

Automated End-to-End PON Fiber Test

This document describes how to automatically test the physical layer of a passive optical network (PON) from the central office (CO). This approach reduces provisioning time, improves quality of service (QoS) and reduces maintenance costs.

Description of PONs

PONs share a single optical fiber among two or more customers. Figure 1 shows the basic PON structure. The network equipment in the CO, or optical line terminal (OLT), is connected via an optical splitter to the optical network terminal (ONT) installed at the customer’s premises. Because multiple customers share the optical fiber and OLT, PONs substantially reduce the investment required to serve a given number of customers.

PON systems use 1310 nm for the upstream and 1490 nm for the downstream wavelength. Sometimes a 1550 nm broadcast video overlay is added.

The International Telecommunications Union Standardization Sector (ITU-T) has created several standards for optical access systems based on the PON architecture. One of the first standards was Broadband PON (BPON). It uses Asynchronous Transfer Mode (ATM) cells for transmission and has a maximum access speed of 155 Mb/s upstream and 622 Mb/s downstream. The BPON standard suggested increasing the transmission capacity to 622 Mb/s upstream and 1.2 Gb/s downstream. The consensus was that the technical hurdle of achieving synchronization at speeds higher than 622 Mb/s upstream is high given the BPON physical layer specification. Therefore, discussion around a PON specification for gigabit-per-second-class transmission began in April 2001. Because the new optical access system is capable of gigabit-per-second transmission, it was called Gigabit PON (GPON), defined in ITU-T recommendation G984.

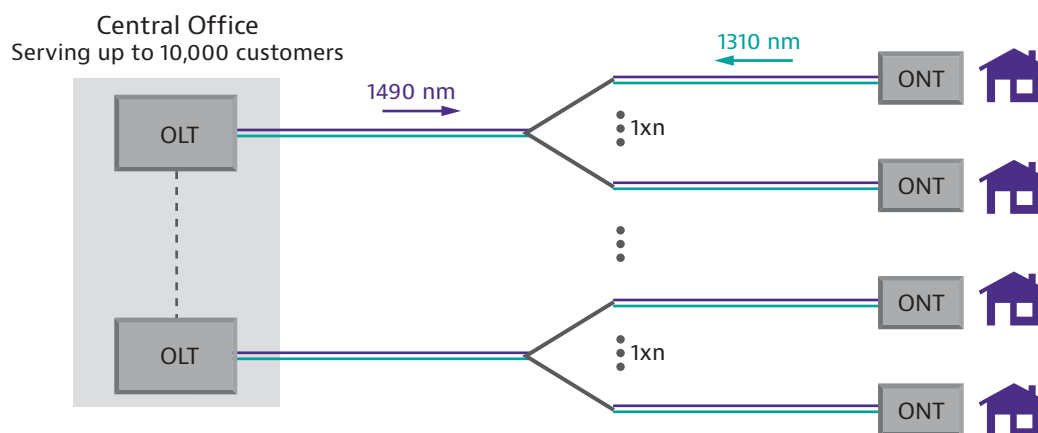


Figure 1. PON architecture

Table 1. Main GPON specifications

Specification	Description	
Service	Full service (10/100BaseT, sound, and dedicated line, among others.)	
Bit rate	Downstream: 1.2, 2.4 Gb/s Upstream: 155 Mb/s, 622 Mb/s, 1.2 Gb/s, 2.4 Gb/s	
Physical distance	Maximum 20 km or maximum 10 km	
Logical distance	Maximum 60 km	
Number of branches	64 is the maximum at the physical layer 128 is the maximum at the transmission convergence (TC) layer	
Wavelength arrangement	Downstream: 1480-1500 nm Upstream: 1260-1360 nm	Capable of multiplexing down-stream wavelength for video distribution (1550-1560 nm)
ODN (optical distribution network) class classification	Classes A (5-20 dB), B (10-25 dB), and C (15-30 dB)	

Table 2. Standardization of G-PON in G-984 series

Specification	Description
G.984.1	GPON: General Characteristics
G.984.2	GPON: Physical Media Dependent (PMD) Layer Specification
G.984.3	GPON: Transmission Convergence Layer Specification
G.984.4	GPON: ONT Management and Control Interface Specification (OMCI)
G.984.5	Enhancement Band for Gigabit Capable Optical Access Networks
G.984.6	GPON: Reach Extension

In 2004, IEEE 802.3 defined the Ethernet PON (EPON), or 10 Gb/s EPON (GEAPON), standard as part of the Ethernet First Mile project. EPON uses standard 802.3 Ethernet frames with symmetric 1 Gb/s upstream and downstream rates. EPON is designed for data-centric networks as well as full-service voice, data, and video networks. The Institute of Electronic and Electrical Engineers (IEEE) then moved on to 10 Gb/s EPON or 10GEAPON.

Table 3. Main E-PON specifications

Specification	Description
Bit rate	Downstream: 1.25 Gb/s Upstream: 1.25 Gb/s
Physical distance	Maximum 20 km or maximum 10 km
Logical distance	Maximum 60 km
Number of branches	Maximum 64 at the physical layer
Wavelength arrangement	Downstream: 1480-1500 nm Upstream: 1260-1360 nm
Optical distribution network (ODN) classification	PX10, (10-25 dB), PX20 (15-30 dB)

Testing PONs with OTDRs

The OMCI specification, defined by ITU-T Recommendation G984-4, determines the status of the ONT and the PMD. OMCI requires communications between the OLT and the ONT. When the ONT does not respond, it is impossible to determine if the problem originates in the ONT or the PMD, which helps explain why many operators desire an external test system that can test the PMD when the ONT is unreachable.

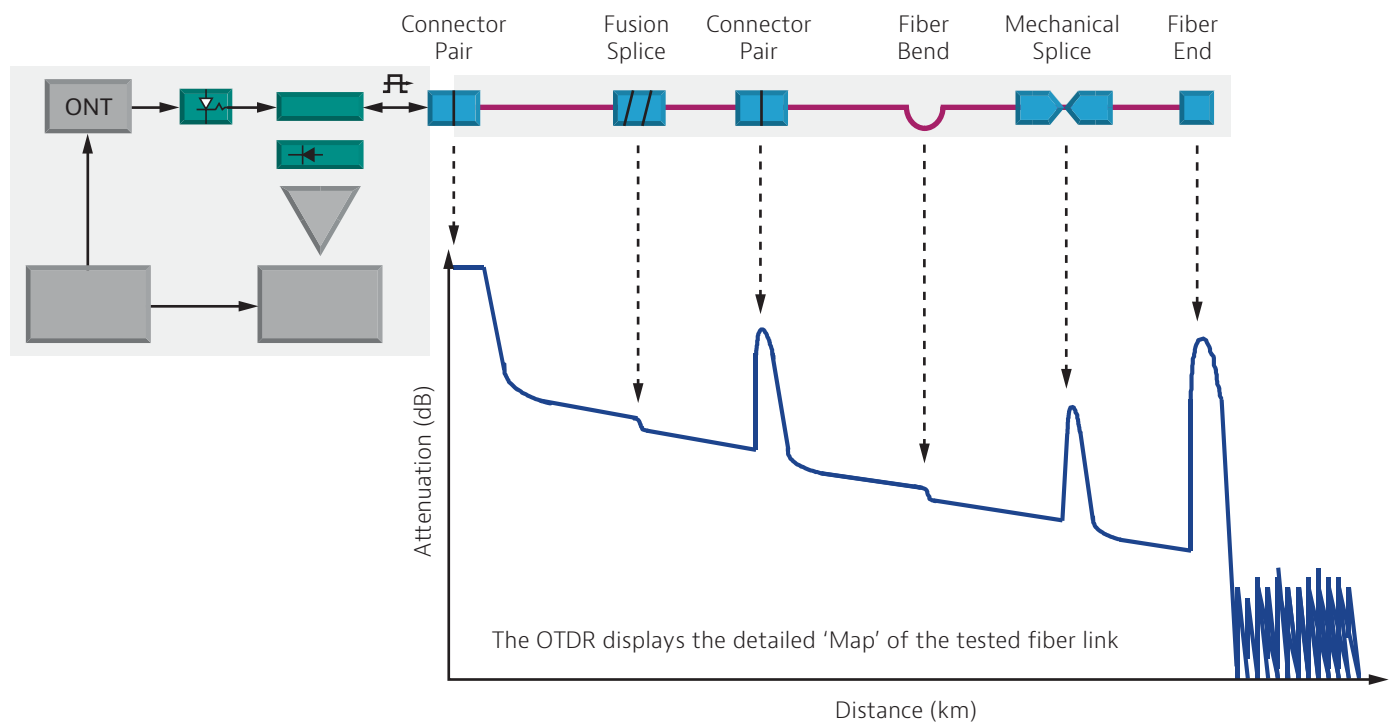
An OTDR can pinpoint the location of faults in a fiber link and certify the workmanship involved in an installation. OTDRs find and characterize both reflective and non-reflective events in optical fiber runs by sending laser pulses of different widths.

Measure OTDR performance with these two main parameters:

- The dynamic range (DR) determines the length of fiber link the OTDR can test (higher values enable testing longer links).
- The event dead zone (EDZ) is the minimum distance of separation between two different optical reflective events that the OTDR can resolve (shorter values enable resolving more closely spaced events).

The DR and the EDZ both increase with longer pulse widths. Tuning the OTDR requires a tradeoff between the EDZ and DR.

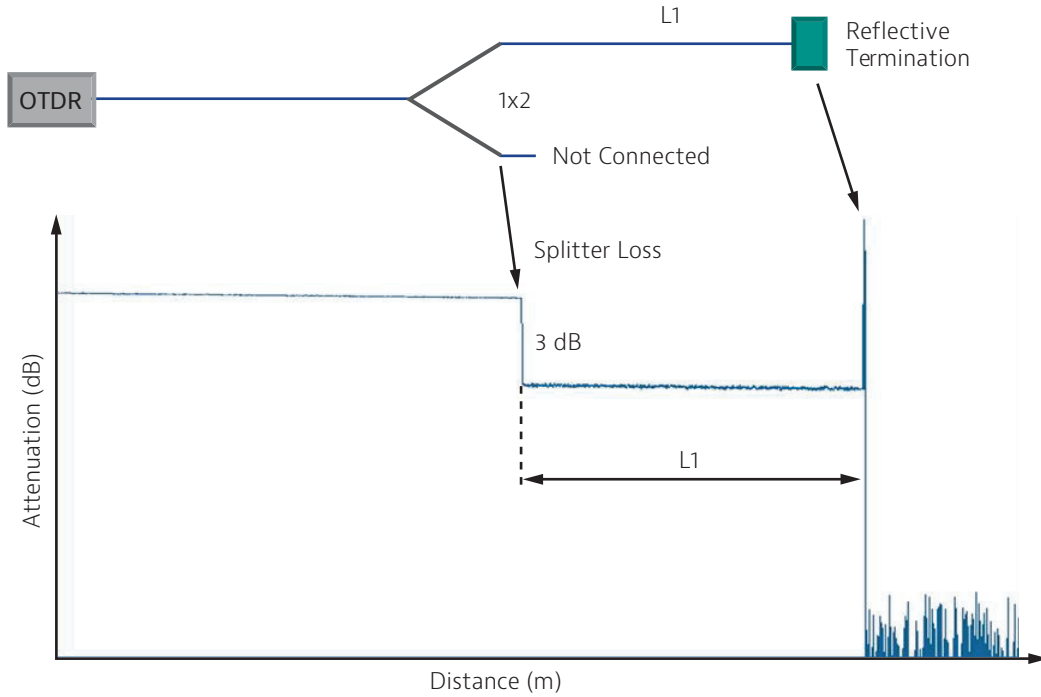
Figure 2. OTDR principle



Distinguishing between the different segments of a PON

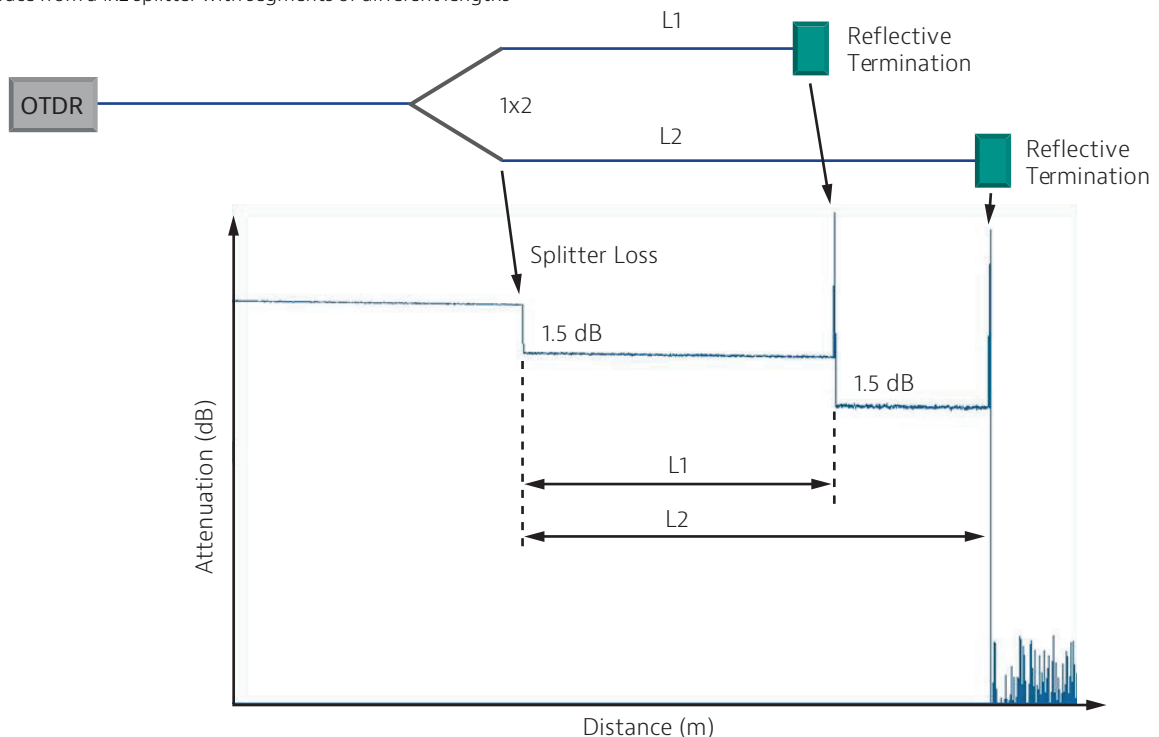
Distinguishing between the different segments of a PON can be challenging. Figure 3 shows the OTDR trace for a simple 1x2 splitter when only one segment is connected. If the second segment is connected, the contributions of both segments appear on the trace, as Figure 4 shows. The different lengths enable identification of the two segments. If each segment were the same length, the OTDR trace would appear similar to that shown in Figure 5.

Figure 3. OTDR trace from a 1x2 splitter with only one segment connected



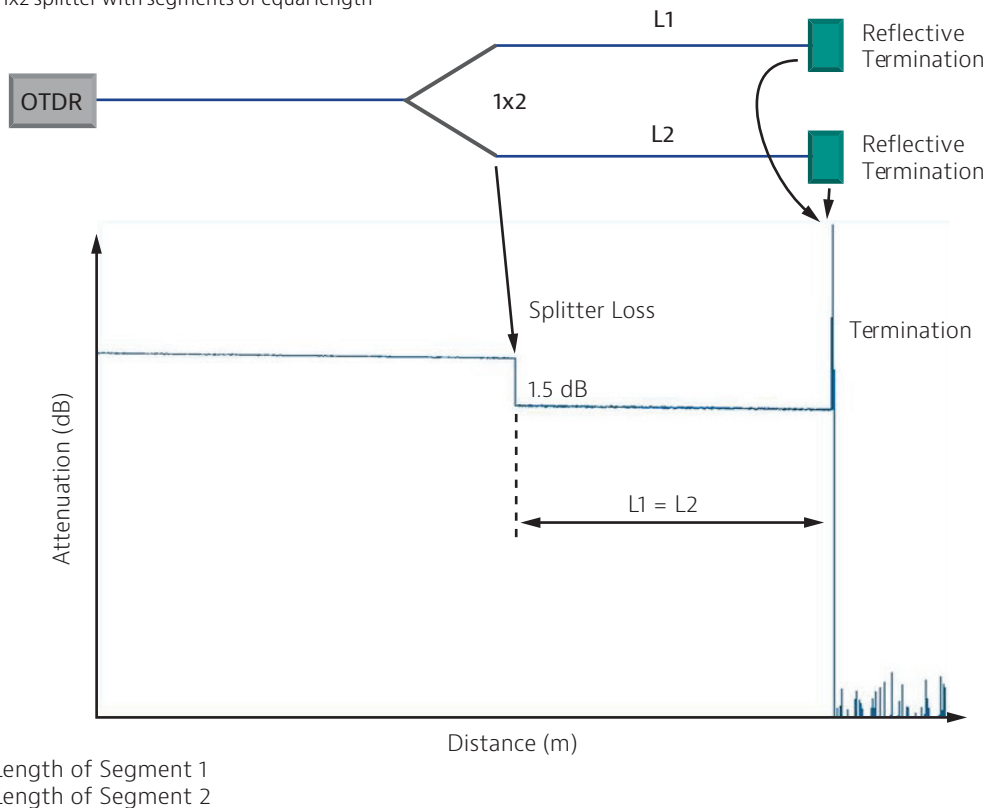
L1 Length of Segment 1

Figure 4. OTDR trace from a 1x2 splitter with segments of different lengths



L1 Length of Segment 1
L2 Length of Segment 2

Figure 5. OTDR trace from 1x2 splitter with segments of equal length

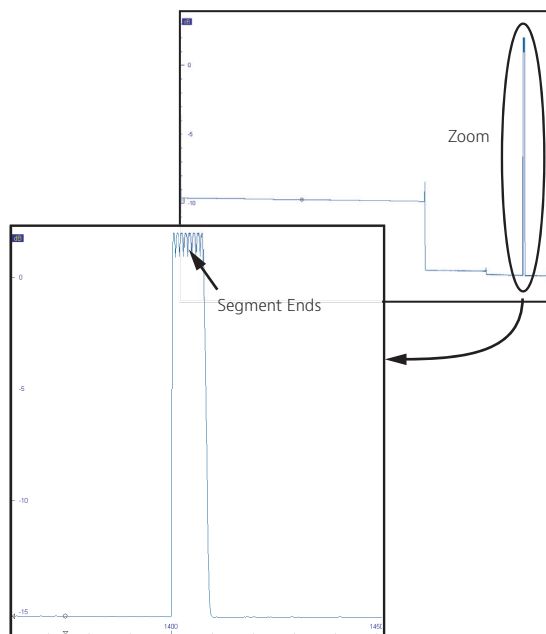


Several factors complicate testing with an OTDR:

- Distances between the splitter and the different ONTs usually are nearly equal, because customer residences are typically located at about equal distances from the splitter.
- Distances between the splitter and the ONT can be as short as a few meters.
- Split ratios are not typically 1x2 but rather 1x16, 1x32, or 1x64, increasing the splitter loss. The typical loss of a 1x64 splitter is 20 dB.

Figure 6 shows an OTDR measurement from a 1x32 PON.

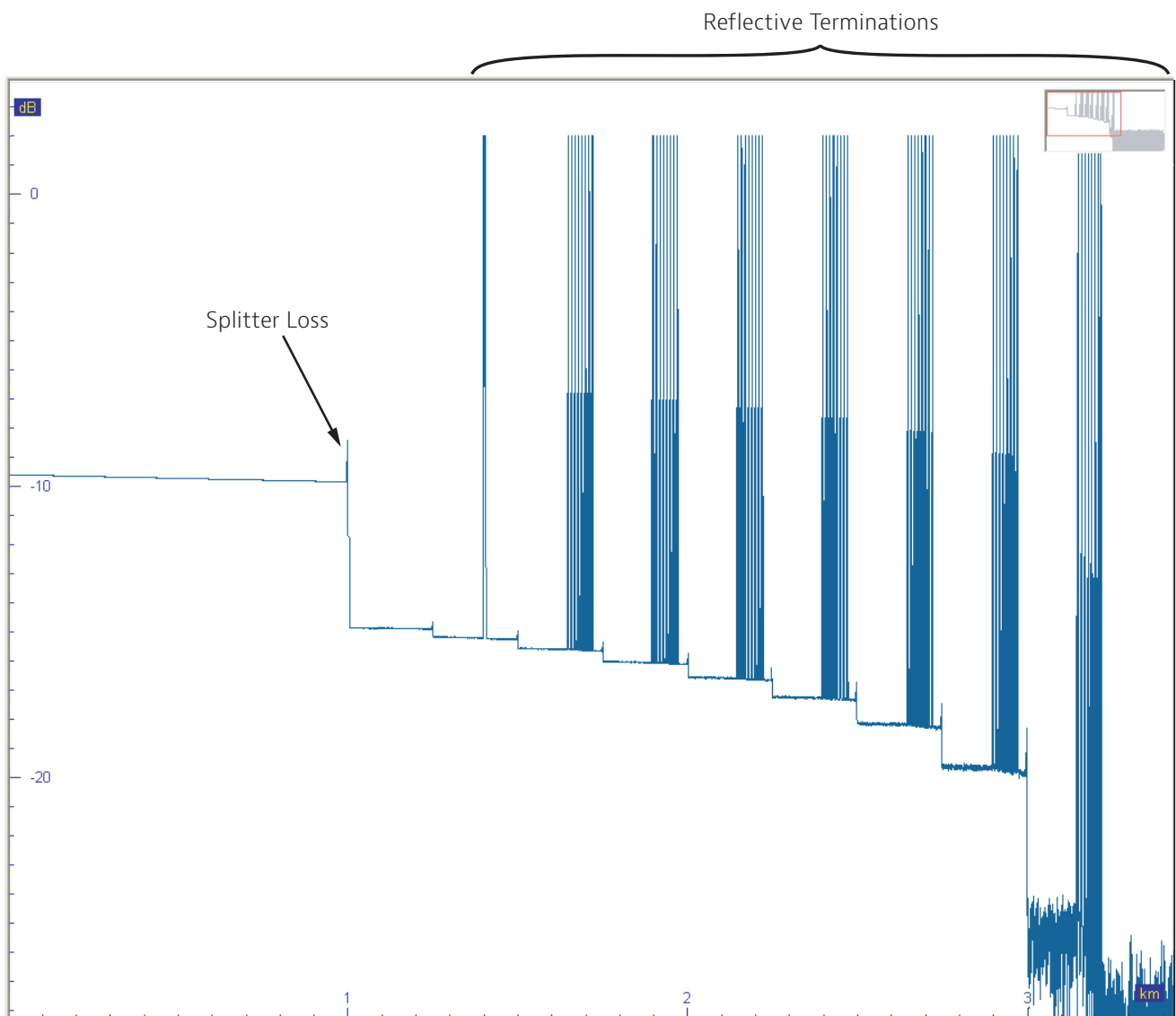
Figure 6. OTDR measurement on 1x32 PON



The ideal PON OTDR would have a very high dynamic range, so it could detect optical events on the fiber branches beyond the splitter and a very short dead zone to differentiate between terminations which usually are not reflective. Resulting from the tradeoff mentioned earlier, OTDRs do not have both high dynamic ranges and short dead zones, making it necessary to add a reflective optical element at each ONT. An OTDR can distinguish this element from noise using a very short pulse width, as Figure 7 shows.

Troubleshooting must be performed while the PON is in service because the OTDR must use a wavelength different from the one used by the traffic. The ITU-T G984.4 recommendation allocates the bandwidth for the test is between 1625 and 1670 nm. Insert the test wavelength by adding a wavelength division multiplexer (WDM) at the near end. ITU-T recommendation G984.5 states that the ONT must not be sensitive to the test wavelengths.

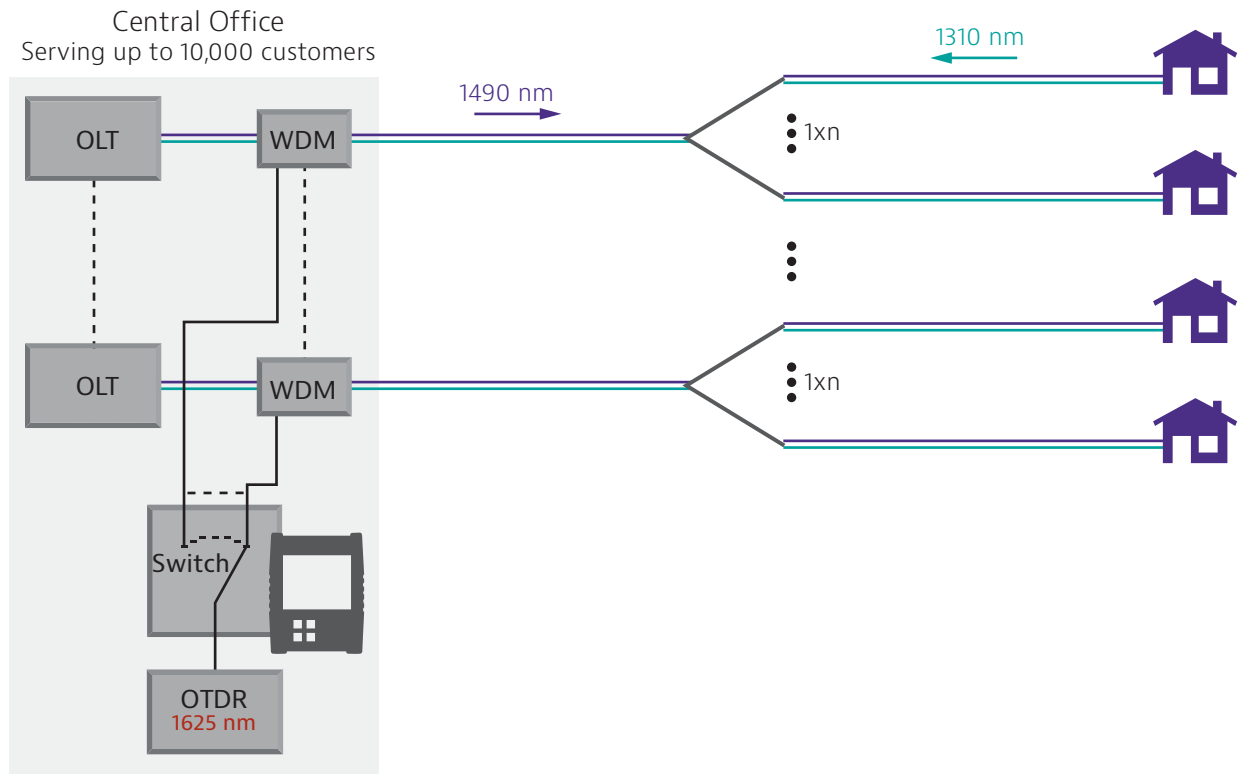
Figure 7. OTDR trace on PON equipped with reflective filters



An Automated Approach to OTDR Testing

Test multiple PONs with the same OTDR using an optical switch to select the PON to be tested as Figure 8 shows. This approach enables a single OTDR to handle testing for an entire site.

Figure 8. PON Test System integrating a switch



Manually operate the optical switch by configuring it to be remotely controlled from an application. Doing so provides these additional benefits:

- Access the PON test system from a remote location using a Web browser or mobile phone.
- Record the network signature at different points in time such as during network construction, provisioning, and troubleshooting.
- A single person can test the network during installation.
- Quickly and easily distinguish between problems in the equipment and in the fiber.

Figure 9 shows how to use the system for provisioning. Technicians log into the application from their mobile phone. After registering the customer ID, technicians enter the optical power measured at customer connector, then triggers an OTDR measurement. The system automatically recognizes the new peak and records its position and level.

Figure 9. PON Test System used for provisioning

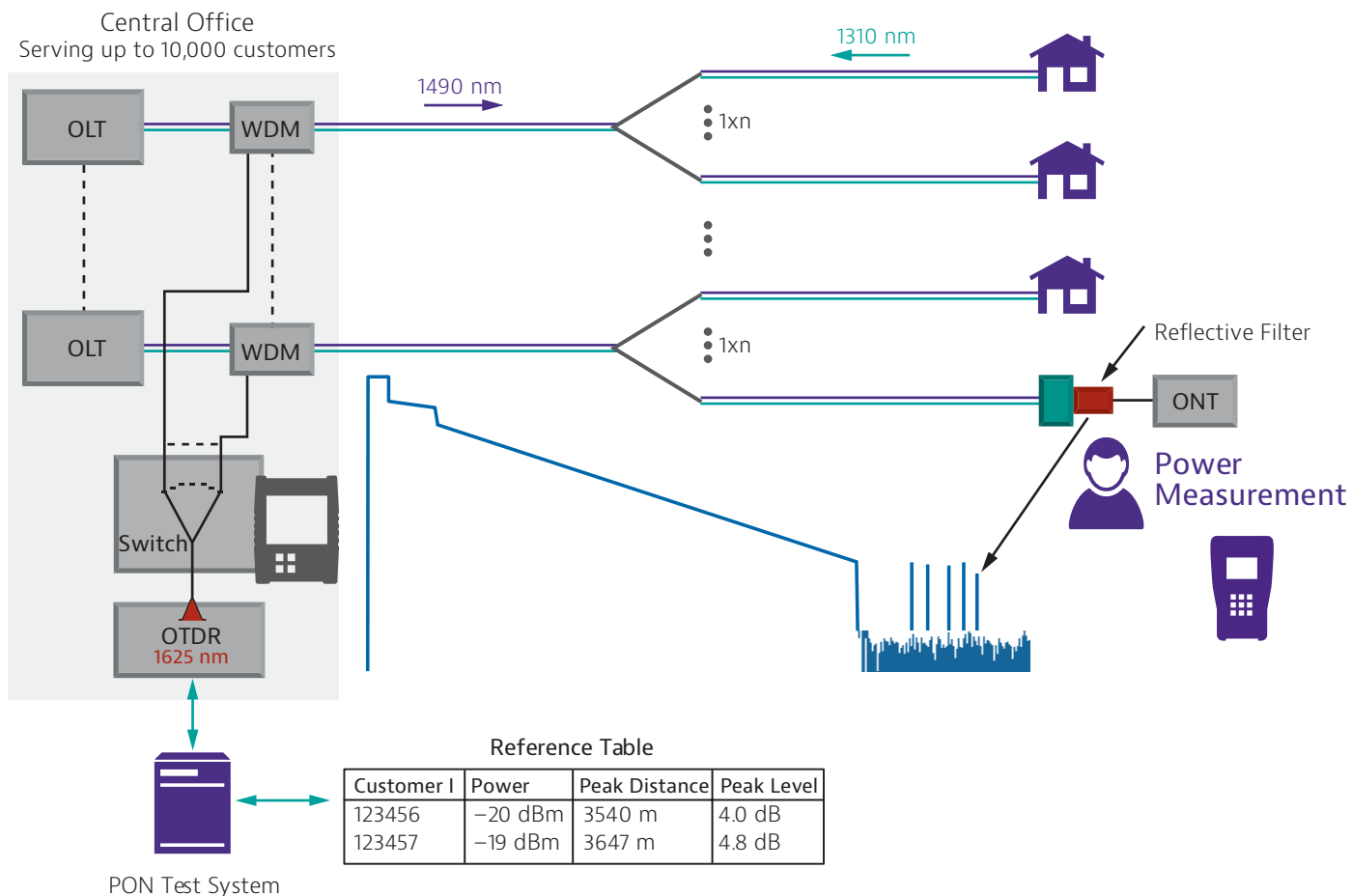
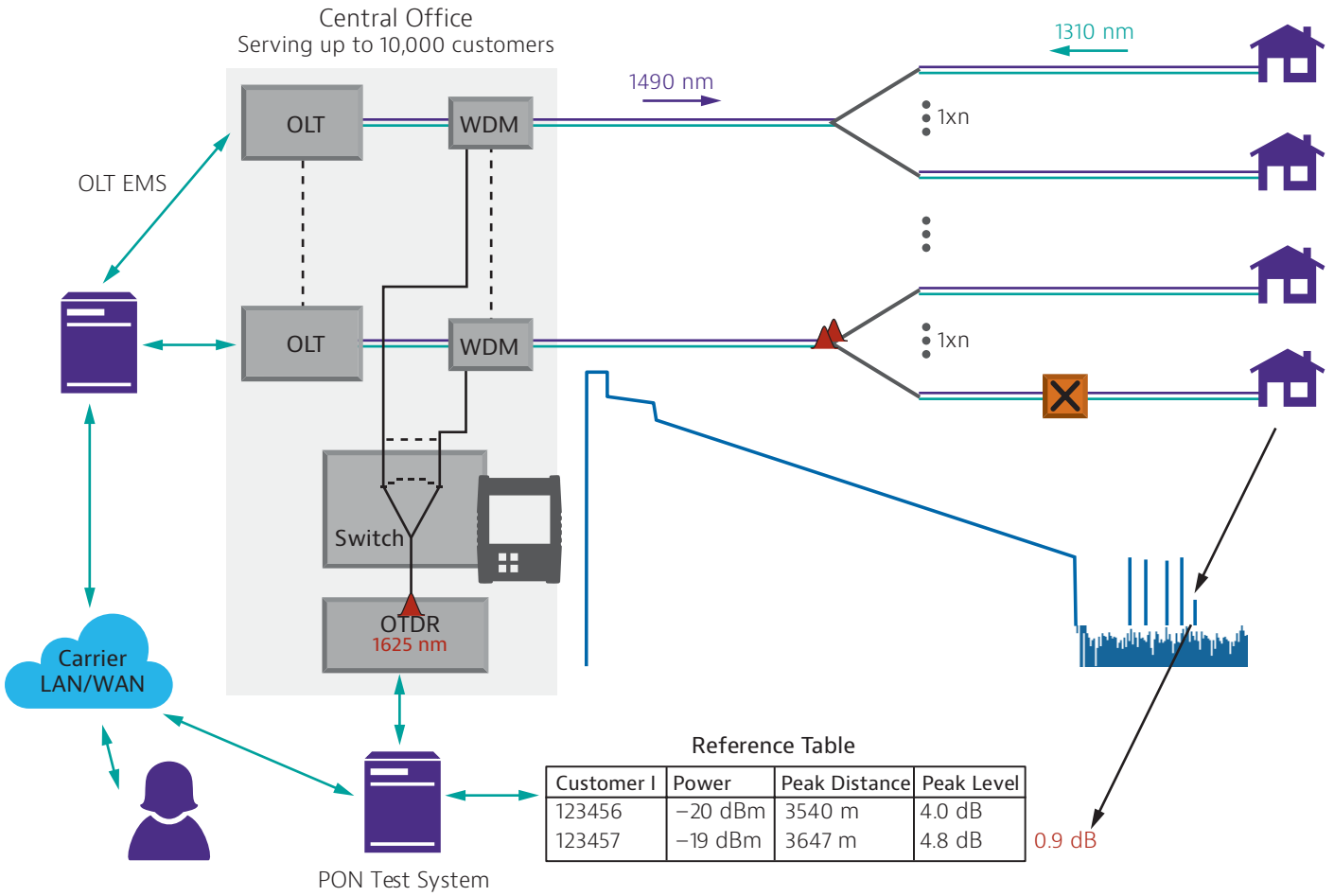


Figure 10 shows how to use the PON test system for troubleshooting. An operator receives an alarm from the OLT or a call from a customer. The operator can immediately check if the fiber is OK by using the PON test system. The operator initiates an OTDR measurement on the suspected PON and the result is compared with the records to determine changes in the customer's fiber attenuation. The disappearance of the peak typically indicates that a fiber cut or additional attenuation is the cause of the problem.

Figure 10. PON Test System used for troubleshooting



Conclusion

The system described here helps operators shorten provisioning time, increase QoS, and reduce maintenance cost.

This system makes it easy to determine before or during installation whether the physical layer is ready, which avoids the expense of multiple truck rolls.

When subscribers report service problems, the system helps to immediately determine the cause, resulting much quicker resolutions at lower costs. The PON fiber testing system described here helps operators shorten provisioning time, increase quality of service (QoS), and reduce maintenance cost. VIAVI can help make it easy to determine whether the physical layer is ready before or during installation, which avoids the expense of multiple truck rolls. When subscribers report service problems, the OTDR fiber testing system helps to immediately determine the cause, resulting much quicker resolutions at lower costs.