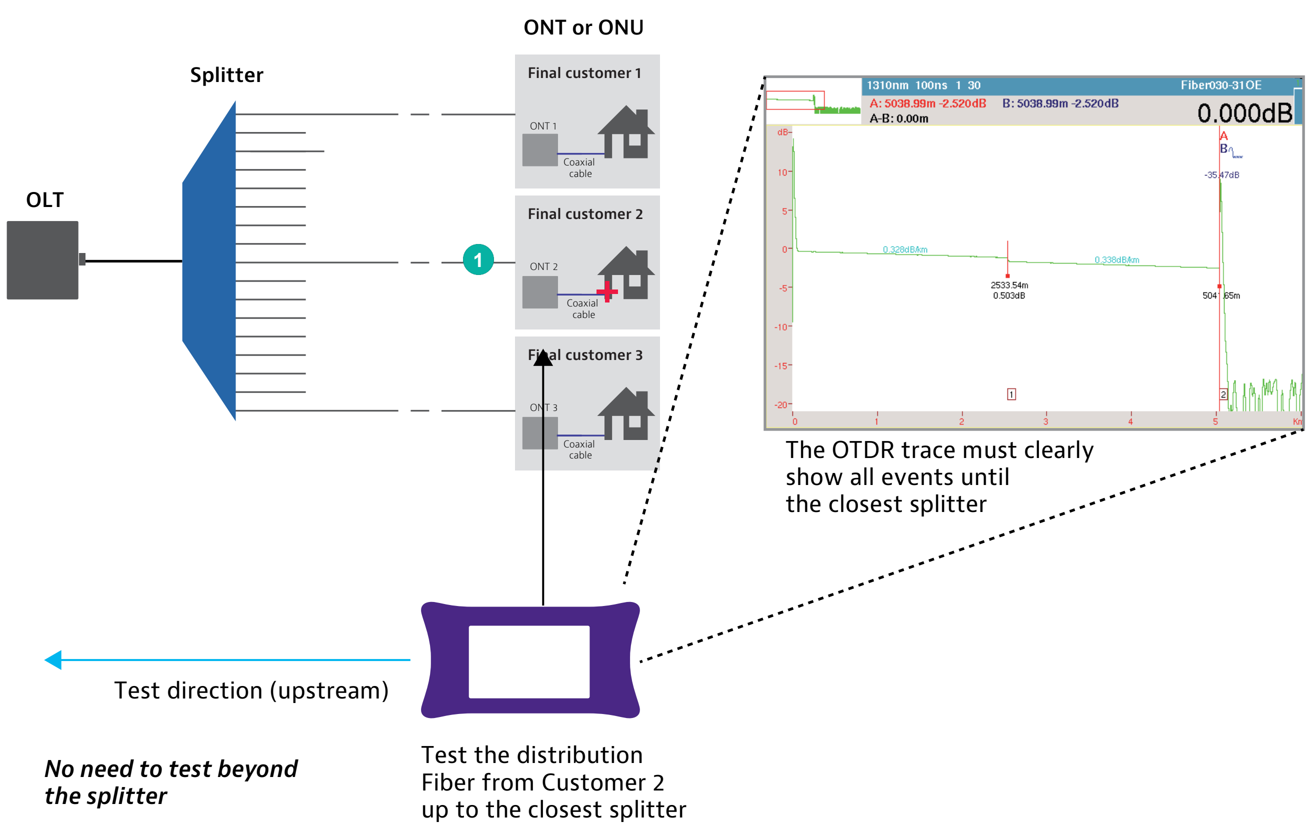

Figure 10. OTDR is Shot Upstream and Trace only Matters up to the Splitter

Case 2: Troubleshooting of the Distribution Fiber and the Fiber between the Two Splitters in case of a Cascaded Network

A cascaded network with 1 x 4 or 1 x 8 splitters is often found in Europe.

Information received at the network operations center (NOC) says that all customers linked to the second splitter are down. Let's consider the case where no connectors are available at the splitter (see Figure 7, Test 5).

Case	Test Location	OTDR Direction	What Must be Seen	Comment	Pulse Width to use	Specific OTDR
Case 2 All customers are down after the second splitter	**Customer's Home** Disconnect the ONT	**Up**stream	**Distribution fiber and fiber** between the two splitters	Testing through the closest splitter is required	**Medium pulse** 100 to 300 ns	**In-service OTDR - Short dead zone**

This case requires viewing the signal after the splitter. The OTDR used must be optimized for this application and have the shortest possible dead zone as the splitter typically provides 7 to 10 dB loss.

1. Fault at the last splitter
2. Fault in the fiber link between the cascaded splitters

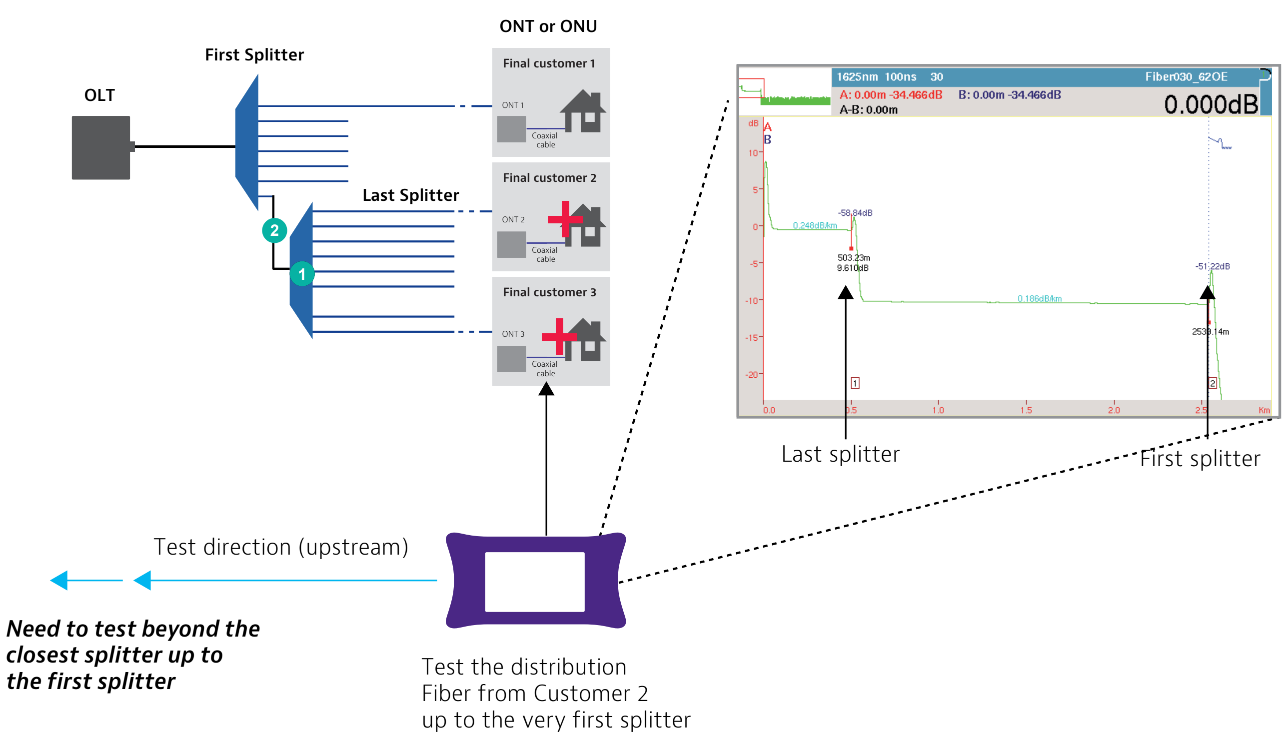

Figure 11. OTDR is Shot Upstream and Trace should Display the Traffic through the Last Splitter up to the First One

Case 3: Troubleshooting of the Feeder

Whether it is a non-cascaded network, which is typical in the USA, or a cascaded network, which is typical in Europe and Asia Pacific, information received at the NOC shows that all customers are down. As the problem likely comes from the feeder side, the most common way to test the faulty network is to shoot an OTDR downstream from the OLT (see Figure7, Test 6).

Case	Test Location	OTDR Direction	What Must be Seen	Comment	Pulse Width to use	Specific OTDR
Case 3 All customers are down	**OLT**	**Down**stream	**Feeder**	Testing through the splitter is unnecessary	**Short pulse** 3 to 30 ns	**Unnecessary**

1 Fault in the splitter closest to the OLT
2 Fault in the feeder fiber/cable of the fiber network
3 Fault in the OLT equipment

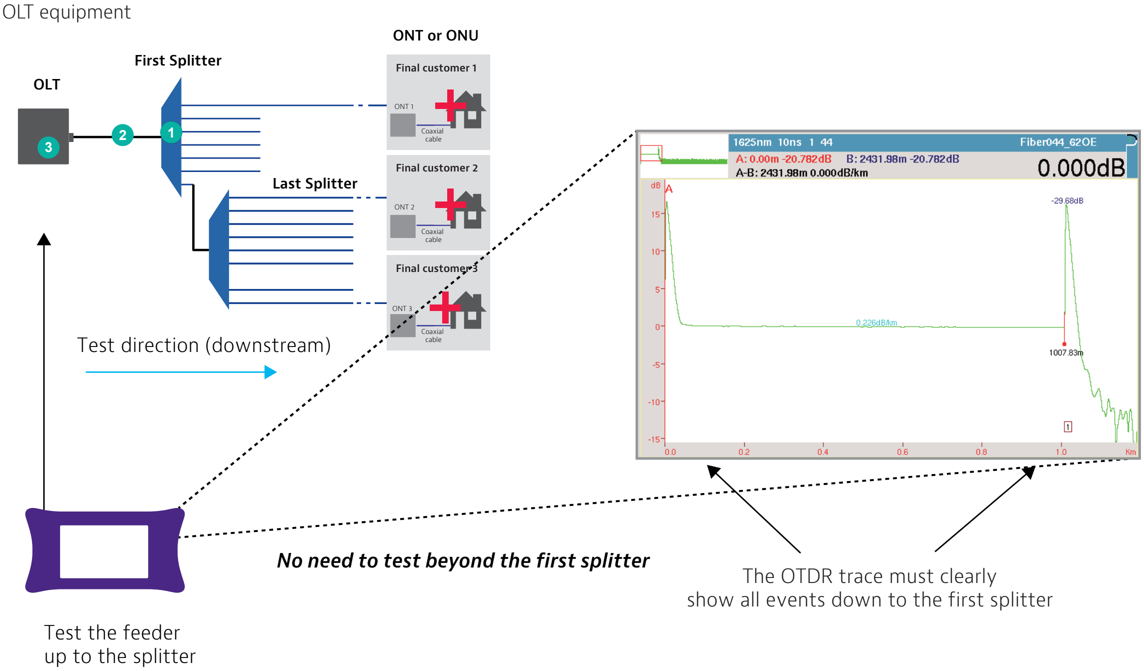

Figure 12. OTDR is Shot Downstream and Trace should Display the Traffic Down to the First Splitter

Troubleshooting the Distribution Fiber and/or the Fiber between Splitters with Alternative OTDR Testing from the OLT

OTDR testing directly from the OLT is certainly the preferred choice when a faulty feeder is suspected (Case 3), but this method is not recommended in the other cases. VIAVI OTDR instruments can indeed test through splitters and provide accurate traces. Nevertheless, complete analysis of the resulting trace requires linking that trace to the exact (precisely documented) network topology.

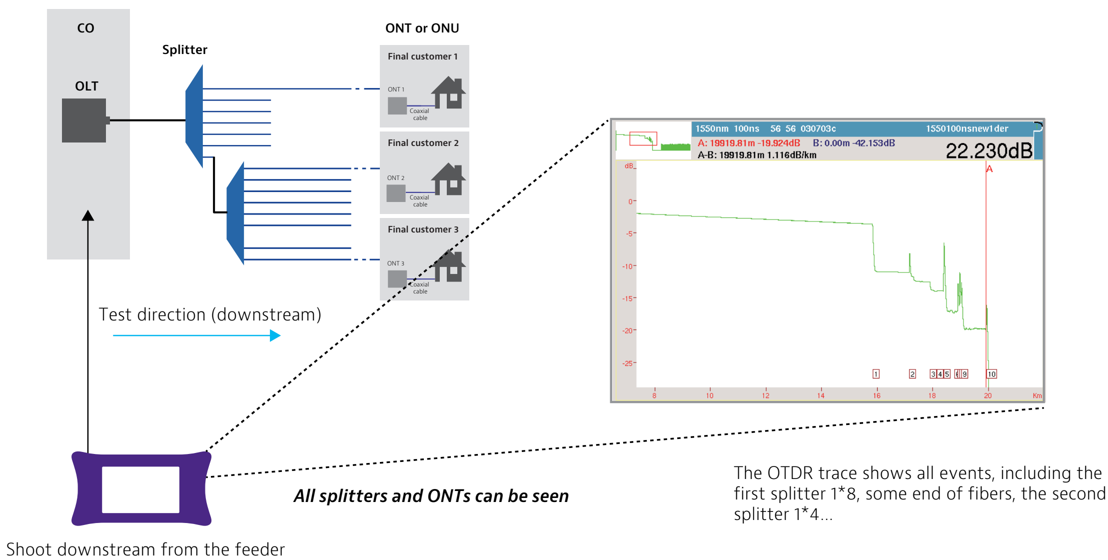

Figure 13. OTDR is Shot Downstream and Trace Displays Many Events that are Difficult to Identify without Exact Network Topology (and corresponding distances)

Complete PON Test Tools

This application note focuses primarily on the maintenance and troubleshooting of a PON network using an OTDR. Nevertheless, other tools can be used during the installation and maintenance/troubleshooting stages:

Installation Phase

The following equipment may be used:

- Loss test set (provides insertion loss and ORL, either unidirectionally or bidirectionally)
- OTDR

For this phase, VIAVI recommends the SmartClass™ Fiber Family and/or the T-BERD®/MTS-4000V2, -2000 or SmartOTDR to optimize this process.

Figure 14. Recommended tools: a SmartClass Fiber Family optical handheld or a T-BERD/MTS-4000 or T-BERD/MTS-4000V2 or -2000 equipped with an OTDR module or SmartOTDR

Turn-up Phase

The following equipments should be used in conjunction:

- A PON power meter (1310/1490, 1490/1550, or 1310/1490/1550 nm)
- Service testers (voice, video, data)

For this phase, VIAVI recommends our SmartClass Family, in particular the PON-dedicated OLP-87 and 88, and the Network and Service Companion (NSC-100).

Figure 15. Recommended tools: a SmartClass Family OLP-87 and 88, and Network and Service Companion (NSC-100)

Maintenance and Troubleshooting Phase

The following equipments should be used in conjunction:

- A PON power meter (1310/1490, 1490/1550, or 1310/1490/1550 nm)
- A loss test set or an OTDR
- Service testers (voice, video, data)

For this phase, VIAVI recommends once more the material described above.

VIAVI Solutions

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