Measuring Enterprise Network Usage Pattern & Deploying Passive Optical LANs

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***Abstract*— Recent advances in the manufacturing and commercialization of passive optical components are now extending the capabilities of fiber to edge and campus networks. This paper presents a comparison between Passive Optical LAN (POL) and copper-based LAN solution, and demonstrate the benefits of PON such as reduced infrastructure footprint and cost, reduced power requirements, future-proof bandwidth, greener infrastructure, safer, higher security and higher reliability.**

***Keywords—component; formatting; style; styling; insert** (key words)*

I. Introduction

A passive optical LAN is an ideal solution for new infrastructure projects and the upgrade of existing infrastructure for a number of reasons:

1. Guaranteed Bandwidth: Today's enterprise traffic patterns fueled by server and data center consolidation, virtual desktop infrastructure (VDI), bring your own device (BYOD), mobile, and cloud computing, are better served by a centralized switch model compared to traditional workgroup technologies with layered active switches.

2. Future Proof: Passive Optical LANs offer a future-proof upgrade path to safer, greener, higher security and higher bandwidths over the same fiber infrastructure.

3. Capex and Opex Savings: Passive Optical LANs replace the active Intermediate Distribution Frame (IDF) equipment (aggregation Ethernet switches) with passive components, reducing space, energy and cooling requirements, as well as lower installation costs. Passive Optical LANs replace traditional copper wiring with fiber saving space and weight. Passive Optical LANs require simpler management and offer advanced capabilities that can be easily integrated with campus-wide provisioning and management applications.

This paper offers a study of the Passive Optical LAN technology and its implications for cabling infrastructure projects. We demonstrate enterprise traffic patterns using network traffic captured in a large enterprise campus, then discuss traditional LAN architecture, Passive Optical LAN components, total cost of ownership (TCO) analysis, and further implications on network management, real estate, and energy consumption. We demonstrate that the passive optical architecture is vastly superior to traditional copper cable-based LANs in terms of deployment flexibility, easiness of management, environment friendliness, capital, and operating costs.

II. Enterprise Network Traffic Patterns

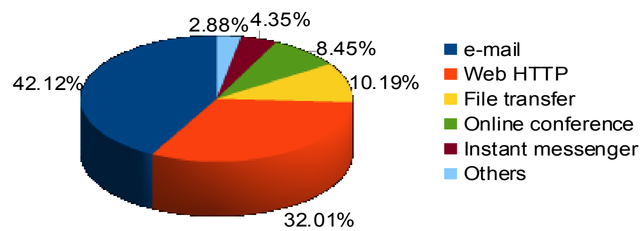

Figure 1: Bandwidth Consumption of Enterprise Applications

We analyze network traffic patterns using data captured in one satellite site of a large enterprise. The site has about 1500 employees with each having an office, and about 30 conference rooms. Each employee has an IP phone and most have only one desktop computer or laptop computer. The networking setup of this site is what can be found typically in large enterprises. Our measurement and analysis focus on traffic between the end user and the core router which is typical in enterprise campus network, rather than data center network as measured in [1] [2].

We observe most traffic goes through the core switch which implies very little peer to peer traffic. This is typical in an enterprise environment since most of the enterprise applications are client-server based and servers are hosted in remote data centers.

For bandwidth consumption of different applications, email and Web traffic consumes more than 74% of the bandwidth, followed by file transfer since the organization uses a distributed file system, and online conference which is commonly used to share screens. A small portion of the file transfer is induced by Cloud services that appear mostly in the HTTP traffic since the Cloud service user interface is Web-based. Figure 1 demonstrates the top applications based on bandwidth usage.

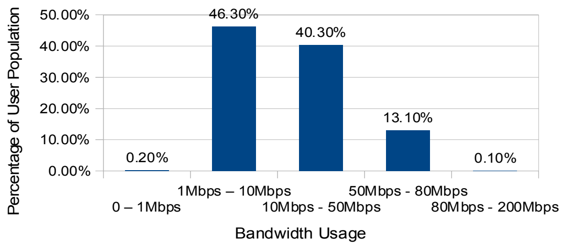

Figure 2: Peak Bandwidth Usage by Individual User

Figure 2 illustrates the percentage of user population for each peak bandwidth usage category. The results show that most users have a peak bandwidth usage less than 50Mbps and almost all users take less than 80Mbps. A further investigation discovers that those who reached more than 50Mbps bandwidth seemed to be file transfer from the enterprise distributed file system and file download from enterprise network.

We measure the bandwidth utilization of applications using HTTP protocol by running the real application and real workload. The typical enterprise applications and their network bandwidth consumption are shown in Table 1.

Application	Configuration	Bandwidth utilization
VoIP phone	64Kbps setup	~ 100 Kbps
Video surveillance	High Definition MPEG4	~ 6 Mbps
eMail	2 minutes refreshing	50 ~ 500 Kbps
Web Browsing	Non video web sites	50 ~ 300 Kbps
Video conference	720p	~ 2Mbps
Cloud access	enterprise application	50 ~ 200 Kbps
Virtual desktop	1080p full screen display	500 Kbps ~ 2 Mbps

TABLE I. TYPICAL APPLICATION BANDWIDTH CONSUMPTION

The measurement results imply that enterprise traffic is very much hub-and-spoke-based, with nearly all application resources residing centrally and being accessed remotely or via other types of non-local protocols. Gartner Research predicts that the trend of less local traffic will continue and by 2016 less than 10% traffic will be local [3]. With understanding of such traffic flows, there is a strong suggestion that the usage patterns that spawned decentralized computing and gave birth to LANs are shifting back to a centralized model and this usage demands a new architecture and economic justification. Our observation shares similarity with some prior work [4].

III. RETHINK ACTIVE SWITCH-BASED LAN ARCHITECTURE

Traditional LAN infrastructures are based on layered active switches commonly referred to as two-tier or three-tier design. In a typical enterprise LAN setup, a group of individual computers connect to a hub or an access layer switch. The access layer switch forwards the network packages initiated from individual computers to the distribution layer switch. Finally the package gets forwarded to the core switch and routed to the destination.

This layered architecture is further complicated by field deployment. To map the different layers to building or campus structures, the concepts of Main Distribution Frame (MDF) and Intermediate Distribution Frame (IDF) are commonly used. The design of IDF is limited by a few factors including cable length limit, power consumption, cooling, and density of end users. Those factors are usually incorporated into building designs by architects to compete with the maximum usable square footage of each building.

The fundamental limitation in this layered architecture is mainly due to the characteristics of the copper cable that is commonly used to connect the workstation and access layer switches. For example, the maximum length for a copper cable link between two active devices is 328 feet; complexity in cable construction to ensure high radio frequencies; amount of copper and plastic used in copper LAN; and installation rules of copper cable.

Another main limitation of the traditional LAN architecture is the complexity of network management. For example, setting up a Virtual LAN (VLAN) in layered infrastructure requires changes of multiple switches and creates complex mapping between the ports and switches. This process is very labor intensive and prone to human error. Monitoring of network traffic will need to be deployed across all the layered switches, if both in-network and out-network packets are to be captured.

IV. PASSIVE OPTICAL LAN AS AN EMERGING ARCHITECTURE

Passive Optical LAN overcomes all the limitations found in traditional copper-based Ethernet implementations: the optical fiber cable used in Passive Optical LAN can travel for a distance of up to 20km ~ 30 km; the fiber cable structure is much lighter than copper-based cables; the use of bend-insensitive fiber radically diminishes bend radii therefore diminishing cable tray and pathways requirements; the passive nature of the intermediate splitter eliminates the need of power and cooling; the single management console provides consolidated access to all devices and network ports in the network.

The main components in Passive Optical LAN architecture are Optical Network Terminal (ONT), passive splitter, and Optical Line Terminal (OLT). The ONT connects computer devices into the Passive Optical LAN network via the Ethernet ports on the unit. Electrical signals from computer devices get converted to optical signal in the ONT. Optical splitters simply split the light signal multiple ways to ONTs and transmit the multiplexed signal to the OLT. The OLT aggregates all optical signals from ONTs and convert them back to electrical signals for the core router. The OLT may also have a range of built-in functionalities such as integrated Ethernet bridging, VLAN capability, end-user authentication and security filtering etc. Figure 3 shows the corresponding layers in traditional LAN architecture and in Passive Optical LAN architecture. Switches in the access layer and building aggregation layer are replaced by a passive optical splitter and those two layers do not exist any longer in Passive Optical LAN architecture.

An OLT may support 8 ~ 72 fiber ports with each port connecting a fiber cable to the splitter. The splitter can support different splitting ratios with 1:32 or less being the recommended split ratio. Therefore, each OLT port supports 32 ONTs. Different ONT configurations are available ranging from 2 to 24 Ethernet ports, multiple analog voice ports, coaxial video ports, and even wireless support. If only 4 devices are attached to each ONT, an OLT with 72 ports will be able to support 9216 devices.

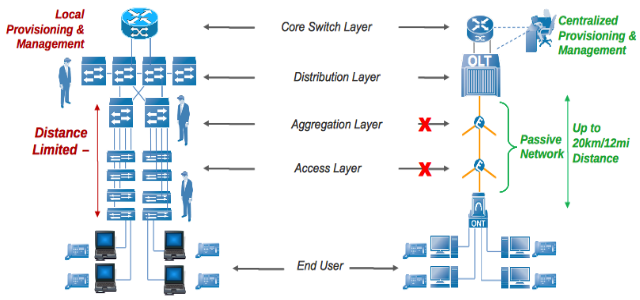

Figure 3: Traditional LAN Architecture vs. Passive Optical LAN Architecture

V. EXPERIENCE IN PASSIVE OPTICAL LAN DEPLOYMENT

In the past years, the IBM Site and Facilities Services team has successfully deployed a number of Passive Optical LAN projects including both new installation and existing infrastructure upgrades, yielding millions of dollars in total cost of ownership savings for customers. The main benefits our customers have realized include lower capital expenditures and operational expenditures, easier network management, more usable floor space, less building design steps, power consumption and cooling cost.

We share a model of a mid-sized with three floors in the building; each floor has 2 IDF/riser closets. Each IDF supports 100 cubicles or 8 office/conference rooms. Each cubicle requires 2 Power over Ethernet (POE) ports and each office needs 4 POE ports. There are 15 wireless access points per

Capital Costs	LAN	PON	Saving
Lateral	$268,800	$260,806	3%
Riser	$374,139	$43,200	88.45%
Main Equipment Room	$93,286	$161,582	-73.21%
Data Center	-	-	
Total CapEx	$736,225	$465,588	36.76%
Operational Expenses	**Year 1**	**Year 1**	
Network Management	$144,532	$ 89,644	37.98%
Floor Space Cost	$ 3,733	$ 942	74.77%
Power & Cooling Cost	$ 19,445	$ 10,013	48.51%
Total Annual Operating Expenses	$167,710	$100,599	40.02%
Total First Year Expenses (CapEx+OpEx)	$903,935	$566,187	37.36%

Figure 4: Total cost of ownership comparison

floor. The total number of cable drops is 1440.

A. *Total Cost of Ownership (TCO)*

We use a hypothesis model developed by multiple parties in the industry to calculate the total cost of ownership. The cost of each category is listed in Figure 4. The solution using a Passive Optical LAN network has a capital expenditure of $465,588 while the cost for a copper network is $736,224, resulting in 37% savings. The Passive Optical LAN network also has lower annual operating expense with $100,598 vs. $167,709, a 40% saving. The net TCO for Passive Optical LAN technology for one year is about $566,186, and over five years will be $891,898. On average, the total cost of ownership for using Passive Optical LAN technology over 5 years will be 38% less than traditional copper LAN networks.

B. *Capital Expenditures*

The main cost in capital expenditure is to acquire the equipment and initial installation. We calculate the cost in three categories: lateral cost, riser closet or IDF, and main equipment room or MDF. Lateral cost includes material and installation of CAT6 cables from the IDF and wall plates if using a traditional LAN network, or material and installation of fiber cables from the IDF and ONT units if using a Passive Optical LAN network. There are a few factors in the capital expenditure that need to be highlighted:

Material costs

Material used in fiber optic cable is significantly less than material used in copper cable. If we only calculate the horizontal distribution cables, one half or even one third of the cables are needed to provide the same number of Ethernet outlets. The fiber cable itself is much thinner than the CAT 5 or CAT 6/6A cables. In this installation case, the Passive Optical LAN solution resulted in a reduction of 3,000 pounds less plastic than CAT 6 cables and 10,500 pounds less than CAT 6A cables, and a reduction of 3,000 pounds copper. The glass used in fiber only weights about 15 pounds in this solution.

Construction costs

The fiber cable infrastructure costs substantially less to install than a copper-based LAN system, since there are fewer cables to install. Improved termination tools and the possibility of using pre-connected fiber also have significantly reduced the cost of fiber installation. Fiber cables are much lighter and require fewer cables per Ethernet port, making the wiring structure simpler that may result in needing a J holder instead of a traditional ladder channel.

The impact of capital expenditure can be more sensitive in existing infrastructure upgrades where old cables need to be removed before installing the new ones. Copper Ethernet cabling has experienced a few generations with new ones on the horizon already. This has an impact on all enterprises but is extremely significant in businesses where each upgrade is mandatory or commonly practiced such as in the healthcare industry.

C. *Operational Expenditures*

Operational cost for LAN infrastructure is one of the biggest expense sources for all enterprises. We discuss and compare the cost of the two solutions in terms of network management, floor space requirement, power and cooling cost.

Network Management

The typical network maintenance tasks include:

- Capacity management such as provisioning a new workstation / port, removing a disposed workstation / port, creation and modification of IP addresses and virtual LAN setup, configuration of any L2 services like quality of service etc.
- Upgrades and patches to keep all the hardware, firmware and management software up to date and replacement of defective devices.
- Regular care such as monitoring and fixing any alerts or defects, checking and fixing any problems within the chassis.
- Testing and certification of all devices, cables and connections.
- Management equipment and software.

In addition to maintenance costs, expenses on service contract, training courses, and sparing need to be included, which are usually offered by network solution providers and/or device vendors as a certain percentage of the entire contract value.

Costs for capacity management, upgrades and patches, and management equipment are significantly lower with a Passive Optical LAN solution than with a traditional solution, since the Passive Optical LAN network eliminates all the active switches in the access layer and distribution layer. The only active device in the Passive Optical LAN solution that requires maintenance and provides management interface is the OLT. Using the built-in provisioning features provided in the OLT, it provides a single interface for well-defined control and monitoring of the quality of service offered to individual users of the shared infrastructure, including dedicated bandwidth and bandwidth restrictions.

The remaining expense sources, floor space, power and cooling, are essentially the major contributors of the cost saving in total operational expenditures. The Passive Optical LAN solution reduces floor space used for networking by approximately 69% and reduces the cooling energy cost by approximately 74% since all the splitters are passive and require no cooling.

Floor space saving

The Passive Optical LAN solution eliminates the need for a dedicated IDF because the passive nature of the splitters and the long distance capability of fiber cable. Splitters do not require any cooling so they can be put in a very small closet on the floors, in enclosures behind walls, shared with the electrical closets, in raised floor architecture, or even in the ceiling space. The only communication closet needed for Passive Optical LAN is the main distribution frame. In this deployment, each building floor is about 20,000 square feet, which traditionally requires 100 – 200 square feet to hold the two IDF closets. Such floor space can be easily converted to usable rooms contributing to extra revenue generation.

The saving for large campus with multiple floors, or multiple buildings is bigger than a small campus. Since each fiber cable can reach up to 12 miles from the main switch closets to the user outlets, it is feasible to have only one full size MDF in one building to serve the entire campus.

Power and cooling consumption reduction

There are many aspects of power consumption reduction in the Passive Optical LAN solution. Power savings resulting from the reduction of cooling and electronic devices in IDF closets is quite straightforward. This reflects a reduction of power circuits, HVAC equipment provided by the building infrastructure, and operational savings with reduced cooling loads. We have observed an approximate 74% cost reduction from the elimination of cooling in IDF closets.

Besides the energy savings from minimal cooling requirements, most Passive Optical LAN equipment is inherently energy efficient. Because a large number of Ethernet endpoints can be supported from one single OLT, ranging from a few hundred to a few thousands depending on the ports the OLT has, power consumption of the OLT is much lower than a comparable traditional distribution switch. Similarly ONTs also consume less power per Ethernet port than a comparable intermediate workgroup switch. In this deployment, we have observed about 26% less power consumption in the Passive Optical LAN network.

VI. CONCLUSION

With the commercialization of Passive Optical LAN technology, it has quickly demonstrated the advantages as one of the most revolutionary technologies in the networking era. It adequately accommodates all the demands required by modern enterprise applications with much lower cost than traditional LAN implementation. The energy-efficient nature of the solution inherently qualifies as a green technology. The rich built-in advanced capabilities provide a seamless enablement for smart buildings and campuses.

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