

# Passive Optical LAN: WHY ALL THE HYPE?

*A Comprehensive Analysis*

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White Paper — January 2010

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## Introduction

The surging demand for consumer-driven high bandwidth applications for the residential market, such as HDTV, 3-D TV, video on demand, IPTV, gaming etc., has led to a large scale global investment and deployment of fiber to the home (FTTH) networks. Almost exclusively, these networks run over single-mode optical fiber cabling. The bandwidth potential and distance capabilities of single-mode fiber give the service providers much greater cost savings and flexibility to deploy these newer high bandwidth applications in comparison to the older traditional copper based networks. The demands placed on service providers today are quite different than in the past.

The traditional role for the telephone company was to provide voice services to the home or office. Likewise, cable television (CATV) service providers delivered their TV programming over coax networks. With the changing dynamics in the market place, traditional telephone and CATV companies are evolving into multiple services providers offering voice, video, data and wireless applications. The legacy copper based infrastructures used by telephone and CATV companies were no longer adequate to meet this technology shift. Local carriers were faced with the challenge of how to cost effectively migrate from their traditional copper infrastructure model, which had very limited bandwidth and distance capabilities, to a model that would allow them to send multiple applications to multiple homes over much larger areas. In order to deal with this consumer driven appetite for more bandwidth, several new technologies and architectures were developed.

The Passive Optical Network, or PON, is at the forefront of this evolutionary shift. Utilizing single-mode fiber optics in conjunction with passive optical splitters allows for different technology platforms to be implemented as a mechanism for simultaneously delivering multiple services and applications to multiple homes. The most common of these platforms are BPON, GPON and EPON. While there are other architectures to deliver converged services to the home, such as Point-to-Point, fiber to the curb and fiber to the node, this paper focuses only on the passive optical networks. The strengths and weaknesses of each of the technologies depend on geographical coverage, density of area, distances from central offices, bandwidth requirements, uptake rates etc. The key to remember is that no single architecture or technology is perfect for every application and/or location.

In the residential market, PON architectures have increasingly become the preferred architecture for many global markets, allowing service/access providers to effectively and efficiently meet the growing consumer demands. With the increasing success of the PON deployments world wide and their ability to cost effectively support the converged network of the residential subscriber, efforts are now being made to use this same technology in the Enterprise LAN environment. This approach is referred to as Passive Optical LANs, shortened to POL. In this paper we will analyze the prospects of deploying PON or POL networks in the Enterprise space.

### Summarized Analysis

Here is a summary of the main factors to consider when evaluating Passive Optical LANs. The paper which follows gives a much more detailed look at each of these factors.

Factors	Traditional Point-to-Point Switched Network	Passive Optical LAN
<b>Cost</b> <ul style="list-style-type: none"> <li>• CapEx</li> <li>• OpEx</li> <li>• Bandwidth</li> </ul>	Moderately more	Moderately less
	Slightly to Moderately more	Slightly to Moderately less
	Much lower cost per “bit” transmitted or more “bits” available per dollar spent	Much higher cost per “bit” transmitted or fewer “bits” available per dollar spent
<b>Performance</b>	Highest throughput with dedicated and symmetrical bandwidth	Limited throughput with asymmetrical and shared bandwidth
<b>Convergence Support</b>	Best potential	Limited potential
<b>IT Resources</b>	Neutral	Neutral
<b>Pathways &amp; Spaces</b>	Significantly more space needed, but depends on architecture, i.e. FTTD, FTTE or Hierarchical Star	Significantly less space needed
<b>Ease of Deployment</b>	Requires more resources, skills and time for conventional deployment, but could also utilize Plug-n-Play approach	Plug-n-Play, quick and less craft sensitive
<b>Security</b> <ul style="list-style-type: none"> <li>• Physical</li> <li>• Logical</li> </ul>	Depends on architecture, i.e. FTTD, FTTE or Hierarchical Star	All fiber, most secure
	Point-to-Point most secure	Broadcast all data to all ports least secure
<b>Redundancy</b>	Good, typically built in	Poor, very limited
<b>Scalability</b>	Greatest potential	Limited potential
<b>Standardization</b>	Cornerstone of Enterprise Standards	No supported standard for Enterprise
<b>Environmental Friendliness</b>	Supports centralized and midspan PoE and convergence which allows the building to become “greener”	Initially “greener”, but does not support centralized PoE or efficiently migrate to convergence so long term becomes less “green”
<b>Port Utilization</b>	Centralized switches which means higher port utilization	Distributed switches so moderate to low port utilization

## Detailed Analysis

### PON Architecture

Passive Optical Networks used in FTTH are networks that deploy strands of single-mode glass from the central office out to a remote terminal where each single-mode strand is passively split in a typical 1x16 or 1x32 scheme. Each single-mode strand coming from the central office serves up to 32 or even potentially 64 houses, see figure 1. In an enterprise passive optical LAN the same approach is taken. However, instead of each single-mode strand serving 32 houses, it serves 32 optical network terminals, or ONTs, that sit in each work area. Each of the optical network terminals has 4 ports, serving either a single user or 2 users, assuming two ports per user. So, in the passive optical LAN network, each single-mode strand would support up to 64 users, see figure 2.

Figure 1 **PON**

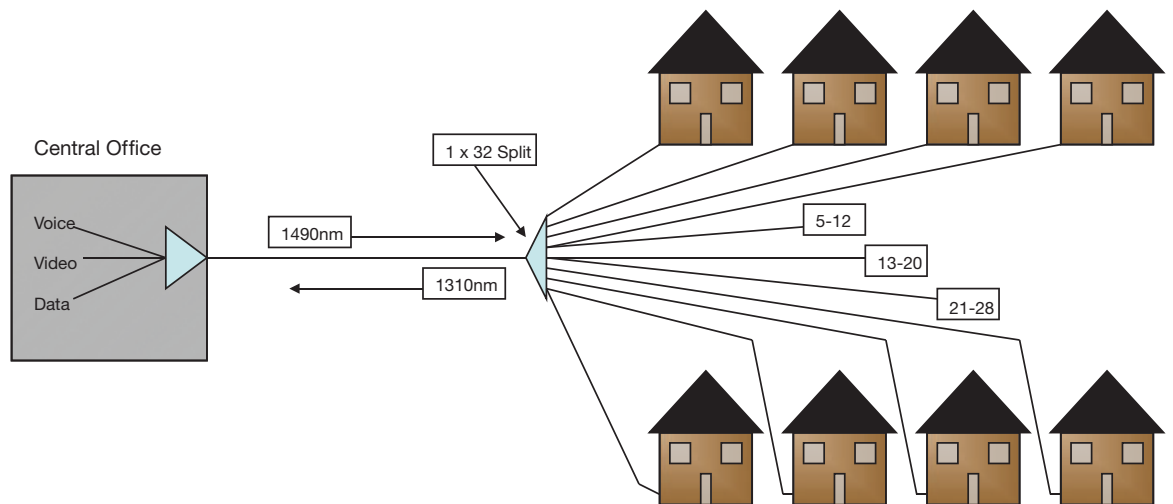


Figure 2 POL

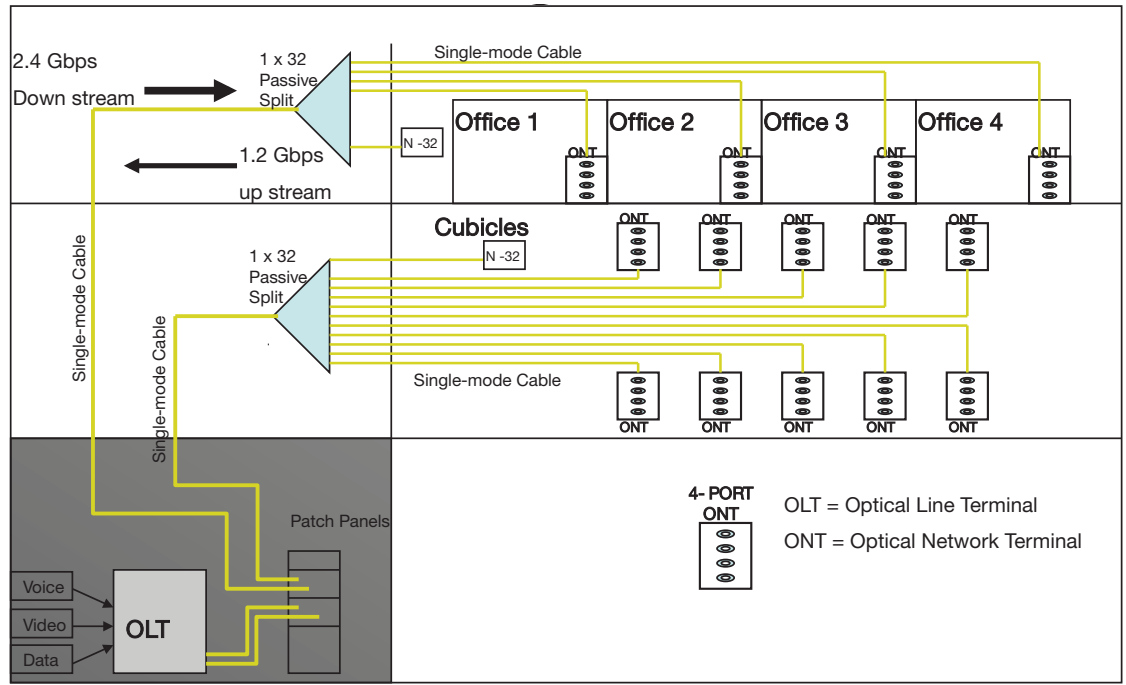
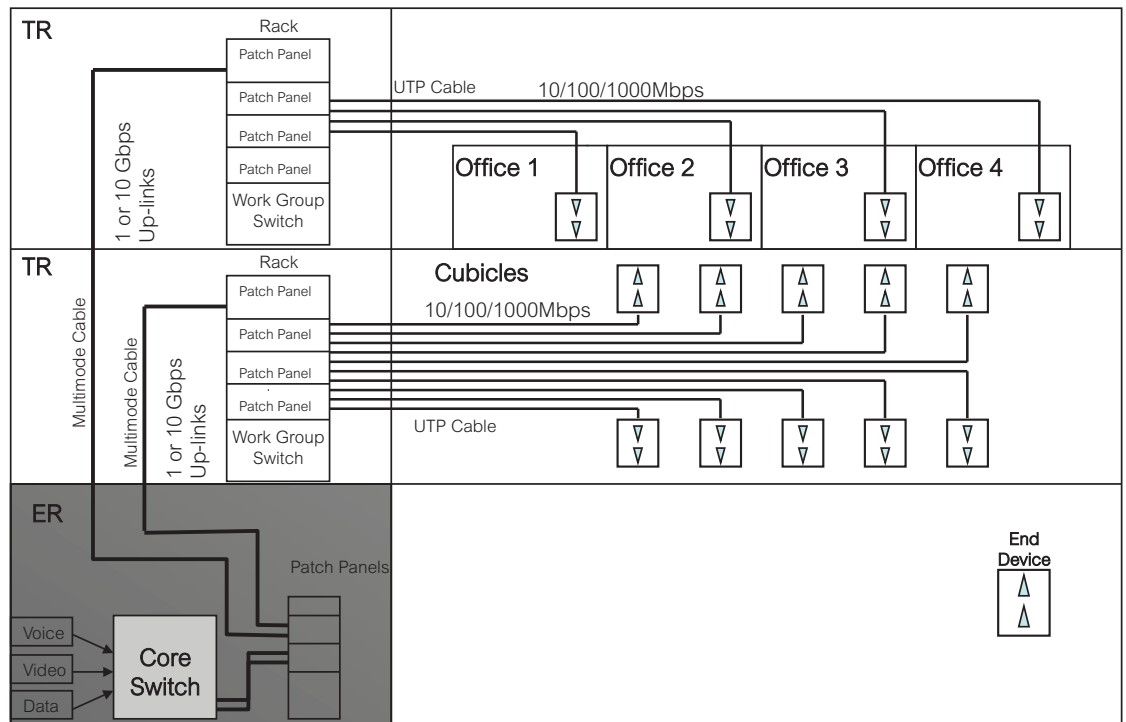


Figure 3 Traditional Network



With the PON and POL architectures, the application platform chosen will determine the overall bandwidth available to each home or user. Since the PON/POL architectures utilize a passive splitter, the total bandwidth is shared amongst all the homes and/or users or devices. This is very similar in nature to cable modems today, where all the bandwidth is shared amongst every user who is attached to that channel. For example, the current Enterprise POL architecture utilizes a GPON network where the down-stream total bandwidth is 2.4Gbps and the up-stream total bandwidth is 1.2Gbps. If the passive split was deployed at a 1x32 scheme then each office user has a potential bandwidth of 75Mbps down-stream and 37.5Mbps up-stream. If the passive split was deployed to accommodate up to 64 office users then the bandwidth potential would be 37.5Mbps down-stream and 18.75Mbps up-stream, respectively. While this seems like a great improvement compared to traditional internet access speeds for the home, i.e. DSL and/or Cable Modems, it is still much slower than what a typical office worker enjoys on the office network, which is generally 100Mbps switched (not shared) or even 1 Gbps switched. As seen in this example, not only is the GPON bandwidth shared amongst 32 or 64 users, but that bandwidth is asymmetrical and based on time slots as determined by the main switch or optical line terminal. In contrast, the traditional office network utilizes symmetrical switched bandwidth which guarantees all users full dedicated access to the total switch fabric.

When analyzing current trends, the general consensus is that in order to have access to all the consumer applications that are on the market, each house needs a minimum of 75 Mbps to 100 Mbps bandwidth capacity today. For example, a standard uncompressed HDTV channel requires approximately 20 Mbps dedicated bandwidth, so if three people in a house are watching three different channels that would require 60 Mbps of dedicated bandwidth, plus any other application that requires bandwidth, such as internet, gaming, VoIP, security etc. Running a fiber to each house gives homeowners the potential bandwidth pipe with which to handle these applications, however, the architecture which is deployed currently may limit that potential.

Since a PON distributes a given amount of bandwidth along a single strand of glass and then splits that bandwidth 32 or 64 ways it effectively limits the overall bandwidth available to any given house. This is not to say that the PON is limited in its ability to serve the residential customer, but rather to say that the way a PON is deployed and the choice of platform affect the overall capabilities. Looking just five to ten years out at the applications already being developed, the bandwidth potential needed for each home is projected to be around 1-2 Gbps so even the current PON platforms are not going to be sufficient.

As shown in the example above, the GPON platform allows for each house to have adequate bandwidth for the current consumer needs. However, this residential GPON bandwidth is not adequate for a traditional office environment. GPON works on an asymmetrical model, where the current platform delivers twice as much bandwidth going to the end user than it does going from the end user back to the main switch.

Because a defined group of optical network terminals share an up-stream path there is the possibility for data "collisions" where multiple transmissions attempt to use the upstream path at the same time. To correct for this, the optical line terminal at the core will allocate specific time slots for each ONT to transmit its data back to the OLT. This works well in the residential space, because video is the primary driver and only requires a down-stream broadcast and voice is a very low bandwidth application only requiring small amounts of dedicated time. In the office environment, the bandwidth requirements are much greater and each user has a greater need for dedicated up-stream and down-stream bandwidth capabilities. Unlike the old days of networking using layer 1 hubs, where every port on the hub shared the total bandwidth of the device, today's networks are built around switching technologies, where the device can automatically allocate the proper amount of bandwidth to each port as needed yielding much greater throughput for each user. As a real-life example of how bandwidth bottlenecks affect behavior, consider how many of us who sometimes work from home will wait to download certain large emails or attachments until we are in the office where we have a 'faster' network, or rather than download a large file while accessing the network through a wireless connection will wait until we have a dedicated wired connection?

In the residential market, for example, if a user has to wait an extra three or four minutes to upload a photo of the kids or a YouTube video or download their favorite book or music file there is no monetary trade off associated with that wait time. In contrast, in the office environment every minute a user is sitting around waiting for file transfers and data reception, there is a monetary value associated with that. Companies are trying to get more efficient with their time management and not less efficient.

Just look at the types of files being processed in the office environment today, i.e. presentations, two-way video conferencing, VoIP, streaming video, email, file sharing, CCTV, collaboration tools, etc. Many require two way dedicated bandwidth, not just downstream/up-stream bursts. To put this in perspective, a single presentation, which could far exceed 35 MB, would take approximately 2.7 times as long to transmit on the POL network than on a traditional 100 Mbps office network, assuming no timing issues and all things equal.

In the emerging high-end Enterprise office, the average user has a network interface card, or NIC, capable of running 1 Gbps. So, if a 1 Gbps symmetrical dedicated speed is the current offering, why would a corporation go backwards and settle for the 37.5 Mbps up-stream burst bandwidth offering of a GPON system? Of course, the Passive Optical LAN could be configured to have fewer splits, i.e. 1x16 or even a 1x8 so that each user has 77.5 Mbps or even 155 Mbps up-stream bandwidth, respectively, but then the number of OLT ports doubles or quadruples and with it the network costs rapidly increase. Available POL cost models comparing POL to traditional hierarchical star networks show a total bandwidth for each user of only 5.1 Mbps and claim that bandwidth allocation is high relative to current use. How many enterprises provision for only 5 Mbps today?

### Convergence

As technology progresses, more and more building sub systems are being added to the IP network. These sub systems consist of such applications as voice, access control, CCTV, building automation, etc. Depending on the nature of the building, i.e. educational, medical, industrial, etc., there could easily be upwards of 60 different sub systems operating, which could be converged onto a common platform. The industry trend is for more and more of these legacy stand alone sub systems to migrate to an IP based interface/system so that they can be combined onto the traditional network.

While many of these disparate building systems require fairly low bandwidth, the combination of all of them adds up. With the heightened need for security, CCTV systems are becoming very prevalent in most industries and locations. While the legacy analog CCTV systems did not require much bandwidth and in many cases only needed simplex communications, the newer digital IP based systems require much greater bandwidth and duplex or bi-directional communications. With the advent of newer CCTV applications like video analytics and HD CCTV, the amount of dedicated bandwidth for each device goes up exponentially. Instead of requiring only a few Kbps of bandwidth, these newer devices and/or applications require 8 Mbps – 45 Mbps depending on the compression algorithm used.

As more and more building sub systems are added to the network the number of connected devices goes up dramatically. While the POL may be able to handle convergence from the viewpoint of supporting voice, video and data on a single platform at the core switch level, the reality is that it will not be able to easily, efficiently or economically accommodate the myriad of building sub systems and devices. With the asymmetrical and passive splitter approach utilized by the GPON network and POL architectures, physically converging and managing all those devices becomes more difficult. With a traditional hierarchical star switch based network, the addition of multiple IP based devices and applications is more manageable because it allows for and accommodates the physical connections and consolidation of all those disparate devices and systems.

The traditional workgroup switch also gives more flexibility in utilizing VLAN technologies because in addition to the logical VLAN assignments, it also allows port based assignment. By utilizing multiple work group switches and VLAN technology, the traffic load can be more efficiently managed on a floor by floor basis yielding greater flexibility. While the POL does offer VLAN capabilities, with a passively split architecture, VLAN control will have more limitations. The POL architecture also requires all the traffic from every ONT, active device and floor to be switched through the OLT so all the traffic is backbone traffic and can't be controlled for local situations and schemes. As the number of active devices goes up, the available bandwidth per device rapidly drops.

The other issue with using POL networks is that most if not all of the building automation device manufacturers are migrating to Power over Ethernet (PoE) devices. With PoE the devices can be powered from the switch and do not require dedicated electrical outlets in the work areas. Deploying single-mode fiber to each work area, as is the case for the passive optical LAN, does not allow for the remote powering of those devices. The traditional switch based network easily accommodates this migration through midspan power injectors or PoE switches. If a passive optical LAN is initially deployed and the customer wants to move to a converged platform, where will the telecom space and power come from to accommodate all the different device connections? When looking at the ANSI/TIA/EIA-862 Building Automation Standard, we see that the recommendation for converged sub-systems will require more Telecom Room space and backup power, not less.

## Passive Optical LAN Cost Model

### CapEx

According to some of the passive optical LAN literature, the POL shows a 40% to 68% CapEX saving compared to the traditional hierarchical star network. When analyzing their cost model it is apparent that these cost savings are a little skewed. According to the literature the assumption is made that in order to upgrade to 10 GbE, single-mode electronics are required. The problem with this assumption is that on average, single-mode electronics cost around 50% - 60% more compared to the same application using multimode electronics. The 10GBASE-SR multimode fiber application has been a standard since 2002, has been well adopted and deployed and is a very economical solution. To claim that single-mode is the preferred or recommended way to deploy 10 GbE in an Enterprise environment is incorrect and yields an invalid real world cost comparison. Again, GPON was developed for the FTTH residential market where single-mode is the only choice because of distances; however, the Enterprise market is different since distances are typically much shorter and are well served by lower-cost multimode solutions.

The other assumption in their cost model is that in order to migrate to 10 GbE uplinks on switches the customer would have to do a major infrastructure upgrade to both the fiber and copper infrastructures. This might be true in some cases; however, OM3, laser optimized 50µm multimode fiber has been sold since 2000, and has been widely deployed. If a customer already has OM3 multimode installed in their backbones between telecom rooms and the equipment room, then there is no need to upgrade. In the horizontal space, 10/100/1000 Mbps to the desk has been the standard for several years and is easily supported with either Category 5e, 6 or 6A media. So, in reality, if the customer already has OM3, laser optimized 50µm multimode fiber installed in their backbones and Category 5e, 6 or 6A UTP installed in their horizontal space, there would be no need to upgrade the infrastructure. The OM3 fiber can easily migrate to 10GbE uplinks, as well as, 40GbE and 100GbE and the Category 5e, 6 or 6A UTP will support 1Gbps speeds out of the work-group switches. Using the single-mode assumptions in the calculations for the traditional network is not an accurate or even realistic comparison.

The POL cost model literature states that a switched network utilizes work-group switches with 100 Mbps user ports and 10 GbE single-mode uplinks. However, in a normal environment the work-group switch would provide 10/100/1000 Mbps user ports and 1 GbE multimode uplinks. The cost of using 1 GbE multimode uplinks is substantially lower than using 10 GbE single-mode uplinks, which is why 10 GbE single-mode uplinks are not widely deployed in Enterprise LAN switches today. The question that needs to be asked is: why were 10 GbE uplinks used for the traditional network scenario. As already stated, the GPON has a shared maximum down-stream bandwidth of 2.4 Gbps and up-stream bandwidth of 1.2 Gbps making this a very biased and unrealistic comparison? In order to accurately compare the two networks, the POL costing should really be compared to a 1 Gbps multimode uplink model.

The next source of cost savings, according to available POL literature, is that of the elimination of the work-group switches. However, every 24 port work-group switch removed from the TR is being replaced with a minimum of six optical network terminals that are distributed in the work areas. A quick internet search reveals the cost of the ONT is around \$230, so six ONTs cost approximately \$1380.00. A typical 24 port work-group switch ranges anywhere from several hundred dollars to a couple of thousand dollars depending on name brand, layer supported and options available. The ONTs being deployed in the POL architecture are only layer 2 switches. So, if a comparable layer 2 work group switch was utilized in the cost comparison there would be little to no cost advantage to the POL approach in terms of equipment cost. So, from a centralized workgroup switch versus a distributed ONT comparison the savings in electronics is negligible.

### OpEx

In the OpEx category the POL literature claims to have drastic savings in power consumption because there are fewer active elements with the elimination of the work-group switch. If the only thing being removed is the work-group switch then this is misleading because replacing one centrally located 24 port switch with six 4 port distributed switches (the ONTs) does not actually reduce power consumption. Any real savings would come from the fact that with the ONTs being located in the work area, there would be no need for any environmental conditioning in the telecom room. But regardless of where it is generated, the heat dissipated by the ONTs must still be handled by the air conditioning system, so the net OpEx savings per port is nil. Conversely, given the 4-port ONT architecture, there could be far more unused ports in a POL compared to a traditional switched LAN. In a POL, port utilization efficiency no longer benefits from consolidation of ports into work group clusters in the telecommunications room. Rather, 4 port ONTs can often strand ports in office spaces that need fewer ports. These unused ports not only add to CapEx, but also to power consumption and attendant air conditioning loads.

An obvious item omitted from the POL cost model is the need for power for the ONTs. These ONTs will need primary power and potentially back up power and that cost has to be factored in. The ONT unit has the option for battery back-up, but was that option included in the calculation and if so, what about the maintenance and replacement of those batteries over the life cycle that is assumed? If battery back up was not included, then how are the ONTs going to have any type of redundant power other than dedicated outlets in the work area and was that cost factored in? Also, even if battery back-up is used, there would still be a need for dedicated outlets in the work area, because according to ANSI/TIA-568 standards, network equipment should be powered on dedicated outlets separate from utility circuits to prevent electrical damage from occurring to network equipment. Providing dedicated power to all these distributed ONTs via a second power distribution system adds significant cost to the overall cost of the POL solution. Powering the ONTs remains a big issue for potential users to address.

One of the actual cost savings with the POL architecture comes from the reduction of long term maintenance contracts with switch providers. In a traditional network, the maintenance contracts with the switch manufacturers to maintain and guarantee a certain level of reliability can be a substantial ongoing cost. By eliminating the workgroup switches, the need for those long term maintenance contracts is greatly diminished. But that is not to say that the POL is maintenance free. Indeed, as with any critical resource, the electronics require periodic maintenance.

With all the factors compared equally, the passive optical LAN may still have a slight to moderate cost savings, but it will be significantly less than the advertised overall 40% - 55%. Remember, the savings will really depend on new construction versus retrofit and long term versus short term. Certainly, for the short term with new construction, the POL will be cost effective. In a long term scenario where migrating to converged and higher speed capabilities, the lack of scalability and available bandwidth will greatly reduce the cost effectiveness of the POL architecture. So, if initial perceived cost is the only factor used for evaluations, then POL would be favorable; however, if the total real cost of the network is analyzed the picture might look different.

## Bandwidth Cost

As stated in the literature and conceded above, the CapEx for the POL should be lower when looking at just equipment and installation cost. However, since the GPON platform utilizes different bandwidth allocation techniques compared to the traditional point-to-point Ethernet LAN, then what is the true cost of the network? Let's assume that the 40% CapEx savings is true. If the cost per port of the POL is \$200 then that would make the cost per port of the traditional network around \$333. With the GPON, each port would have 18.75 Mbps down-stream and 9.4 Mbps up-stream non-dedicated burst bandwidth. (2.4Gbps or 1.2Gbps/(32 ONTs x 4 ports)) This means 93.75 Kbps per dollar spent down-stream or 46.9 Kbps per dollar spent up-stream for bandwidth. For the traditional network deployment using 100 Mbps per port, this would yield 300 Kbps symmetrical bandwidth per dollar spent. This represents approximately 69% savings per bit with the traditional Ethernet based network on the down-stream and an 84% savings per dollar spent on the up-stream bandwidth. Another way to look at it is to say with a traditional network for every dollar spent you get 3.2 times more down-stream bandwidth and 6.4 times more up-stream bandwidth.

With the GPON, the bandwidth is not proportionately scalable so the bandwidth will not change without upgrading to a higher bit rate platform. When looking at upgrade options for the GPON and POL approach, the next level would be 10GPON, which is not yet available, but will have a proposed down-stream bandwidth of approximately 10 Gbps and a proposed up-stream bandwidth of only 2.5 Gbps. So, even with an expensive upgrade (not yet available) the available shared up-stream bandwidth for each user only doubles.

Most desktop computers today come standard with a 10/100/1000 Mbps network interface resident on the motherboard. So now, for every dollar spent you get 3 Mbps symmetrical bandwidth, which is 32 times more bandwidth per dollar spent, compared to the current GPON down-stream model. If an upgrade is made to the traditional network each user will get a 10x increase in bandwidth for about double the cost, so the total bandwidth cost is substantially lower. Remember, all this is based on the assumption of a 40% CapEx savings with the POL. The actual passive optical LAN savings are probably going to be much lower, once all things are factored equally and this in turn will make the cost per bandwidth unit much more favorable for the traditional point-to-point Ethernet network.

## IT Resources

From a network management perspective, the passive optical LAN is advertised as a great way to reduce the amount of IT resources needed to maintain the network. The assumption is that since all the core switching is centralized in the computer room and there are no work-group switches to maintain, fewer IT resources are needed. But remember, for every centrally located 24 port work-group switch replaced; there will be six ONTs to maintain. And these ONTs are no longer located in the centralized secured TR; instead, the ONT is located in the work area, usually one per user or one is shared between two users. To put this in perspective, if you have a four story building with 10,000 square feet of usable space per floor, then based on the ANSI/TIA-568 standards; you could have a minimum of a 100 users per floor. If each user is assigned two ports then 200 ports per floor would be needed. With the traditional hierarchical star approach that would mean nine 24-port work-group switches would be utilized per telecom room. To migrate to the POL architecture, those 9 centrally located switches would be replaced with 50 distributed ONTs per floor. So for the building, instead of 36 work-group switches to maintain in four secured centrally located TRs you would have 200 distributed ONTs to maintain in potentially 200 different offices or locations. While most of the maintenance and upgrades for these ONTs can be handled remotely just like the workgroup switches, the fact still remains that the number of active devices to maintain goes up drastically.

The argument for fewer active electronics in the POL comparison really only applies to the distribution switches in a campus environment where multiple buildings need to be connected to the main computer room. In that scenario, there would be more distribution switches to maintain in the traditional architecture due to that third tier of switches added. However, in a single building environment utilizing only a two tier switch approach, the amount of equipment will actually be greater for the POL than for a traditional point-to-point network.

The other major factor would be at the core switch. Here, the POL has an advantage in port density. One of the advertised optical line terminals (OLT) will accommodate up to 7168 ports in a 13 RU space. In a traditional network, multiple chassis would be required to achieve the same port count.

One other issue to take into consideration is the fact that most IT personnel have been working with traditional Ethernet networks for years and completely understand the ins/outs of how to deploy, configure and trouble shoot in that environment. With the passive optical LAN a whole new level of expertise will be needed to deploy and maintain the system. In addition, with the POL architecture, because of the splitting scheme and sharing of bandwidth on a single fiber, trouble shooting becomes more difficult than in a traditional point-to-point architecture. So, from an IT Resource efficiency perspective the POL might have some slight advantages with the core switch environment and having a consolidated software platform, but as far as the quantity of actual hardware and amount of personnel to maintain a 6x increase in distributed switches, the math seems confusing at best.

## Pros & Cons

Thus far we have discussed in detail the bandwidth issues, convergence, economics, bandwidth economics and the IT resource efficiencies associated with the POL GPON architecture. Now, let us examine in a summarized format some of the other aspects of the POL:

### 1. Pros

- **Supportable Distance** – Utilizing single-mode fiber in the POL architecture certainly allows for greater distance support without the need for additional electronics. This only becomes an asset in a campus environment or any single building where a single run from the equipment room to the telecom room would exceed 1800 feet or 550m. With the new OM4 standard, 10GbE can be supported over multimode fiber up to 1800 feet (or 550 meters). As for the campus environment, most campuses already use single-mode between buildings with the traditional architecture so this really would not be a significant advantage. The reality is that the distance advantage would apply to any fiber based architecture not just specifically the POL.
- **Pathways and Spaces** – With the POL architecture there will be significantly less cable pathways and telecom room space needed in comparison to the traditional hierarchical star network. This space savings will also contribute to an overall lower cost both upfront and long term. The reality is that any fiber based architecture, i.e. fiber-to-the-desk and fiber-to-the-telecom enclosure is going to require far less pathways and telecom room space than the equivalent copper based architecture. So this is not an argument for POL as much as it is for using fiber in general. Plus we have to remember that when the building moves to a converged network, there will need to be adequate space for both the cabling infrastructure and telecom room. If the POL is deployed initially, that space will probably not have been allocated.
- **Simplicity** – In a campus environment the POL would have a more simplistic layout. The number of levels both in the equipment and physical infrastructure would be less.
- **Security** – From an EMI/RFI data radiating security perspective and the ability to physically tap the media, the POL, just like ANY fiber based architecture, will be far superior to copper based systems.
- **Ease of Deployment** – The POL advertises using only plug-n-play media, so the deployment of the POL will be much faster and less craft sensitive. Again, this is true for any plug-n-play solution not just the POL. The most difficult portion of the deployment would be the administration aspect of making sure the right fibers are connected to the right ports and the polarity of the system is maintained, which is something that must be done with all installations.

## 2. Cons

- Redundancy** – As stated previously, without dedicated power outlets at the work area and/or some type of battery backup, the system is vulnerable to power failures where all voice and data would be unavailable. Also, with only a single fiber routed to each ONT what happens if that fiber gets damaged? Instead of only losing one port, all four ports of the ONT are lost. If this ONT only serves a single user then it would not be a major problem, but if this ONT is handling some building security devices, wireless access points or emergency response devices it could create serious issues. In a traditional standard based point-to-point architecture each work area is served by a minimum of two dedicated home run outlets. With the POL design, back in the telecom room, 32 fibers are all converging into a single splitter module and that module is feed with only a single feeder fiber. This creates another single point of failure for 128 user ports. In a traditional network, there are typically two feeder uplinks to every switch, dual power supplies, and dual ports going to each desktop run separately, and all of the key components are located in a secured TR. A single port failure or media failure would only inconvenience one user and not completely cripple them. For POL, the ONT is located in the work area and therefore subject to the activities of all personnel.
- Non-standards based** – The POL architecture is not recognized by any of the North American or international standards bodies as being a standard based architecture for the Enterprise environment. This architecture is a proprietary approach with limited support. The traditional hierarchical star architecture has been the cornerstone by which all the commercial building telecom standards have been based. This is a well accepted and adopted standard with great support from multiple vendors of all aspects of the system. Following the standard architecture allows greater flexibility and choice for deploying a network. When compared to other industry accepted fiber architectures like fiber-to-the-desk or fiber-to-the telecom enclosure, the POL does not comply with those accepted standards. Additionally, the ANSI/TIA-568 standard does not allow any type of passive splitter to be used in the horizontal subsystem, because of the limitation it might place on future applications.
- Upgradability** – With the POL utilizing the GPON technology there is no easy upgrade path currently available. There are some efforts underway to create a standard for the next generation of GPON, which would be 10GPON, but that will not be available for at least another two years. Even with the addition of 10GPON, because of the current asymmetrical nature of GPON architecture the available bandwidth would only migrate to 10 gigabits down-stream and 2.5 gigabits up-stream and that bandwidth is still shared among a minimum of 32 users, but could be as much as 64 users. So, while the down-stream channel increases by 4 the upstream channel only increases by 2. Also, in order to migrate to the 10GPON not only would the line cards in the chassis have to be replaced, but all the ONTs would need to be upgraded. Imagine the disruption to all of the work areas as this upgrade occurs. This would come at a substantial cost especially in comparison to the amount of bandwidth actually gained. In contrast, a typical Ethernet network allows symmetrical upgrades from 10 Mbps to 10 Gbps and beyond. In reality, most switches and network interface cards or NICs are already standardized on a tri speed standard of 10/100/1000 Mbps so the upgrade is seamless. In looking at the history of how Ethernet has evolved, the next generation of equipment and NICs would probably have a quad speed approach allowing for the seamless migration from 10 Mbps to 10 Gbps out to the desk. In addition, with each Ethernet upgrade the available bandwidth to each user increases by a factor of 10, which is much more economical.

- **Security** – While we listed security as a positive for the POL in respect to the physical access of the data because it uses fiber optics, we must now consider the logical access to the data. Since the GPON operates by “broadcasting” all information to every user, this puts the data at higher risk for internal network intrusion. In fairness, the GPON does use a high level, 128 bit encryption and does support the 802.1x port authentication which makes accessing the data more difficult, but the reality is that every user on a given channel could potentially have access to the data.

The interesting argument made in some of the POL literature is that since the government agencies are the early adopters of this technology it must be secure. Using the government as the base line for your network security does not guarantee security. In reality, we have seen this trend for years in the government space, where they tend to adopt fiber optics to the desktop as their preferred choice for physically securing their networks; however, this is only one component of security.

By allowing all information to flow to every user, the chance of security compromise increases significantly, especially when compared to a traditional Ethernet network, which only sends information addressed to each specific user. Remember, in order for the encryption scheme to work between the core switch and the end devices, the encryption/decryption keys are physically stored on the devices, so a well educated individual with physical access to the end devices could potentially access any data coming to the device.

Just look at the trend in encryption technology. With each new level of encryption from 32 bit to 64 bit to 128 bit etc, it has been claimed it would take years for an individual to crack the code, but in reality it only took months in some cases. Also, does the POL architecture allow for the use of SNMP traps to help boost security? The point is, with GPON, all data has a higher level of logical exposure when compared to the traditional point-to-point Ethernet.

- **Green** – The POL might appear to be a “greener” solution initially, because it deploys small fiber cables in the horizontal space as compared to the traditional larger copper cables. This will equate to fewer and smaller cables being deployed. It will also utilize less real estate and reduce the amount of HVAC capacity needed in the Telecom Rooms. The ONT units out in the work area do have the option for PoE, but where are they getting power from? They get the power from the AC outlets at the work area not from a centrally located backed up dedicated source. This may be acceptable for VoIP phones, but what happens when the customer starts to converge more systems and the number of PoE devices in a building goes from a few to thousands? Where is the “green” in having all those thousands of ONTs and AC outlets throughout a building adding to the overall energy usage, building cooling, etc?

In reality, long term the POL approach will be counter “green”, because of its overall lack of ability to efficiently and economically support converged sub-systems and take advantage of more efficient centralized PoE options that permits sharing of power sources by many devices. With the new Power over Ethernet Plus, PoEP standard, PoE is becoming the standard for providing power to building devices because of the cost savings both in initial power deployment and also long term operational costs.

Green building initiatives are promoting smart buildings using automated building systems to reduce the overall consumption of resources like water, power and gas, as well as reducing the carbon footprint and landfill materials. Any architecture that does not efficiently and economically support those initiatives will limit how green a building will be.

## Summary

While the Passive Optical LAN has some advantages over a traditional hierarchical star Ethernet network, one has to carefully think through their individual situations and needs. The passive optical network approach works great for the residential market, because the residential consumers don't require dedicated symmetrical bandwidth, don't have the same security issues, regulatory requirements or efficiency standards to meet. In the residential space, the largest consumer of bandwidth is streaming video, which only requires down-stream bandwidth today. For those applications requiring up-stream bandwidth, home users generally accept waiting to up-load multimedia and data files, because there are no economic consequences.

Trying to compare the network demands of the Enterprise space to the demands of a residential space is like trying to compare the network needs of a hospital to the network needs of a convenience store. From an initial cost perspective, the POL may look more attractive; however the cost per bandwidth unit and the cost to upgrade versus the amount of new bandwidth gained will favor the traditional approach. Remember that many of the benefits associated with the POL approach are not so much based on the passive aspect as much as the fact of utilizing fiber, which would also hold true for other fiber based architectures.

For new construction, where real estate has not already been allocated for the network, the POL could certainly be more cost effective than trying to deploy it in an existing infrastructure which already utilizes the traditional approach. As stated in the opening paragraphs of this paper, the passive optical network approach works very well for the residential market, which is what it was designed for. The requirements and dynamics of the residential market are significantly different than for the Enterprise space.

Companies are being judged on their ability to quickly and effectively manage and address the markets for which they serve. Having more computing power, more bandwidth capabilities, tighter security and being able to accomplish more with less are the prevailing initiatives. Deploying a residential network in the commercial space is in many ways contradictory to these underlying goals. Technology is evolving faster than during any time in history. The concept of putting in an architecture which does not allow for ease of migration to a total converged building in the future and takes you backwards over 15 years from a bandwidth perspective just does not seem like a logical step forward.



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