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Communication Markets Division

White Paper

Design and Installation Challenges and Solutions for Passive Optical LANs

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Introduction

Passive Optical Network (PON) technology is finding its way deep into the Local Area Network (LAN) to provide significant features, benefits and cost savings to large businesses and organizations. This is particularly true for the Gigabit PON (GPON) flavor, which is standardized by the International Telecommunications Union (ITU) and used extensively around the world for fiber-to-the-home (FTTH) triple-play service delivery.

A passive optical network (PON) is a point-to-multipoint network architecture that is now being implemented to provide a fiber-to-the-desktop solution in which unpowered (hence passive) optical splitters are used to enable a single optical fiber to serve multiple end points with multiple services. Passive Optical LAN (POL) solutions are implementations of PON technology platforms that have been optimized for enterprise LAN environments. Although this technology has only been made available in the last couple of years, it is quickly gaining traction in the communications industry.

Passive Optical LAN: Drivers Toward Adoption

The drivers contributing to a successful POL adoption are primarily:

- Scalability and reliability
- Ease of use and administration
- Energy savings and environmental sustainability
- Optimized bandwidth connectivity
- Advanced security
- Lowest total cost of ownership (savings in initial capital equipment cost as well as ongoing operational cost)

Due to one or more of these drivers, decision makers are increasingly choosing to forgo the status quo of a copperbased Ethernet LAN and take advantage of what POL has to offer for the long-term benefit of their organizations.

POL is best suited for larger LAN deployments, where scalable and immediate cost savings are most realized and longer-term operational benefits of the solutions can be gained. Verticals that could benefit most from POL include:

- Department of Defense military bases/posts
- Federal, state and municipal government agencies/entities
- Large hospitality facilities/hotels/resorts
- Higher and lower education campus area networks
- Healthcare facilities/hospitals
- Large enterprise businesses
- Financial institutions
- Media companies
- Cruise/Naval ship communications
- Industrial/manufacturing plant networks
- Airports and stadiums

Until recently, the high cost of a future-proof, fiber-to-the-desktop LAN architecture kept it out of reach for many organizations. However, today, capital expense related to POL equipment and infrastructure can run up to 40 percent less than the traditional copper-based Ethernet solution. In addition, deploying a POL system can result in 50 to 70 percent savings in system operational expenses compared to a copper system due to less energy consumption, reduced HVAC and UPS cooling requirements, and lower monitoring and maintenance costs. This disruptively low total cost of ownership savings along with the many other benefits of the future-proof fiber infrastructure contributes to POL gaining traction in the market.

POL Design and Install Challenges

As can be expected with the fast adoption of any new technology, some challenges may be encountered with regard to the design and installation of the network infrastructure.

Deciphering Industry Cabling Standards Support for Pol Applications

In August 2012, the Telecommunications Industry Association (TIA) published Addendum 2 to the ANSI/ TIA 568-C.0 Generic Telecommunications Cabling for Customer Premises. In this addendum, the TIA generic cabling standards have been updated to support singlemode fiber PON applications for the LAN. The standard now provides the following guidance with regard to PONs:

- Link and channel definitions have been updated to accommodate PONs.
  - Link attenuation does not include any active or passive devices other than cable, connectors and splices (i.e., link attenuation does not include such devices as optical bypass switches, couplers, splitters, repeaters or optical amplifiers).

  - Channel attenuation includes the attenuation of the constituent links, patch cords and other passive devices, such as bypass switches, couplers and splitters. Channels begin and end at active devices and they do not include active devices, such as repeaters, switches and amplifiers. The channel attenuation is the sum of all link attenuations and attenuation values for all passive components.
- Optical Fiber Application Support Information Table 9 added for PONs.
  - Table 9 has been added to the standard, indicating "Maximum Supportable Distances and Minimum and Maximum Channel Attenuation for singlemode Passive Optical Network Applications." The table provides guidelines for designing the minimum and maximum channel attenuation and supported distances for various PON applications.
- With regard to the GPON Class B+ (ITU-T G.984) POL application support, the standard states the following:
  - Minimum attenuation = 13 dB, Maximum attenuation = 28 dB, 20 km distance

(Based on minimum performance requirements of singlemode fiber as established by TIA568-C.3 Optical Fiber Cabling Components Standard)

POL technology uses singlemode type of fiber, which is necessary to enable wave division multiplexing of upstream and downstream signals on a single fiber (no separate transmit and receive). It also incorporates the use of passive optical splitters located anywhere between the main equipment Ethernet aggregation chassis or optical line terminal (OLT) and workgroup terminals, also known as optical network terminals (ONTs). Note that the POL application can be designed over a 20 km (about 12 miles) distance. The passive optical splitters serve to branch the signal from one PON port on the OLT to typically up to 32 ONTs located in or near the work areas. With typically four gigabit Ethernet ports per workgroup terminal, a single OLT can support up to 7192 Gigabit Ethernet ports.

As required for POL, TIA 568-C.0 has long recognized singlemode fiber media type in the cabling subsystems for the backbone and horizontal links and specifies minimum performance requirements in TIA-568-C.3. Additionally, the fiber connectors typically required by POL applications (primarily SC/APC) are also allowable connector types. Regarding topologies supported, TIA-568-C.0 requires generic structured cabling to be installed in a hierarchical star. Strict adherence to the standard allows the optical splitters to be installed in the telecommunications spaces distributors A, B or C. This allows some amount of opportunity in the design to take advantage of the flexible POL infrastructure. Keep in mind that the permanent links for the backbone or horizontal as defined and specified per the standards should not include the optical splitter losses in the attenuation calculations. Regarding the horizontal fiber distribution, the standard recommends a two-fiber or higher count to each work area.

The recent update to the TIA cabling standards represents a significant development for enablement of PON LAN technology adoption in our industry. With the changes made to the TIA-568-C.0-2 publication, POL can now be designed and supported in accordance with the industry standards intended to ensure the longevity of the infrastructure life cycle as well as to ensure the performance of the application system bandwidth over the distances specified.

Consider the following statement of stewardship by the TIA (Telecommunication Industry Association), "Telecommunications infrastructure affects raw material consumption. The infrastructure design and installation methods also influence product life and sustainability of electronic equipment life cycling. These aspects of telecommunications infrastructure impact our environment. Since building life cycles are typically planned for decades, technological electronic equipment upgrades are necessary. The telecommunications infrastructure design and installation process magnifies the need for sustainable infrastructures with respect to building life, electronic equipment life cycling and considerations of effects on environmental waste." POL adoption for an organization promotes significant energy conservation and environmental sustainability by enabling all of the following:

- Reduction in overall power consumption on a per-Ethernet port basis in comparison to traditional technologies as well as effectively eliminating electrical and HVAC requirements in the telecommunications room.
- Reduced physical cable plant infrastructure (significant reduction in cabling and interconnect materials; up to 90 percent less cabling materials required, depending on configuration).
- Reduction in building construction square footage required for the telecommunications space requirements by eliminating the active electronics support normally required on each floor (this building space can be re-purposed for other uses and/or savings spent on advanced IT features instead).
- Increased infrastructure life cycle by utilizing singlemode optical fiber with properties of high bandwidth supported over long distances (further enabling a sustainable infrastructure capable of supporting future generations of electronics over the building life).

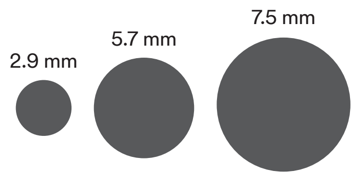
In these ways, POL can provide quantifiable benefits with regard to energy and sustainability stewardship.

Overcoming the "Fear of Fiber"

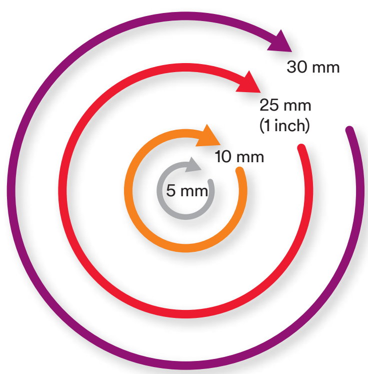
Fiber cabling as well as the design and installation of it for an in-building LAN network is in many ways more robust and simpler than copper structured cabling. Over the years, network designers and installers as well as building architects have become accustomed to dealing with the many technical challenges and limitations imposed by 100- ohm balanced twisted-pair structured cabling to support the traditional copper-based Ethernet LAN. However, POL and the singlemode fiber-to-the-desktop infrastructure provide higher performance over longer distances and can reduce installation challenges associated with the copper-based LAN.

In 2002, the first bend-insensitive singlemode fiber cable was launched in the U.S. It was capable of a 10 mm (about 3/8 inch) bend radius without affecting signal performance. Since then, manufacturers have improved upon this feature and developed fiber with specifications that support 7.5 mm (about 1/4 inch) and even 5 mm (3/16 inch) bend radii. Current low-water peak fiber (OS2) has less than 0.35 dB per km at 1310 nm. This means that fiber cabling media can be easily handled. Compared to copper structured cabling solutions, the fiber cabling media that is available today has numerous advantages with regard to durability and performance. (See Figure A.)

Cable Diameter Relative Comparison



Bend Radius Relative Comparison



Riser-rated Cables	Bend-insensitive SM Fiber Cable	Category 6 UTP	Category 6A UTP
10G Distance	40,000 m	45 m	100 m
Cable Outer Diameter	2.9 mm	5.7 mm	7.5 mm
Weight	4 lb/1,000 ft	22 lb/1,000 ft	39 lb/1,000 ft
Minimum Bend Radius	10 mm (down to 5 mm)	22.8 mm	30 mm
Tensile Strength (Installation)	At least 50 lbf	25 lbf	25 lbf

Figure A

Fiber media is easier to install than copper structured cabling due to the following traits:

- **Much lower bend radius.** The minimum bend radius for fiber cable is 5-10 mm, depending on the type, compared to approximately 30 mm for Category 6 copper cabling and up to 50 mm for Cat 6A, depending on the diameter and shielding of the copper cabling. This makes the fiber installation bend radii specifications much easier to obtain with suitable smaller interconnect and cross-connect apparatus than that required for copper cabling.
- **Robust pulling tension.** Fiber media typically has a 50 to 100 lbf pulling tension specification, compared to traditional copper media, which is relatively delicate and specified to only 25 lbf tension for cables that are installed by pulling. This 25 lbf limit is imposed in order to safeguard the required twists of the copper conductor pairs. Otherwise, performance degradation due to crosstalk and other parameters can occur during the installation.
- **Fiber is small.** Typical fiber cables used for longer distribution runs are 2.9 mm or less in outer diameter, compared to copper structured cabling, which is twice that for Cat 6 and more for Cat 6A. For this reason, fiber solutions compared to copper structured cabling can significantly reduce installed space requirements, congestion and install time.
- **Fiber is lightweight.** Fiber cabling media weighs a fraction of copper media. Fiber typically weighs four pounds per 1,000 feet, compared to 22 or 39 pounds per 1,000 feet for Cat 6 or Cat 6A, respectively. Fiber's lighter weight makes it easier and less costly to install.

Fiber can be an environmentally responsible and sustainable choice:

- An all or partial fiber choice for the installed in-building network can provide benefits of environmental sustainability. For example, an all-fiber LAN can save thousands of pounds in raw materials of plastic and copper when substituting for just one sizeable copper structured cabling project.
- The LEEDs (Leadership in Energy and Environmental Design) internationally recognized Green Building Council program can reward building owners who choose fiber with certified accreditation based on a points criteria. LEED certification can lead to increased property values for certified buildings.

With a general lifetime reliability expectancy of 25-50 years and longer, fiber is a very good choice for future-proofing the infrastructure investment.

Let's look at an example: A traditional Ethernet Category 6 copper structured cabling system in a ten story building supporting 2500 Ethernet ports should require about 500,000 feet of copper cable weighing about 24 lbs/1000' which equates to about 12,000 lbs total. (This estimate includes a small amount of fiber in the riser, and a large amount of horizontal copper cabling, and all copper patch cords required). In comparison, 2500 Ethernet ports with POLS supported by duplex fiber optic cabling to work area outlets and fiber patch cords to the ONTs (which have four Ethernet ports each) requires only about 150,000 feet of cable which weighs less than 5 lbs/1000' and equates to about 1200 lbs total. (This estimate includes all fiber in the riser and in the horizontal, and the fiber and copper patch cords to connect Ethernet end devices.) Overall, the POLs provides more than 90% savings in cabling materials! In addition, significant savings are also gained in the cabling infrastructure support materials (ladder rack, spaces, fire barrier, etc.).

Other benefits of fiber cabling media:

- Fiber is more secure as a transmission media because it is harder to tap into than copper cabling, and it is not vulnerable to compromising emissions of radiated signals.
- Fiber networks do not require shielding to mitigate issues of EMI/RFI interference, which causes performance degradation.
- Fiber cable is all-dielectric, so it presents no grounding and bonding issues.
- Fiber is better suited than copper to allow for converged services because it can support numerous separate or converged networks (like POL) on independently managed multiple transmission light wavelengths.

In addition to the above advantages of fiber cabling media, some are surprised to learn that fiber inside plant cabling is very easy to test and verify for correct installation and qualification required to obtain a manufacturer's typical extended warranty certification. According to ANSI/TIA cabling standards (which among other things is often used as a basis for obtaining the manufacturer's extended warranty), the fiber inside plant requires only one measurable metric in order to verify a proper installation: the channel attenuation/loss. This is obtained by the use of a simple power meter and light source reading. If arrayed fibers are used in the network, they should be visibly checked for proper polarity, and the length of the fiber itself should be recorded as read from the cable jacket. According to industry standards, OTDR (optical time domain reflectometer) readings are recommended only for outside plant or when troubleshooting problems (tier 2 testing).

In contrast, according to the ANSI/TIA 568-C.0 cabling standards, copper cabling requires measured verification of no less than seven technology parameters for confirmation of the installed copper infrastructure performance characteristics: insertion loss, return loss, pair-to-pair NEXT, pair-to-pair ACR-F, propagation delay, wire map, continuity for signal conductors, short circuits, open circuits and screened conductors, if present. If any of these parameters are out of limits, troubleshooting activities will be required. Therefore, the fiber inside plant may be easier to test, certify and commission compared to traditional copper structured cabling.

Many vendors, including the 3M Communication Markets Division, offer fiber optic installation courses to customers.

For more information on 3M fiber training courses, please visit www.3M.com/telecom.

Solutions for POL Installations

The 3M™ Passive Optical LAN Solutions (POLS) portfolio offers a complete, end-to-end fiber solution. From the equipment room to the work area and everywhere in between, 3M offers plug-and-play connectivity, high reliability and low cost of ownership. The result is a network that is better for the environment and for business. Visit 3M.com/POLS for more information. Also, see the 3M whitepaper "Connectivity Solutions for Passive Optical LAN Installations" for further discussion on the 3M POLS portfolio.

1. “Hot Topic Report - Passive Optical LAN,” by Summer Chardine, Building Services Research and Information Association (BSRIA) research analyst, October 2011
2. “Transformation of the Enterprise Network using Passive Optical LAN,” whitepaper commissioned study by Network Strategy Partners, May 2009
3. ANSI/TIA-568-C.0-2-2012 Generic Telecommunications Cabling for Customer Premises-Addendum 2, General Updates
4. ANSI/TIA-568-C.0-2009 Generic Telecommunications Cabling for Customer Premises

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