Leviton Network Solutions

White Paper

Gigabit Passive Optical Networks

Passive Optical LAN Solutions (POLS)
Theory, Design, and Installation Considerations

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Abstract

Today's diverse and ever-changing technology applications require options for the distribution of information in commercial, public, and governmental markets. Gigabit Passive Optical Networks (GPON) provide a solution that minimizes the physical footprint, increases distance and bandwidth, reduces latency, and improves physical and network security.

Other potential benefits include:

- Adherence to green and sustainability initiatives – LEED® and STEP
- Reduced costs for moves, adds, and changes
- Lower price per port on passive components
- Pre-terminated systems are easy to install and reduce labor and installation errors

Standards

The implementation of Passive Optical LAN Solutions was adopted by ANSI/TIA in August of 2012 under ANSI/TIA 568-C.0-2 General Cabling Addendum 2, General Updates.

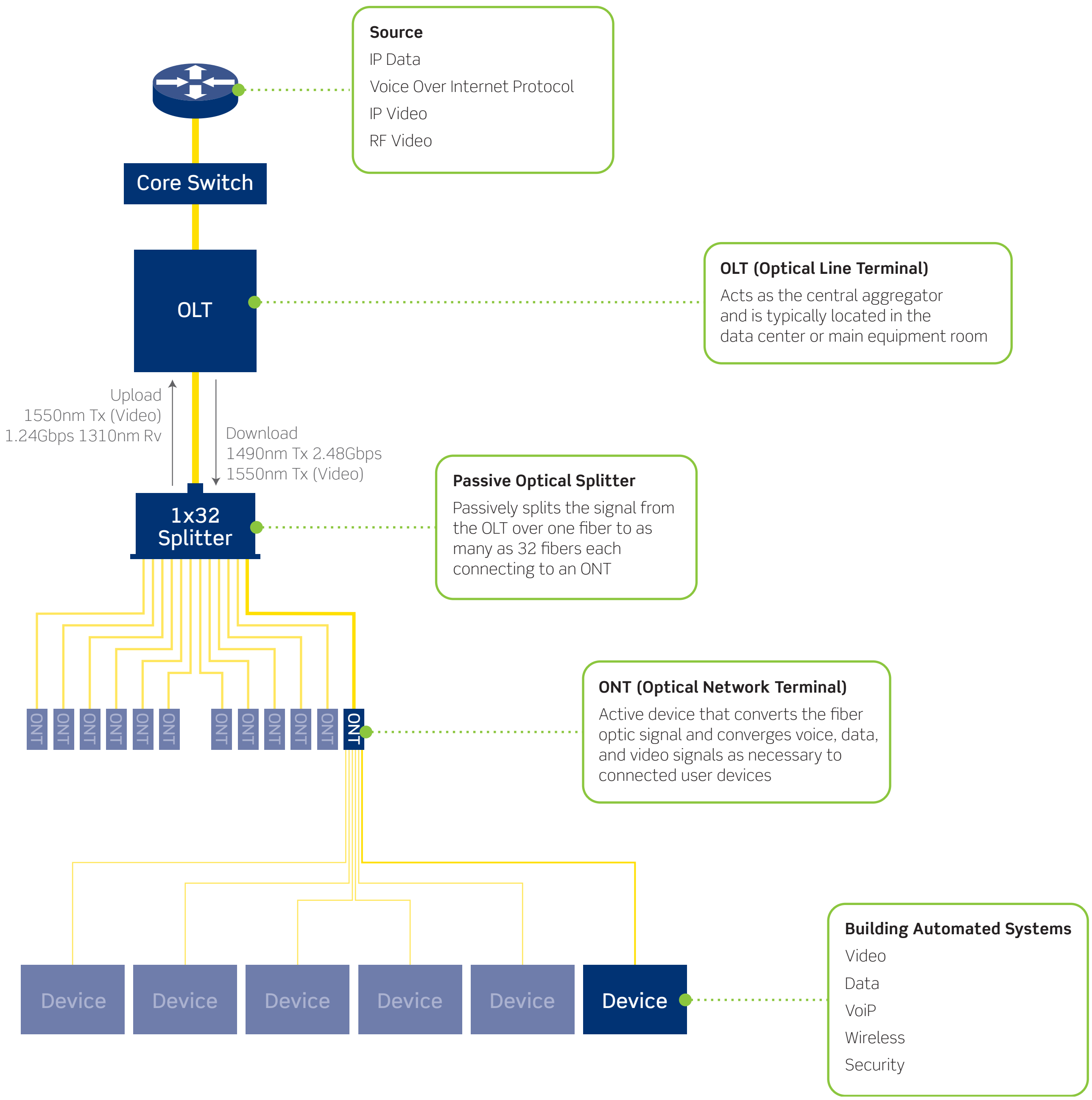
Other applicable standards include:

- ANSI/TIA 526-7 Method A.1 Measurement of Optical Power Loss of Installed Single-mode Fiber Cable Plants
- ANSI/TIA 568-C.0 Generic Telecommunications Cabling for Customer Premises
- ANSI/TIA 568-C.1 Commercial Building Telecommunications Cabling Standard
- ANSI/TIA 568-C.2 Commercial Building Telecommunications Cabling Standard, Balanced Twisted-Pair Cabling Components
- ANSI/TIA 568-C.3 Optical Fiber Cabling Standard
- ANSI/TIA 569-C Commercial Building Standard for Telecommunications Pathways and Spaces
- ANSI/TIA 606-B Administration Standard for Commercial Telecommunications
- ANSI/TIA 607-A Commercial Building Grounding (Earthing) and Bonding
- ITU-T G.984 addresses PON systems (BPON, EPON, GPON)
- ITU/Telcordia GR-1209 CORE Generic Requirements for Passive Optical Components
- ITU/Telcordia GR-1221 CORE Fiber Optic reliability

Understanding Passive Optical LANs and GPON

Network Architecture

While there are many applications for GPON, this paper will address Fiber-to-the-Desktop (FTTD) deployment often used in commercial, educational, and governmental office environments. The most commonly used POLS follow the ITU-T G.984 GPON Class B+ standard. In this application, GPON is distributed via single-mode, simplex optical fiber connectors, and passive optical splitter(s) typically using Angled Polish Connectors (APC) to provide precision terminations that minimize the impact of insertion and return loss. There are four major components to this GPON system: the Optical Line Terminal (OLT), the transport media (cabling and components), the fiber optic splitter, and the Optical Network Terminal (ONT). These components are identified in the following line diagram.



GPON Components

Optical Line Terminal (OLT)

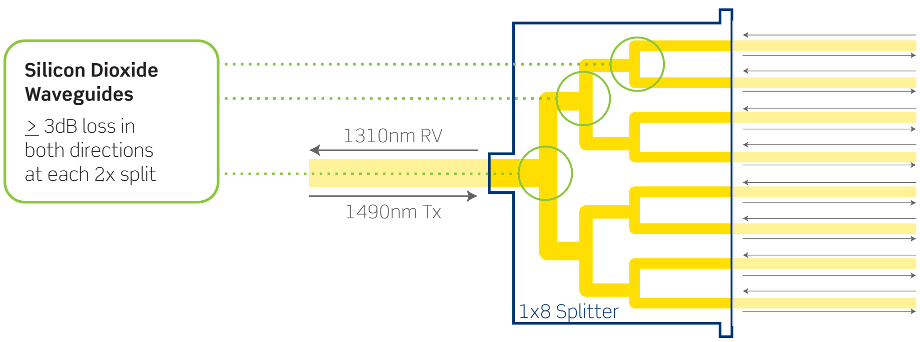
The OLT is an active Ethernet aggregation device typically located in the Main Equipment Room or Data Center of a facility. An OLT converts the aggregated fiber optically transmitted signals to an electrical signals and presents them to a core Ethernet switch. The OLT replaces multiple layer 2 switches at distribution points (ERs, TRs, and TEs). Backbone cabling or horizontal cabling connects to the OLT distributing signal through optical splitters, which are connected to the Optical Network Terminal at each work area outlet.

Transport Media – Structured Cabling Systems

GPON uses the passive, physical cabling infrastructure to transmit a signal. This includes copper and fiber optic patch cords, enclosures, adapter plates, connectors, splitters, backbone and horizontal cable faceplates, and pathway support materials. All transport media components should be factored into the channel loss budget when verifying the systems performance.

Passive Optical Splitter

Part of the transport media, the splitter enables multiple devices to be serviced from a single inbound fiber. The passive optical splitter uses a series of silicon dioxide waveguides to split a fiber from one to two strands. The amount of outputs in the splitter determines the number of splits that occur. Approximately -3dB of loss occurs at each split, as shown here.



For this 1x8 splitter example, a perfectly terminated and performing splitter would have a -9 dB loss per output.

Optical Network Terminal (ONT)

The ONT is a device typically located near the work area outlet. The ONT provides conversion of GPON signals from optical to electrical for delivery to the end device. ONTs also provide AES encryption via a security key. The ONT typically has multiple Ethernet ports for connection to IP devices such as CPUs, phones, wireless access points, cameras, or other video components.

PON Equipment Vendor Options:

- Some ONTs support Power over Ethernet (WAPs, VoIP phones, etc.) IEEE802.3af, at
- Some ONTs support copper horizontal distances (100m)
- Redundancy for fiber facility and/or added equipment redundancy
- Remote powering and/or battery reserve at ONT

Link vs. Channel Attenuation (as defined by ANSI/TIA-568-C.0-2-2012)

Link attenuation only includes cable, connectors, and splices (excludes active devices and splitters)
Channel attenuation includes all passive components (cable, connectors, patch cords, splices, couplers, and splitters)

Transport media consists of:

1. Pre-terminated (recommended) or field terminated:
    - Multi-fiber backbone cable assemblies
    - Simplex backbone cable assemblies
    - Simplex horizontal cable assemblies
2. Fiber Optic Splitters (typically 1x16 or 1x32)
    - Can have redundant input capabilities (2x16 or 2x32)
3. Simplex fiber optic patch cords
4. Fiber optic connectors and couplers – Angled Polish Connector (APC)
    - Typically the SC/APC connector is used, but LC connector and UPC solutions are available
5. Copper patch cords (Category 6 or better recommended)

The ITU-T G.984 standard determines the minimum and maximum channel attenuation allowed over a maximum distance. ITU-T G.984 GPON Class B+ values are as follows:

		Nominal Wavelength (nm), Wavelength Range {nm}			
		1270 {1260-1280}	1310 {1260-1360}	1490 {1480-1500}	1577 {1575-1580}
Application		Upstream		Downstream	
GPON Class B (ITU-T G.984)	Min. Channel Attenuation, dB		10	10	
	Max. Channel Attenuation, dB		25	25	
	Max. Supported Distance	20,000m (65,620 ft)			
GPON Class B+ (ITU-T G.984)	**Min. Channel Attenuation, dB**		**13**	**13**	
	Max. Channel Attenuation, dB		**28**	**28**	
	Max. Supported Distance	**20,000m (65,620 ft)**			
GPON Class C (ITU-T G.984)	Min. Channel Attenuation, dB		15	15	
	Max. Channel Attenuation, dB		30	30	
	Max. Supported Distance	20,000m (65,620 ft)			
GPON Class C+ (ITU-T G.984)	Min. Channel Attenuation, dB		17	17	
	Max. Channel Attenuation, dB		32	32	
	Max. Supported Distance	60,000m (196,850 ft)			

Notes: The channel attenuation is the sum of all link attenuations and attenuation values for all passive components including splitters, couplers, and jumpers.

System Overview Using Leviton Components

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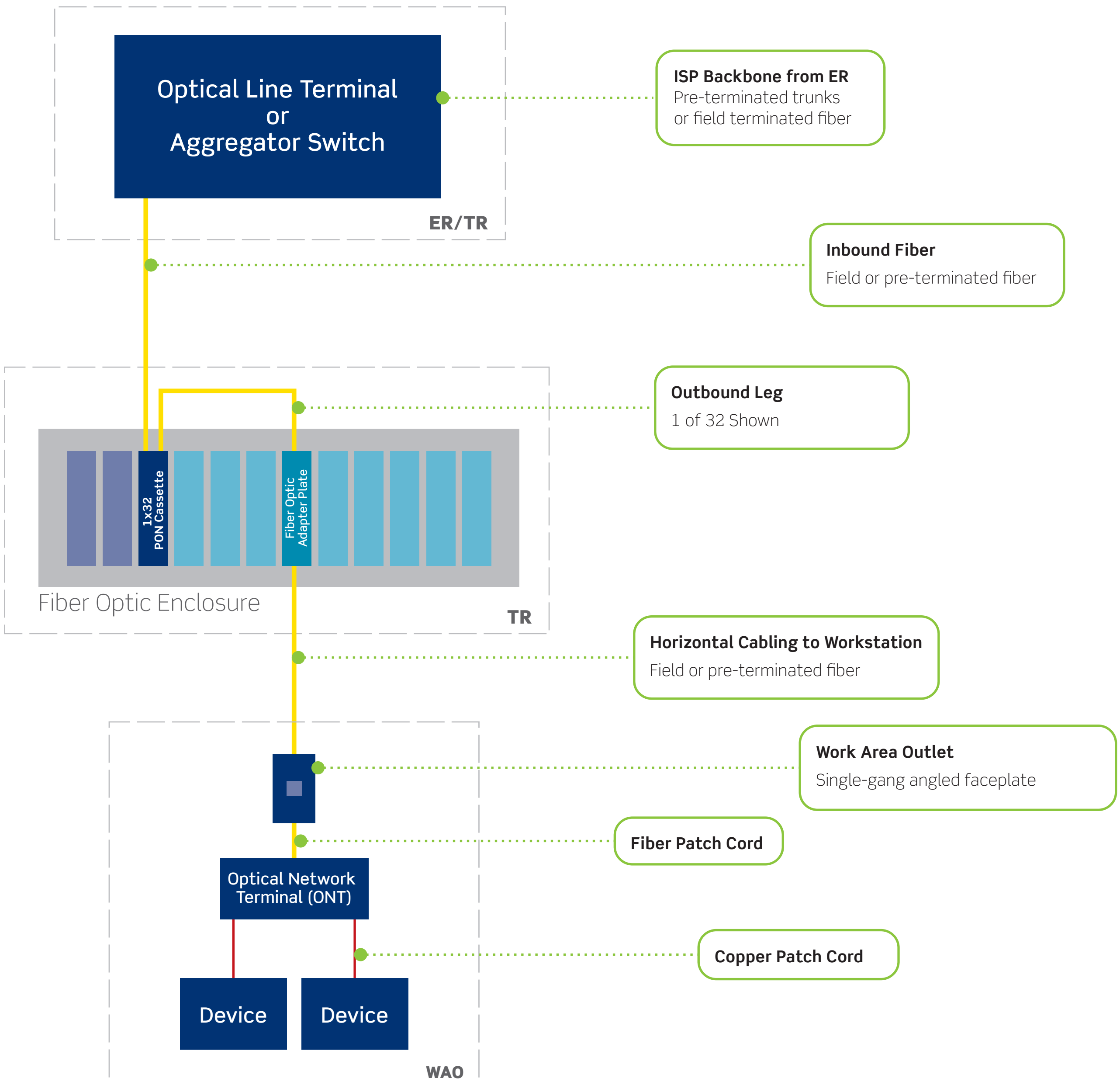
Installation Options

Star/Hierarchical Star Topology

1. Follows traditional hierarchical star topology and uses common horizontal distribution methods from an Equipment Room (ER)/ localized Telecommunications Room (TR)
2. Uses existing TR located in a dedicated floor space on every floor
3. Requires longer horizontal cable runs and less backbone fiber
4. Allows interconnect or cross-connect methods at the ER/TR location
5. Allows easy access for IT personnel for any required maintenance, much of which is centralized away from office spaces

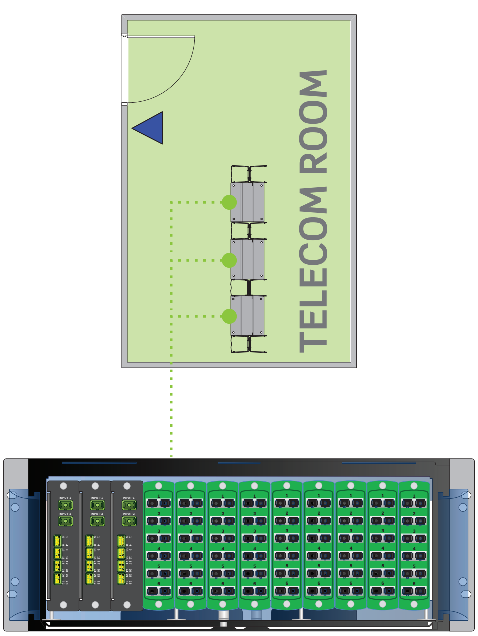


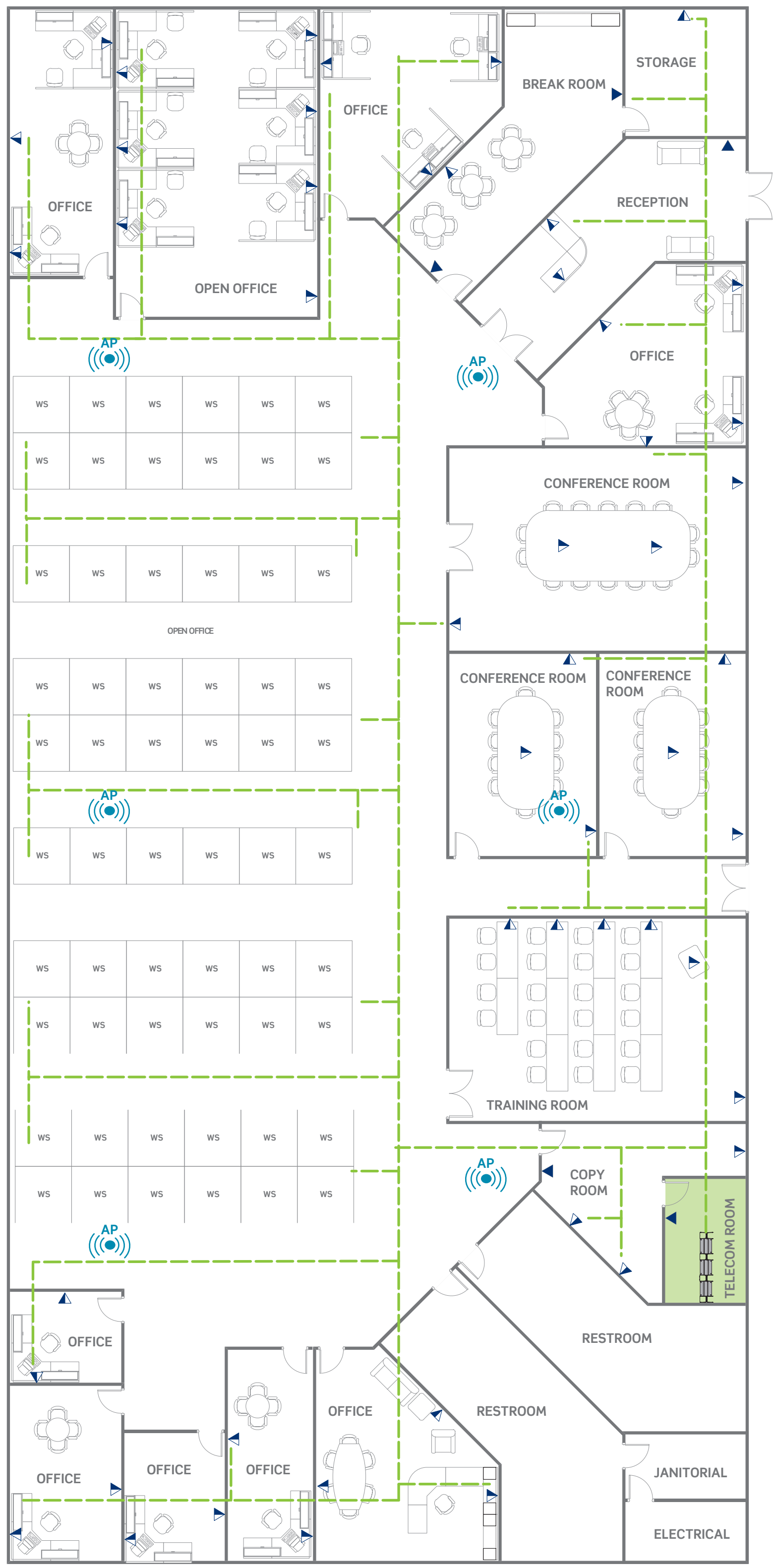
In this example of the traditional hierarchical star topology method, 1x32 splitters are located in the Telecommunications Room. Simplex, single-mode cables are installed from the Telecommunications Room to the Telecommunications Outlet.

Legend

- Horizontal Cable Pathway
- (1) OS2 SM Fiber Port (UON)
- (2) OS2 SM Fiber Ports (UON)
- (1) GPON OS2 SM Port (AP)

Fiber Optic Enclosure in the Telecommunications Room (Typical)





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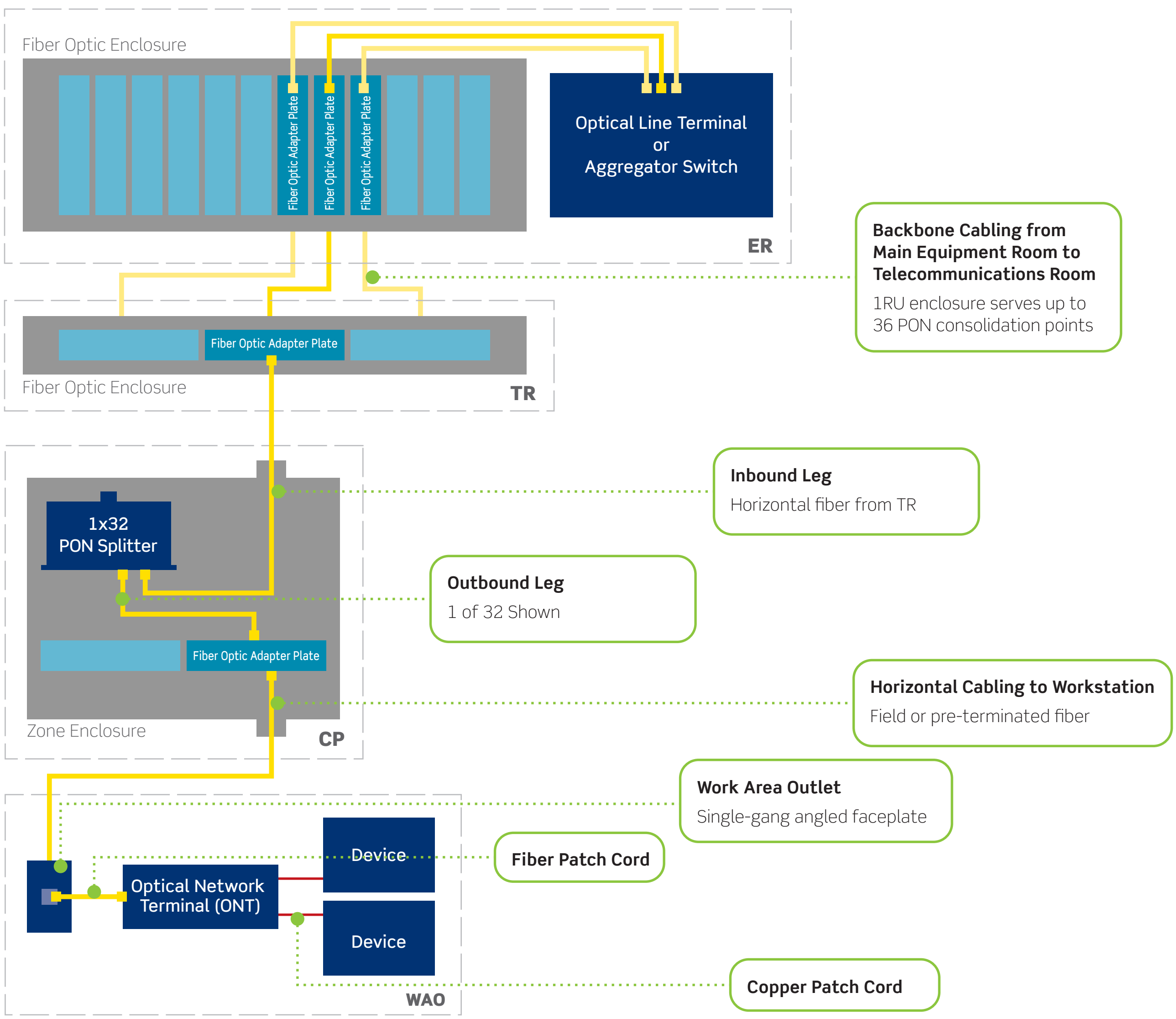
Zone Distribution Topology

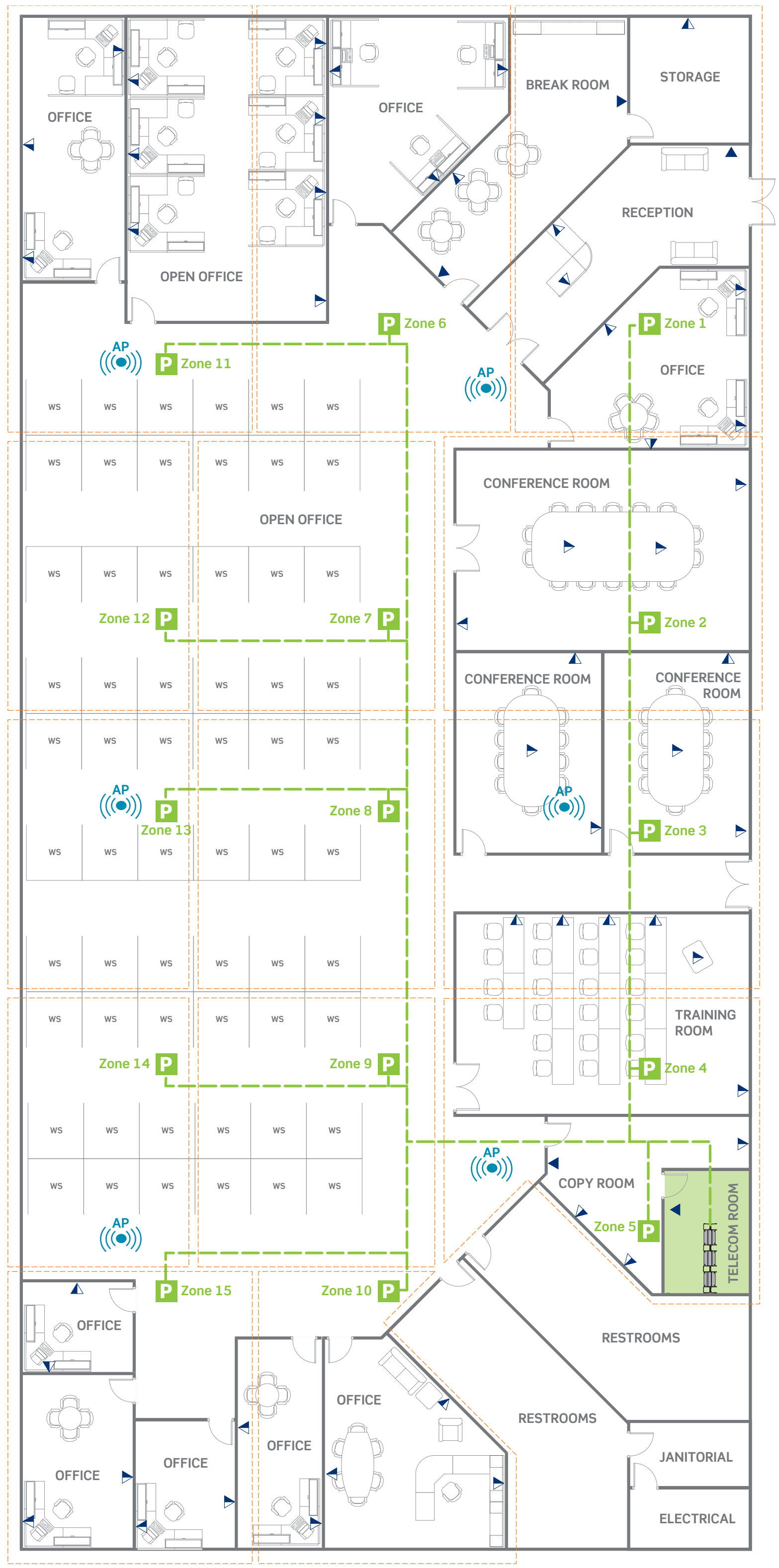
1. Allowed per ANSI/TIA standards. Requires additional design considerations from hierarchical star
2. Uses telecom enclosures located:
    - Under raised floors;
    - On or in wall;
    - Mounted in an open ceiling space; or
    - In or above a reflected ceiling
3. Requires longer backbone cabling and shorter horizontal fiber runs (less fiber cabling)
4. Uses enclosures which may be an added expense in existing environments or a lower-cost alternative in new environments (as opposed to needing a TR)
5. Allows interconnect or cross-connect at the enclosure location. Provides modularity and scalability
6. Allows easy access for IT personnel for any required maintenance, and minimizes the impact of moves, adds, and changes



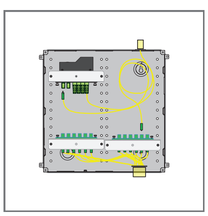
In this example of the zone distribution topology method, simplex, single-mode cables are installed from the Telecommunications Room to the Zone Consolidation Point. 1x32 splitters are located at each consolidation point to allow for adequate redundancy and future expansion. Horizontal cables are installed from the feeding consolidation point to each telecommunications outlet.

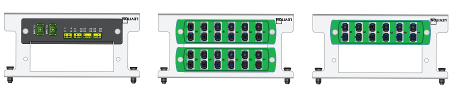
Legend

- **P** GPON OS2 SM Consolidation Point (32-PORT UON)
- Consolidation Point Zone Boundary
- (1) OS2 SM Port (UON)
- (2) OS2 SM Ports (UON)
- AP (1) GPON OS2 SM Port (AP)

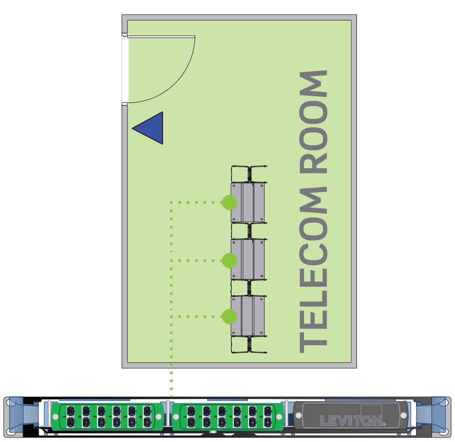


Connectivity in the Consolidation Point Enclosure





Fiber Optic Enclosure in the Telecommunications Room (Typical)



POLS Safety Issues

Working with, installing, and servicing fiber optic components requires special care, materials, and consideration. While LED and VCSEL laser sources operate at relatively low power levels, systems using fiber amplification (CATV and video links at 1550nm or Telco DWDM) can be damaging to the eyes. The correct and safe approach to take is to always verify the link is inactive and never look directly into the end of a fiber connector or port.

Testing

General Testing Guidelines

POLS are tested the same way as traditionally installed fiber optic cabling. All cabling should be tested to ANSI or IEC standards, as applicable. It is essential to use reference-grade cords and proper inspection and cleaning practices for accurate and successful results.

For more information regarding testing methods and cleaning practices, visit Leviton's series of Application Notes at: http://www.leviton.com/appnotes

Channel Optical Budget

Determining an attenuation budget prior to installation of the system is critical to verifying the system will function properly as designed. The budget is calculated to factor in the maximum loss allowed from each component of the fiber channel.

- Required to determine a budget:
- Length of the cable used
- Properties of the cable used
- Type of fiber
- Physical topology of the cable plant
- Specifications of the equipment to be used
- Need for future changes or damage allowances

The chart to the right is an example of a Link Budget Calculation and the evaluation against actual loss data. The maximum loss allowed for the channel per GPON Class B+ (ITU-T G.984) is -28dB.

Channel Link Budget Sample
400ft (0.122km) Total Length

Item	Qty	Loss (dB)	Total Loss (dB)
Total Channel Link Distance (km)	0.122	-1	-0.122
Total Fiber Splices	0	-0.3	0
Total Mated Fiber Pairs	7	-0.75	-5.25
Passive Fiber Splitter (1x32)	1	-16.7	-16.7
Total Estimated Channel Link Loss (dB)			**-22.072**

Actual Channel Link Attenuation

Item	Qty	Loss (dB)	Total Loss (dB)
Total Channel Link Distance (km)	0.122	-0.035	-0.00427
Total Fiber Splices	0	-0.3	0
Total Mated Fiber Pairs	7	-0.32	-2.24
Passive Fiber Splitter (1x32)	1	-16.05	-16.05
Total Channel Link Loss (dB)			**-18.29427**

Total Estimated Channel Link Loss (dB)	**3.77773**
Total Estimated Channel Link Loss (dB)	**9.70573**

Notes: 0.5dB/km loss allowance for outside plant fiber, 1.0dB/km loss allowance for inside plant fiber, 0.3dB allowance for splices, 0.75dB allowance for mated pair connectors, splitter loss provided by manufacturer, includes the loss of all patch cords

Tier 1 Testing

Tier 1 testing is required per ANSI/TIA and IEC standards. It is achieved by performing a visual inspection of the end face of all connectors, documenting the length via cable markings or testing apparatus, verifying polarity (if applicable), and using an optical power source and optical meter. The optical meter measures the end-to-end loss (attenuation in dB) of the link.

The recommended method is ANSI/TIA 526-7 method A.1, One Reference Jumper method. Testing needs to be performed unidirectionally or bi-directionally at the appropriate wavelengths (1490nm for the downstream and 1310 upstream). As most optical test sets operate at 1550, this wavelength is typically acceptable as a substitute for the 1490 wavelength as the difference in loss will be small. A PON power meter is capable of the specific wavelengths in use: 1310 upstream, 1490 downstream, and 1550nm (used for video BPON [Broadband PON] if applicable).

Tier 2 Testing

Tier 2 testing is achieved by using an Optical Time Domain Reflectometer (OTDR). An OTDR sends pulses of light into an optical fiber and measures the strength of the power returned to the instrument as a function of time. The OTDR creates a graphical output (trace/picture) depicting the fiber link under test. The OTDR has the capability to measure the length of the fiber and estimate the loss between any two points along the fiber link.

Tier 2 testing is not required by ANSI/TIA standards and is not a substitute for Tier 1 certification. Tier 2 may be requested by the end user to provide added test detail and a historical benchmark for each individual link performance. OTDR testing is also valuable in determining cable attenuation and fault points during troubleshooting.

Troubleshooting

While there are often several components in the channel, troubleshooting a POLS system is relatively easy. The scenarios below address the probable fault points:

PON Troubleshooting Scenario 1: Simple PON - only one customer is affected
When only one user cannot receive service, three potential faults are probable:

- Fault in the distribution fiber between the work area outlet and the closest splitter
- Fault in the ONT equipment
- Fault in the horizontal wiring

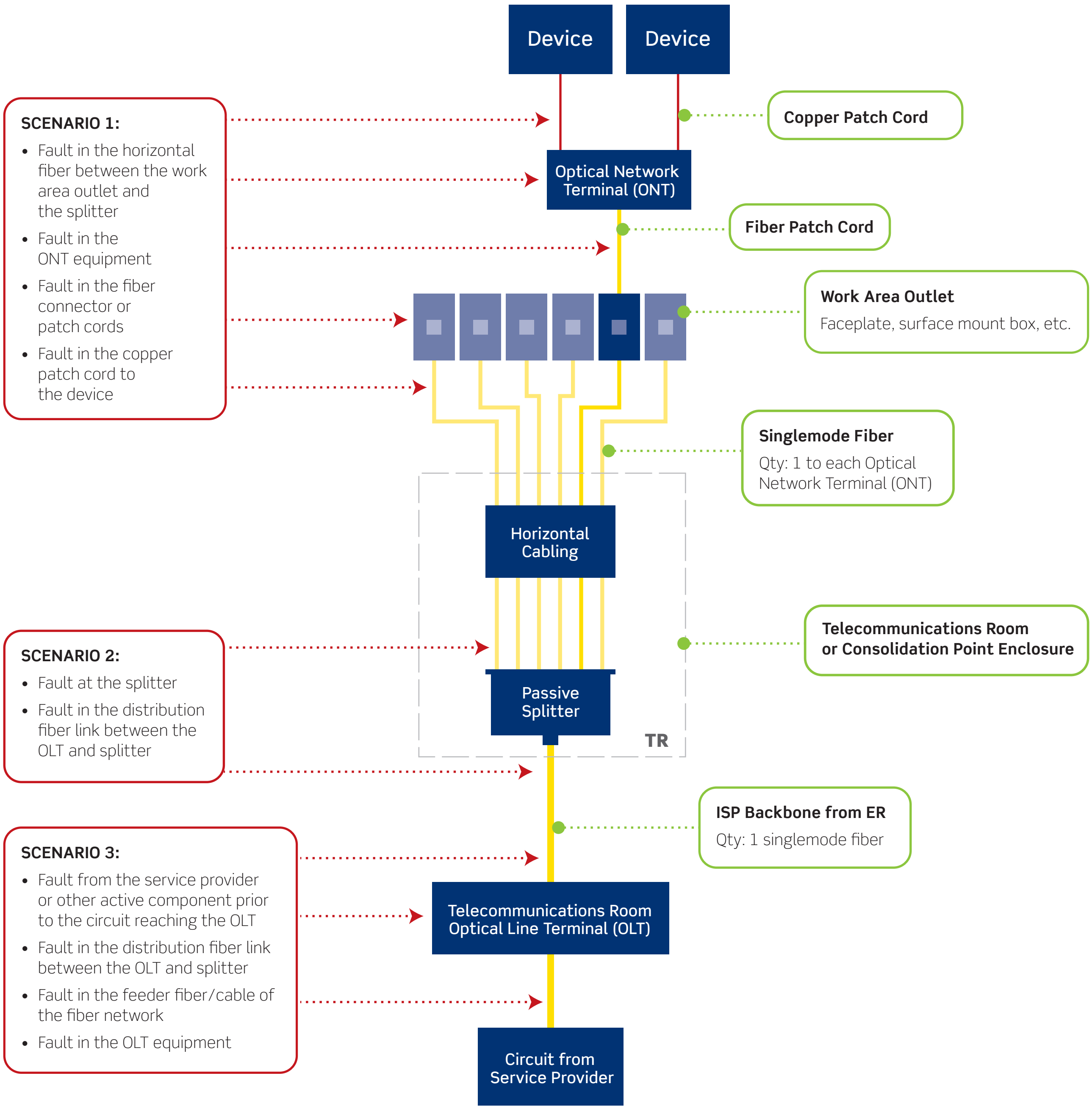
PON Troubleshooting Scenario 2: Multiple PON users affected from the same splitter
When all customers connected to the same splitter cannot receive service, but others connected to the same OLT can, the cause may be because of one of the following:

- Fault at the splitter
- Fault in the fiber link between the OLT and splitter

PON Troubleshooting Scenario 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:

- Fault at the splitter closest to the OLT
- Fault in the feeder fiber/cable of the fiber network
- Fault in the OLT equipment

Troubleshooting Schematic:



Conclusion

POLS and GPON, while still a relatively new concept as a method for commercial structured FTTD cabling systems, are becoming more common due to flexibility, reduced physical footprint, improved physical and network security, and potential and realized cost savings. While not for every user or scenario, a carefully designed and properly commissioned POLS system will provide a scalable, bandwidth-rich and secure solution.

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