A Lippis Consulting Industry Paper

GPON vs. Gigabit Ethernet in Campus Networking

By Nicholas John Lippis III
President, Lippis Consulting

February, 2012

Abstract:

The telecommunications industry, led by Verizon, is offering Gigabit Passive Optical Network or GPON technology, as an alternative to Ethernet switching in campus networking. GPON is being especially targeted at IT leaders in Federal and state level government. GPON is the core underpinning of Verizon's FiOS (Fiber Optic Service), a consumer-oriented triple play service. Verizon officials assert GPON cuts floor space and electricity usage in office buildings by as much as 95% compared to traditional copper networks, leading to the claim that GPON is a green technology. In this white paper, we review GPON as a campus network technology and conclude that it's suited to niche applications. Further, we find that many GPON assertions and claims are overstated.

The GPON Argument

During the first years of the Obama administration, then White House CIO Vivek Kundra championed green IT as a requirement for Federal government IT procurement. As such, many IT vendors positioned their solutions to meet the new green requirement. GPON vendors repositioned GPON from a last-mile technology, which is prevalent in Verizon's FiOS fiber-to-the-home solution, to a campus-networking alternative to Ethernet switching, challenging the best practice of two-to-three tier network architecture.

GPON has long been a favorite approach for the US Department of Defense, thanks to properties of fiber optic physical security plus high bandwidth. GPON's bandwidth advantages have been eliminated as Ethernet switching has progressed from 1 Gigabit per second (Gbps) to 10 Gbps to now 40 and 100 Gbps. In addition, GPON's physical security afforded by difficulty of tapping fiber optic cabling without detection is not an exclusive GPON attribute, but any and all networks that utilize fiber optic transport, including Ethernet switching. But most importantly, over the years, fiber optic taps have become available with insertion losses as low as 0.5 dB and lower, making fiber optic cable physical security no more secure than copper.

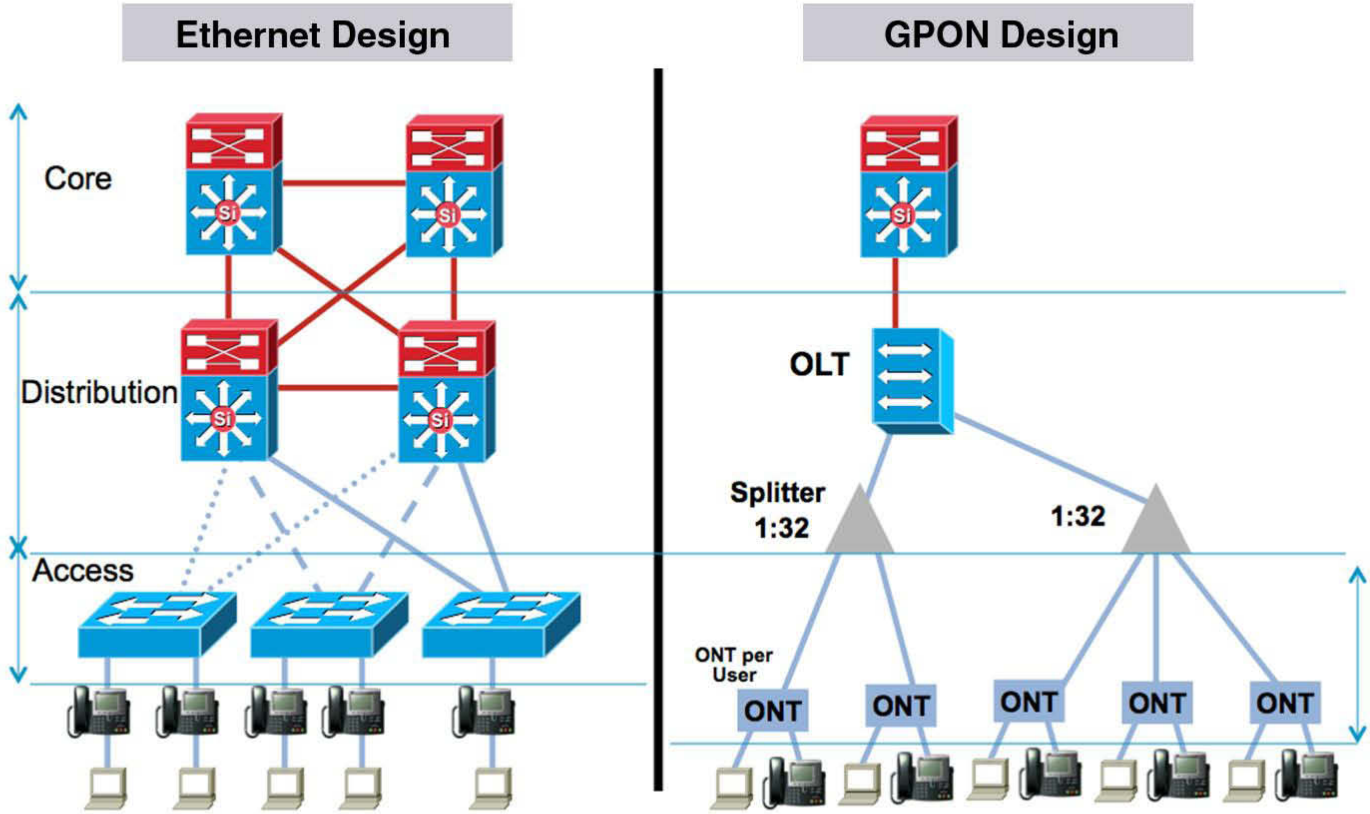
Other GPON claims are lower cost cabling, lower power consumption and fewer network devices required. The use case of GPON is commonly defined as those that require 1 Gbps at the desktop. A review of GPON campus network architecture is presented before we review these claims.

GPON vs. Traditional Ethernet Computer Network Architecture Differences:

Verizon and its systems integrator Science Applications International Corp. (SAIC) are the primary advocates for GPON to Federal IT executives. GPON is positioned to reduce the number of active switching devices in the design of a computer network. The best practice of campus computer network design is based upon standard three-tier network architecture of access, distribution and core. Note that new price points and inter-Ethernet switching protocols that eliminate spanning tree protocol (STP) are allowing access and distribution layers to be collapsed into one, offering choice of a two- or three-tier campus network design. For this discussion, we focus on the most widely utilized three-tier Ethernet network design.

In three-tier network architecture, at each tier, active Ethernet switches forward packets to their destination, affording a mesh of traffic flows to traverse the network. Endpoints or desktops connected on a common access switch may communicate directly with each other without the need for packets to travel to distribution and/or core switches, reducing latency via efficient forwarding. This is especially important for real-time communications, such as Voice over IP and video conferencing, which are increasingly peer-to-peer flows.

In addition, Ethernet vendors have been investing in network services such as security, quality of service, Power over Ethernet, application monitoring, power consumption monitoring, video enablement, etc. Many of these network services start at the access tier, thanks to software features embedded within Ethernet access switches and traverse the entire campus network.



GPON in the campus replaces this three-tier architecture with a two-tier fiber optic network by eliminating active access and distribution Ethernet switches with passive optical devices consisting of:

ONT or Optical Network Termination: The ONT connects desktops into the GPON network and primarily provides the optical to electrical signal conversion. ONTs also provide AES encryption via ONT key.

Splitters: Optical splitters are used to fan in or multiplex, usually 1:32, fiber optic signals to a single upstream fiber optical cable. Careful consideration of power budget analysis needs to be performed to assure adequate optical signal strength.

OLT or Optical Line Terminal: The OLT aggregates all optical signals from vendor dependent ONTs into a single multiplexed beam of light which is then converted to an electrical signal, formatted to Ethernet packet type standards and presented to a core Ethernet switch for layer 2 or 3 forwarding. A typical OLT supports some 72 ports, each port being a fiber optic cable that has been multiplexed via a splitter in the upstream direction. A typical OLT port supports 32 ONTs, however technical literature states 128 ONTs per OLT port. All traffic from endpoints is multiplexed up to a core switch for layer 2 or 3 forwarding. While some OLT vendors are starting to offer VLAN-aware products, this does not avoid the hairpinning of traffic where the core switch provides forwarding. OLT possesses approximately 200 Gbps of switching capacity.

The following are attributes of the GPON campus network:

- The physical GPON network is a hub and spoke architecture that multiplexes upstream and broadcast downstream traffic flows.
- The logical GPON network is a single layer 2 broadcast domain as layer 3 services are provided in the core Ethernet switch.
- Traffic is restricted to flow from desktop to core Ethernet switch and back. Therefore, mesh flows are not supported.
- All traffic flows to the core Ethernet switch creating the potential for a chock-point or bottleneck.
- All network intelligence and network services are placed in the core Ethernet switch.

- Transmit and receive bandwidth rates are different, such as 2.488 Gbps from OLT-ONT and 1.244 Gbps from ONT-OLT, as in the Motorola AXS220 OLT, for example.
- Traffic is broadcast in downstream from OLT-ONT direction, thanks to splitters.
- As most IP phones are equipped with a four-port Ethernet switch, these switches are left as unconnected islands.
- Each endpoint or desktop requires an ONT.
- Bandwidth is shared per splitter.
- Power over Ethernet is not supported resulting in IP phones and WLAN access points needing 120V outlets.
- Encryption is used from OLT-ONT, but not from ONT-OLT, thanks to the broadcast nature of GPON.

One of the attributes of GPON is its alleged power consumption benefit being some 80% less than a three-tier network. The following is an analysis of a 2,500 node network using GPON vs. Ethernet.

Power Consumption

To understand GPON power consumption, we compare a 2,500-node campus network made up of GPON and Ethernet switching equipment. The numbers in the matrix represent Gigabit Ethernet via fiber optics to every desktop. We chose Motorola equipment for GPON and Cisco Systems for Ethernet switching, as both firms are leaders in their respective markets. The point is not to compare Motorola and Cisco, but GPON and GbE. A few assumptions where made including:

1. An 85% conversion power efficiency was applied to both Motorola GPON and Cisco switching equipment.
2. IP phones and Wireless LAN (WLAN) access point (AP) power requirements were not considered, as there would be no difference in both designs. However, connectivity for IP phones and office WLAN APs is provided in both designs.
3. Power, measured in Watts, was obtained from spec sheets versus lab measurements.
4. A single building with four floors and four access closets per floor was assumed. In addition, a single core and distribution network was assumed.
5. Power over Ethernet or PoE was not factored.

Power Consumption Calculation
2,500-Node Campus Network
Does Not Include PoE

GPON	Equipment	Qty	Watts
Core Switch	Cisco 7604	1	836
OLT	Motorola AXS 1800	2	2,550
ONT	Motorola ONT 1120GE	2500	31,875
GPON Total			**35,261**
GbE Desktop Solution			
Core Switch	Cisco 7604	2	836
Distribution	Cisco 4503-E	2	724
	WS-X4448		
	Sup6-E		
Access	Cisco 4510R-E	16	15,571
	4-WS-X4448 SFP		
	4-WS-X4248-FE modules		
	Supervisor V		
GbE Total			**18,691**

From the matrix above, GbE consumes nearly half as much power as GPON. This may seem paradoxical as GPON providers often site that GPON consumes less than 80% power than a traditional three-tier Ethernet campus network design. GPON vendors often do not include ONT power consumption in their calculations, which dominates power draw. Perhaps GPON vendors are accustom to service provider deployments where ONTs are placed in and powered by customer sites.

The GPON network is built with Motorola ONT 1120GE, which provides four 10/100/1000bT Ethernet ports, enough to connect a computer, laptop, IP phone and WAN AP for each office. In the GbE design, each desktop is provided a GbE SFP and 100 MbE RJ45 port, thus requiring two cables to each office. It's assumed that the GbE connects the desktop while 100MbE connects an IP phone to the campus network. As most IP phones provide an integrated four-port switch, additional connectivity is available for laptops, WLAN APs, etc. Note that the Motorola ONT 1120GE boasts sustained 400Mbps burst over Ethernet, while the Cisco 4503-E with WS-X4448GbE modules will burst to the max performance of the desktop NIC. Therefore, the GbE network offers higher desktop network performance and lower overall network power consumption than GPON.

Further, PoE was not included in this analysis and while there is no difference in IP phone power requirements in a GPON or Ethernet network, there is a difference in power draw, however. As GPON ONT devices such as the Tellabs 1600-709GP have recently supported PoE providing power to each IP phone, for example, the ONT delivers PoE via its connection to a 120V power outlet.

There are power consumption opportunities not afforded to GPON installations such as Cisco's EnergyWise or HP's Adaptive-Power Architecture. These initiatives provide a campus-wide virtual thermostat and power consumption monitoring management where all PoE devices may be throttled or powered down after hours, for example. In addition, IT operations are offered a power consumption management screen showing where power is being consumed with control and command to manage power consumption. In addition, many firms including Cisco's EnergyWise now offer adaptors to manage power of non-PoE devices such as building environmentals including heating, cooling lighting, etc., offering the same monitoring, control and command as PoE devices.

Cabling Cost

True fiber prices continue to fall while copper prices (and the more sophisticated hardware needed to support high bandwidth transmission) rise. The cable plant is equal, comparing Cat 5 and fiber. Both are about the same price after factoring everything needed, including fiber and copper testers. The difference is in skilled technicians and electronics cost that attach to either fiber or copper cable.

Fiber-based Ethernet cards are more expensive than copper. 1 GbE PCI Express Cat 5 NIC pricing ranges from $20 to $170, while a 1 GbE 1000BASE-LX10 fiber card is $700 to $1,000 or so. Further, most, if not all, PCs and Macintoshes ship with 1 GbE copper interfaces. But the additional cost of fiber is usually offset by additional cost imposed by local telecom closet copper hubs due to limited distance of copper at high speed. Copper tends to drive up the cost of conditioned, uninterruptable power supplies (UPS), data-quality grounds and HVAC for every closet! Even so these costs still made fiber $9 more expensive per desktop in one job estimate.

With cost of fiber versus copper not being a determining factor, skilled technicians for installation and device requirements for copper tend to tilt the decision toward copper. Installers and IT executives are more comfortable with copper wire. Installers tend to have more experience with copper and are equipped with the tools of the trade. IT executives see more devices that require copper wiring such as physical security cameras, IP phones, printers, thermostats, WLAN APs and PoE over copper infrastructure, providing power distribution vs. running 110V lines. In addition cable plant is a one-time capital cost that is recouped over time, thanks to the above-mentioned advantages.

GPON vs. GbE Network Design Attributes

While single mode fiber optic cables and associated lasers can produce ultra high bandwidth capacity in the Terabit per second range, thanks to dense wave division multiplexing, it should not be assumed that GPON delivers such benefits. In fact, GPON delivers 2.5 Gbps downstream and 1.25 Gbps upstream. But this physical layer bandwidth does not tell the entire GPON network capacity story. There are significant differences between GPON and GbE switching in campus networking such as:

GPON Offers a Lack of Network Design Flexibility: GPON does not offer a separation of physical and logical networking, meaning that the physical layout of a GPON dictates how traffic will flow. The physical design is a hub and spoke topology. As there is no active switching in the Optical Distribution Network or ODN, just passive components, all traffic is forced to flow between ONT-OLT. This structure creates reliability and performance difficulties when real-time communications, such as voice and video services, are added to it as has been reported by GPON customers. In addition, increasing reliability and availability to a hub and spoke structure with no active switching components is accomplished through equipment redundancy, which drives up cost and only marginally increases reliability. A two- and/or three-tier campus Ethernet network is more inherently reliable, thanks to the user of layer 2 and 3 forwarding at each tier as well as the use of STP, EtherChannel and VSS. Physical and logical networking are separate, allowing traffic to flow independent upon physical layout, delivering high application performance and the support of both real-time and best effort traffic types.

Ethernet Networking Scales: The GPON hub-spoke design restricts traffic to one point of entry and exit, being the ONT, whereas within Ethernet networks, devices can be connected at any tier in the campus. In addition, Ethernet networks are designed for upgradability as the industry has progressed from 10Mbs to 100Mbs to 1Gbps to now 10Gbs plus 40 and 100 Gbps. Most importantly, speeds can be mixed within an Ethernet network providing bandwidth where needed to optimize application performance or user needs. GPON networks do not allow for mixed speeds; every user gets the same bandwidth independent upon need.

Thanks to competition in the Ethernet switch market, vendors continue to improve performance and power consumption plus network services are continually added to Ethernet networking. Network services such as application monitoring, quality of service, PoE, network security, WLAN integration, etc., are added to campus network switching. For example, power per 10GbE port is as low as 3 Watts according to the Lippis Report Cloud Networking Industry test at Ixia's iSimCity. GPON has no such history, as it's a simple layer 1-transport service.

GPON Network Capacity: GPON network performance is constrained by a number of factors including 1) ONT throughput performance, which is approximately 400 Mbs, 2) the optical fiber power budget between ONT and OLT, 3) the backplane capacity of the OLT which is 200 Gbps for high end devices and 4) the interface speed between the OLT and core switch. The GPON network is a TDMA (Time Division Multiple Access)-based scheme where an OLT grants time slots to ONTs every 125 micro seconds limiting overall throughput. The ONTs constrain network throughput at access with 400 Mbs burst capabilities. The OLT is the primary limiting factor in network capacity with 200 Gbps of backplane capacity. This pales in comparison to most campus switches, such as Cisco's Catalyst 6500-E with Supervisor 2T, offering 2 Terabit per sec of switching capacity. Further, thanks to the support of Virtual Switching System (VSS), the Catalyst 6500-E platform allows two 2 Tbps switches to combine into a single 4 Tbps virtual switch.

The most limiting factor of a GPON network is the link between OLT and core switch being a 1-to-10GbE 802.1Q trunk. All traffic must flow over this link to receive layer 2/3 forwarding service. In short, this is the largest bottleneck in a GPON network, as it forces hairpinning of all traffic. Some GPON vendors, such as Tellabs, are starting to offer layer 2 services in their OLT modules to mitigate some hairpin traffic.

GPON's Very Dumb Access Devices: ONTs provide access to the GPON network. By design, their functionality is limited to optical-to-electrical conversion, a few levels of quality of service, limited PoE support, upstream encryption and a four-port Ethernet switch. In contrast, Ethernet access switches provide bi-directional encryption via MACsec, NetFlow application visibility, packet tagging for video quality of service and troubleshooting, security services such as

802.1x, identity and context aware based security and troubleshooting, power monitoring and control, etc. In particular, an intelligent access edge for video surveillance offers dynamically discoverable cameras that can be remote controlled via access switch.

Lack of Troubleshooting Tools: The market for GPON in campus networking is small on the order of tens of millions, while the campus Ethernet switch market is tens of billions. This larger Ethernet market enables many vendors to participate, offering troubleshooting tools, for example. Tools such as Wireshark®, which is a network protocol analyzer, are either not available or limited in GPON installations. In addition, skilled technicians in campus fiber optic networks that span desktop to campus are limited too, posing difficulties in trouble isolation and remediation. Finding skilled GPON technicians is challenging, too, where troubleshooting is often relegated to ONT LED observation versus management tools. This lack of tools often degenerates into vendor finger pointing as clear demarcations of responsibilities and faults are lacking.

Ethernet enjoys a twenty-year plus history that brings with it standardized approaches to management, optimization and troubleshooting.

Too Many Single Points of Failure: GPON, unfortunately, has multiple single points of failure. A splitter will take out all ONTs it connects. The link between OLT and core switch is another single point of failure, as this is the only link to GPON-connected devices to communicate with each other as well as the outside world. The OLT is another single point of failure in the scenario that if it was to go down, the entire GPON network would be off line. Ethernet has no such single point of failure.

An Adjacent Supplier to Government/Enterprise Markets: GPON vendors receive their revenues primarily through service providers, and as such, their view of the enterprise and government markets are limited and in essence, represent adjacent markets. Therefore, GPON vendors will find it hard to compete on features required for this market segment. For example, engineering network services into GPON that support video communications, unified communications and collaboration, WLAN integration, desktop virtualization, mobile and cloud computing etc., tend not to be GPON supplier vernacular.

Closing

With Federal and state budgets under increasing pressure, IT executives are seeking lower cost solutions to their IT requirements. While not in the analysis above, GPON tends to be lower in capital/acquisition cost than a traditional three-tier Ethernet campus network. But this cost advantage comes at a price. As outlined above GPON lacks flexibility, consumes greater power than campus Ethernet networks, is limited in network capacity, upgrades are system-wide events, troubleshooting tools and skilled technicians are limited and lacking, and multiple single points of failure exist.

As government IT executives move to deploy cloud services, consolidate data centers and deploy real-time communications services, such as video communications, surveillance, unified communications and collaboration, a standards-based reliable Ethernet campus network assures that these strategic initiatives deliver the cost savings and productivity improvements promised. A three- or two-tier Ethernet campus network offers a platform where incremental changes or upgrades plus cost saving opportunities are available. Platform improvements such as PoE, power management, application visibility and management, security, etc., can be cost analyzed and added when needed.

With the Ethernet market being tens of billions of dollars, research and development is assured while competition provides the motivation for innovation and feature enhancement. An Ethernet campus network is a safe investment.

About Nick Lippis

Nicholas J. Lippis III is a world-renowned authority on advanced IP networks, communications and their benefits to business objectives. He is the publisher of the Lippis Report, a resource for network and IT business decision makers to which over 35,000 executive IT business leaders subscribe. Its Lippis Report podcasts have been downloaded over 160,000 times; ITunes reports that listeners also download the *Wall Street Journal's* Money Matters, *Business Week's* Climbing the Ladder, *The Economist* and *The Harvard Business Review's* IdeaCast. Mr. Lippis is currently working with clients to design their private and public virtualized data center cloud computing network architectures to reap maximum business value and outcome.

He has advised numerous Global 2000 firms on network architecture, design, implementation, vendor selection and budgeting, with clients including Barclays Bank, Eastman Kodak Company, Federal Deposit Insurance Corporation (FDIC), Hughes Aerospace, Liberty Mutual, Schering-Plough, CampDresser McKee, the State of Alaska, Microsoft, Kaiser Permanente, Sprint, Worldcom, Cigitel, CiscoSystems, Hewlett Packet, IBM, Avaya and many others. He works exclusively with CIOs and their direct reports. Mr. Lippis possesses a unique perspective of market forces and trends occurring within the computer networking industry derived from his experience with both supply- and demand-side clients.

Mr. Lippis received the prestigious Boston University College of Engineering Alumni award for advancing the profession. He has been named one of the top 40 most powerful and influential people in the networking industry by Network World. TechTarget, an industry on-line publication, has named him a network design guru while Network Computing Magazine has called him a star IT guru.

Mr. Lippis founded Strategic Networks Consulting, Inc., a well-respected and influential computer networking industry-consulting concern, which was purchased by Softbank/Ziff-Davis in 1996. He is a frequent keynote speaker at industry events and is widely quoted in the business and industry press. He serves on the Dean of Boston University's College of Engineering Board of Advisors as well as many start-up venture firms' advisory boards. He delivered the commencement speech to Boston University College of Engineering graduates in 2007. Mr. Lippis received his Bachelor of Science in Electrical Engineering and his Master of Science in Systems Engineering from Boston University. His Masters' thesis work included selected technical courses and advisors from Massachusetts Institute of Technology on optical communications and computing.