WHITE PAPER

Transformation of the Enterprise Network Using Passive Optical LAN

NETWORK STRATEGY PARTNERS

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Network Strategy Partners, LLC (NSP)

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Passive Optical LAN Study Commissioned by:

MOTOROLA

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Executive Summary

The rapid growth of bandwidth requirements and the changing role of enterprise networking are causing disruptive change in the enterprise Local Area Network (LAN). Incumbent vendors are recommending upgrading Ethernet switches to 10 Gigabit Ethernet (10GbE) uplinks which typically require single-mode rather than multimode fiber optic cable and replacement of lateral CAT 5 cable with CAT 6 cable. Enterprises facing such disruptive change to either an existing enterprise site or a new enterprise site have the opportunity to dramatically reduce Total Cost of Ownership (TCO) by moving to a Passive Optical LAN (POL) solution, rather than continuing with the Present Mode of Operations (PMO), which uses a two- or three-tier switched Ethernet solution.

The following two scenarios were created to analyze the TCO for the build-out and operation of an enterprise LAN with a 10GbE backbone:

- Single-building scenario – This scenario analyzes a single four-floor enterprise building that provides 1,044 Ethernet connections (1 Gbps) using a mix of ports with and without Power over Ethernet (PoE).
- Multiple-building scenario – This scenario analyzes a six-building office park or campus that provides a total of 18,936 Ethernet connections (1 Gbps) for the entire office park. The same mix of ports that is used with and without PoE is also used for the single-building scenario.

Motorola's POL solution is compared to two PMO solutions. The solutions are as follows:

- POL – A Motorola AXS1800 Enterprise Aggregation Switch (EAS) employing GPON (Gigabit Passive Optical Network) based technology, 10GbE uplink, and single-mode fiber together with passive optical splitters to the desktop.
- PMO – Single building (a two-tier Ethernet switch with 10GbE uplinks, single-mode riser cables, and CAT 6 cable to each end-user port).
- PMO – Multiple buildings (a three-tier Ethernet switch with 10GbE uplinks, single-mode riser cables, and CAT 6 cable to each end-user port). The tier 2 and tier 3 Ethernet switching layers employ a 10GbE high-availability design.

Table 1 summarizes the TCO results.

Table 1. Percentage of TCO Savings: POL Versus PMO

Scenario	CapEx	OpEx	TCO
Single Building	39%	52%	45%
Multiple Buildings	41%	71%	54%

The primary source of savings for the POL, compared to the PMO, is the elimination of the workgroup switch, an active network element, by the POL. This dramatically reduces capital expense as well as most categories of operations expense because a design with fewer active network elements uses less power and less floor space. It also reduces the work of maintaining, operating, and managing the enterprise LAN.

Introduction

Enterprise networks are facing disruptive change caused by the use of Internet versus enterprise based applications, increasing video content, integration of voice services onto the LAN, and the transition from wired to wireless LANs. Increasing video content is driving an acceleration of bandwidth requirements, while the use of Internet-based applications, voice, and wireless LAN are forcing network managers to find a new approach to network security because former perimeter-based strategies are losing their effectiveness as the network perimeter dissolves.

Overall, enterprise issues also are forcing disruptive change to enterprise networks. Enterprises acknowledge the need to adopt environmentally sensitive ("green") policies. Enterprise network designs must therefore minimize use of energy, heavy metals, petroleum-based materials, and real estate. Finally, it is incumbent upon network designers to reduce TCO, as this simultaneously reduces environmental burdens by reducing resource requirements while improving the enterprise's operating cost position.

End-user bandwidth requirements driven by new video applications are exploding. While the consumer market leads the demand-side push for more video, enterprises also are identifying new video requirements. New enterprise video applications are emerging from the bottom up as individual employees discover tools that make them more productive. For example, software developers are using "agile" development environments where they sit close together in a bullpen to facilitate a rapid and informal exchange of ideas. A virtual bullpen can be created by nailing up day-long desktop video conferences. This extends agile development to include work-at-home initiatives. Also, enterprise software users receive product training via video streaming, and demand for high-end conference room video conferencing is increasing—it makes scheduling meetings easier and eliminates travel expenses and employee downtime. Finally, enterprises are discovering business applications for consumer services such as Google, YouTube, news services (MSN, Yahoo), and social networking. All these services make extensive use of video content.

LAN vendors now recommend that 10GbE switches be interconnected with single-mode fiber and CAT 6 cable connections to end-user devices in order to meet expected bandwidth increases. This requires wholesale replacement of switches and cable. This is a disruptive change and should prompt enterprises to rethink their LAN strategies.

Accommodating increased bandwidth, though it is the primary agent causing disruptive change, is not the only one. Other change agents include the need to accommodate wired and wireless connectivity; support voice, video, and data services; migrate from perimeter to role-based security; reduce labor-intensive network operations tasks; and deploy environmentally friendly solutions.

POL technology offers an alternative to the two- or three-tier switched Ethernet designs used by most enterprises. It is an adaptation of GPON which is deployed to more than three million residential customers for the delivery of triple play services. Current GPON technology delivers a downstream data rate of 2.5 Gbps and an upstream data rate of 1.25 Gbps, reaching a distance of up to 20 km and serving up to 64 users. POL represents a substantial bandwidth upgrade for enterprise networks currently operating with 1GbE backbones, while its asymmetrical data rates fit well with the emerging Internet-centric usage patterns of office workers. POL, furthermore, is less costly and is not as resource- and labor-intensive as tiered switched Ethernet solutions and, thus, better meets emerging enterprise network requirements.

This paper provides a TCO analysis that quantifies the advantages of POL over the tiered switched Ethernet (PMO). The analysis approach is depicted in Figure 1.

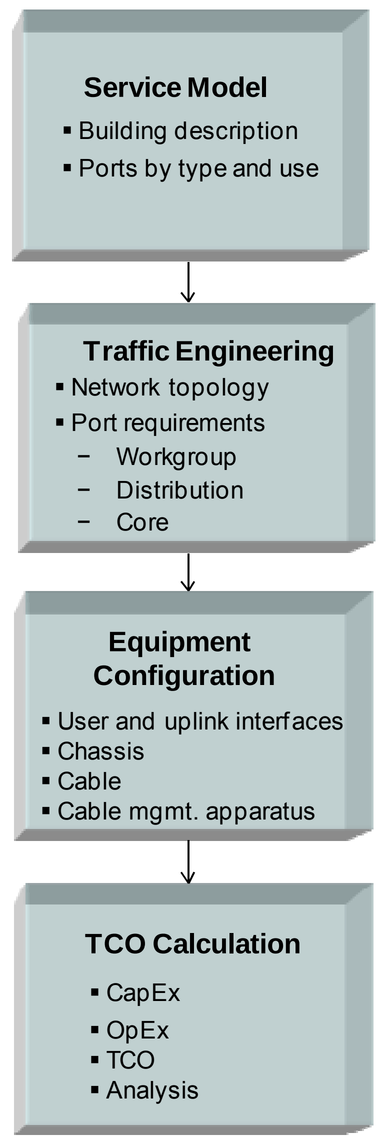

Figure 1. TCO Modeling Process

The TCO modeling process consists of four steps. In the first step, the layout of each building (or buildings) is defined as well as the types of ports used in each cubicle, office, wireless access point, or other location. In Step 2, these definitions are used to create a network topology and to estimate port requirements for workgroup, distribution, and core switches.[1] In Step 3, detailed equipment configurations are developed for all interfaces, chassis, copper and optical cables, and cable management apparatus such as patch panels and passive optical splitters. In Step 4, costs are calculated for all active network elements as well as for cables, cable apparatus, and other network elements. This step also develops a detailed operations expense estimate for each solution alternative. Once TCO is calculated, cost analyses are produced.

Modeling Scenarios

In this section, two modeling scenarios are defined: (1) a single enterprise building with multiple floors and (2) a large enterprise campus with multiple high-rise buildings.

Single-Building Scenario

The single-building scenario describes a four-story building with total floor space of 40,000 square feet. Network connections are provided to 109 cubicles, 11 offices, 10 other locations, and 1 wireless access point on each floor. The other locations are assumed to be for network printers and reception desks. Table 2 shows the number of ports, by use and type, assigned to each network end-point.

Table 2. Unit Port Requirements

Data Ports			
Ports Per	**No PoE**	**PoE**	**Bandwidth (Mbps)**
Cubicle	1	0	5
Office	1	0	5
Floor - Other	10	0	1
Floor - Wireless Access Point	0	1	30

Voice Ports			
Ports Per	**No PoE**	**PoE**	**Bandwidth (Mbps)**
Cubicle	0	1	0.1
Office	0	1	0.1
Floor - Other	0	10	0.1
Floor - Wireless Access Point	0	0	0

Each port is designated as either using PoE or not using PoE, by application and by bandwidth requirement. This scenario provides a data port and voice port to each office and cubicle. Cubicles share the Work Group Terminal (WGT) used by the POL solution while the other locations do not. The per-port bandwidth allocations are high relative to current use; however, both the POL and PMO solutions can easily meet these bandwidth requirements.

Multiple-Building Scenario

The multiple-building scenario consists of a campus or office park with six buildings and a separate data center that is located 300 feet from each of the six buildings. Each building has six 20,000 square feet floors with the same distribution of offices, cubicles, and other locations on each floor. Four wireless access ports are located on each floor. The mix of end-user ports is identical to that defined for the single-building scenario. Each building has a main equipment room where riser cables are connected to the outside plant cables that connect the building to the data center.

[1] The POL solution uses a passive optical splitter in place of the workgroup switch, while no distribution element is required.

Passive Optical LAN (POL) Solution

The POL solution shown in Figure 2 uses three active network elements—the Motorola AXS1800 EAS, a WGT, and a core Ethernet switch/router. The Motorola AXS1800 EAS is a 200 Gbps Ethernet switch. It provides a 10GbE interface to local servers and a 1GbE interface to the Wide Area Network (WAN) router. Two WGT models are used. The Motorola ONT1130GE WGT provides four POE ports (1 Gbps), while the Motorola ONT1120GE WGS provides four ports (1 Gbps) without POE. The core Ethernet switch/router provides switching and routing function required for peer-to-peer connections within the building as well as connection to on-site servers and the WAN router.

One single-mode fiber connects each WGT to one downstream port on the passive optical splitter. One single-mode fiber also is used to connect each optical splitter to one POL port on the AXS1800 EAS. Though not shown in the diagram, optical patch panels are used for cable management between the lateral cables on each floor and the passive optical splitter. They also are used between the passive optical splitter and the riser cables between floors and between the riser cables and the AXS1800 EAS. It is important to capture all optical cable costs in order to ensure that all TCO elements are accounted for in the comparison of the POL with the PMO.

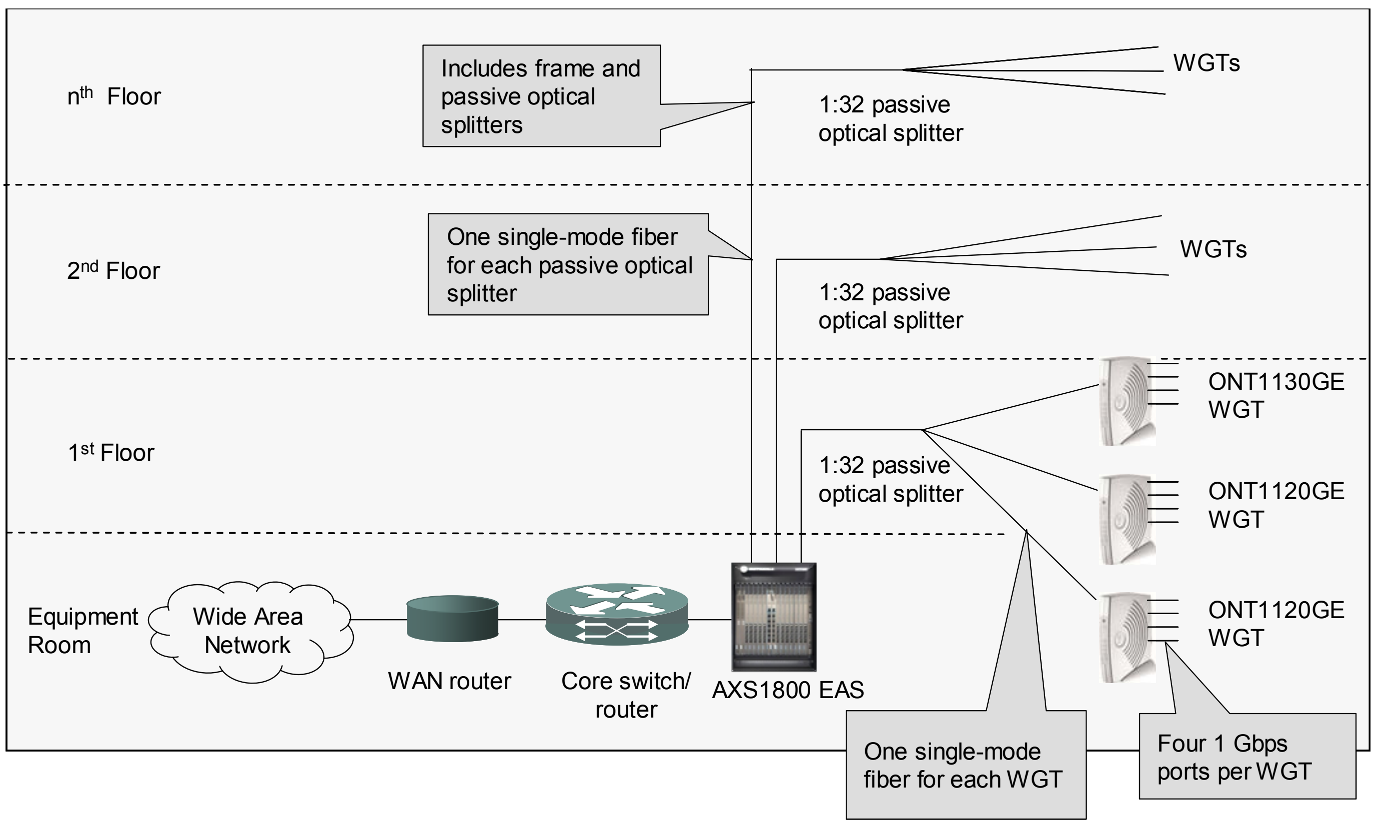

Figure 2. Network Schematic for POL Single-Building Solution

The POL deployment for a multiple-building campus is identical to the single-building deployment. The only active network elements are the AXS1800 EAS, which is collocated with the WAN routers, the WGTs that are located close to end-users' desks, and the core Ethernet switch/router. Riser closets contain only passive optical splitters and optical patch panels used to connect lateral cables to splitters and riser cables to splitters. A small optical patch panel is required in each building's main equipment room to connect riser cables to the outside plant cable that connects each building to the data center.[2]

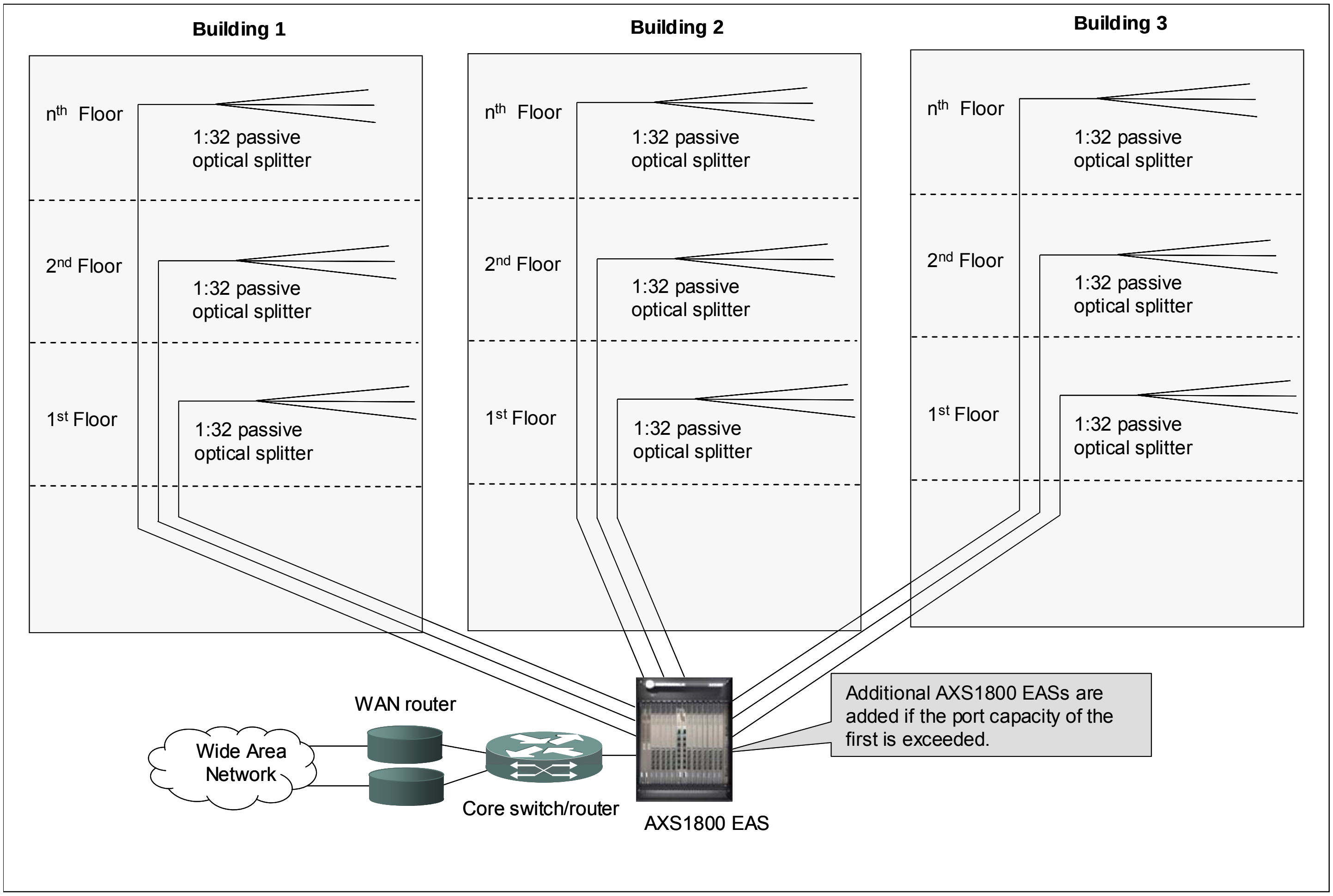

Figure 3. Network Schematic for POL for Multiple Buildings

[2] While this scenario assumes that the WAN routers and AXS1800 EAS are located inside an on-campus data center, a managed service alternative could be used where the EAS is located in a service provider's central office.

Present Mode of Operations (PMO) Solution

The network schematic for the single-building PMO solution is illustrated in Figure 4. The single-building PMO solution employs workgroup switches in the riser closets on each floor. CAT 6 twisted-pair copper cable is used to connect each end-user port to the workgroup switch. This scenario uses stackable fixed configuration workgroup switches to minimize cost. Each switch stack can include up to nine switches. One 10GbE port utilizing two single-mode fibers is used to connect each switch stack to a 10GbE port on the core Ethernet switch/router located in the building's main equipment room. Also, an Uninterruptible Power Supply (UPS) is located in each riser closet to protect the workgroup switches.

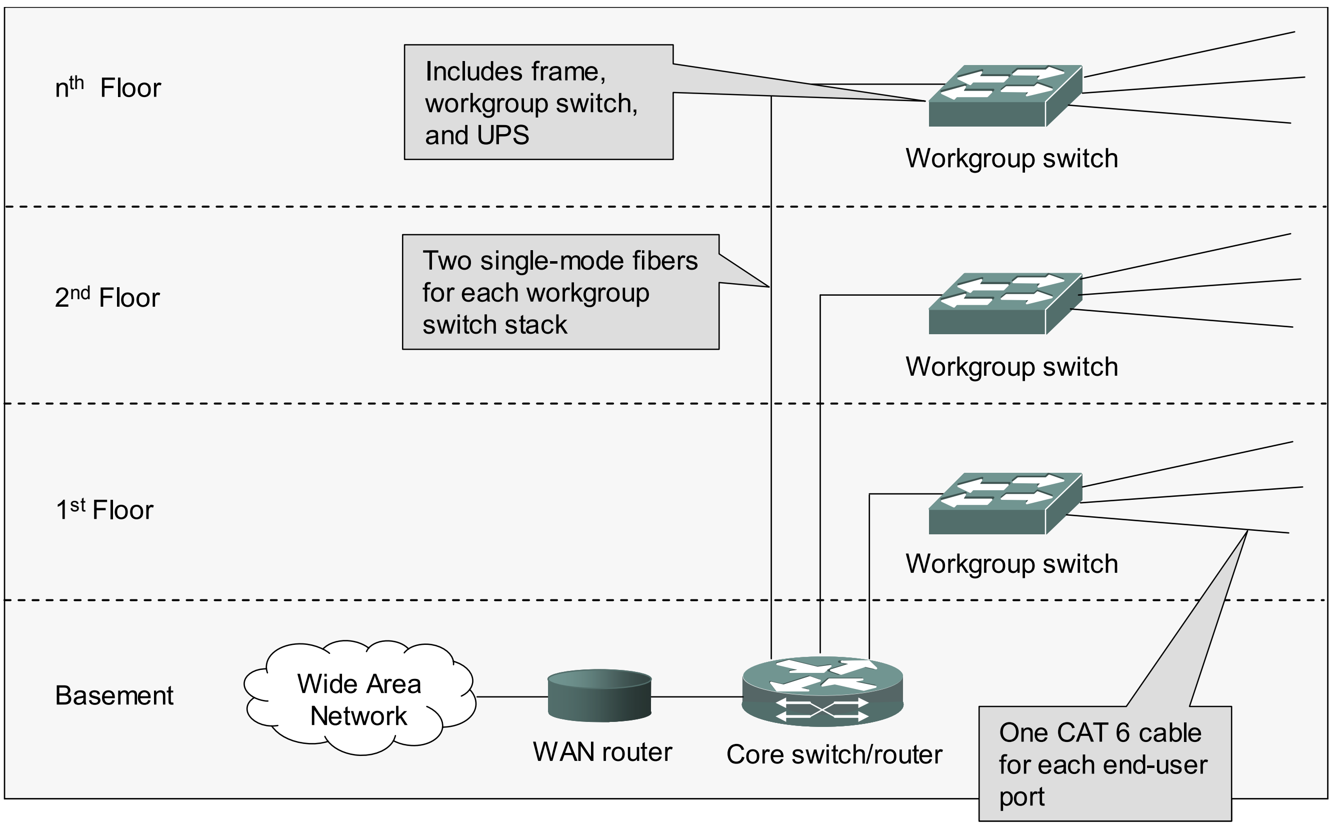

Figure 4. Network Schematic for PMO for a Single Building

Figure 5 shows the network schematic for the multiple-building PMO solution. The PMO solution for multiple buildings adds a third Ethernet switching layer, compared to the two switching layers used for the single-building PMO solution. A 10GbE Ethernet distribution switch is located in the main equipment room of each building. These switches are connected to dual core switch/routers in the campus's data center. Dual core switch/routers and the associated dual ports and fibers from each distribution switch create the high-availability design required to assure availability among the many active network elements of this solution.

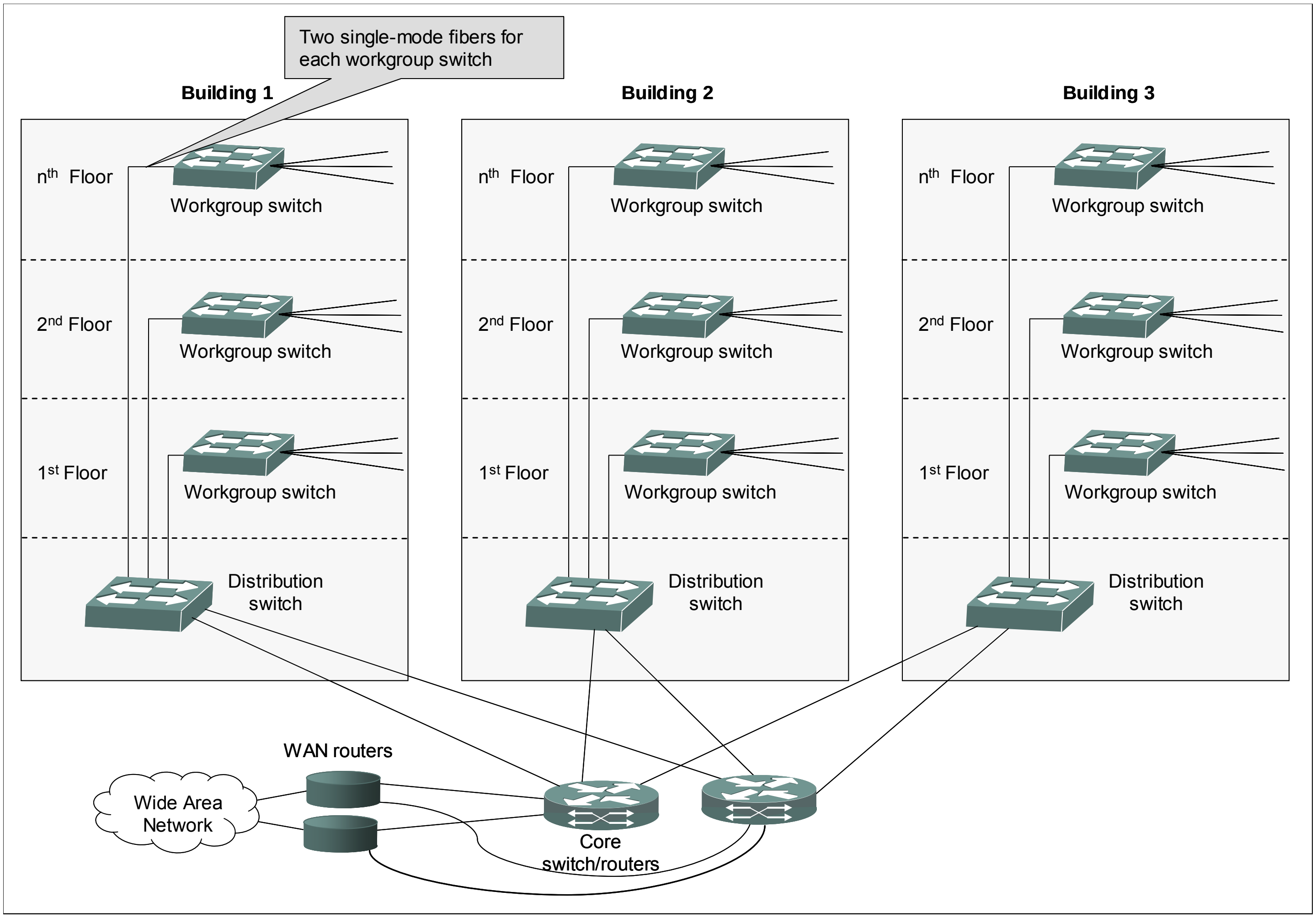

Figure 5. Network Schematic for PMO Multiple-Building Solution

Total Cost of Ownership (TCO) Comparisons

Figure 6 shows the five-year TCO comparison for the single- and multiple-buildings scenarios. The POL five-year TCO is 45% less than the PMO solution for the single-building scenario, while the POL five-year TCO is 54% less than the PMO solution for the multiple-building scenario. CapEx is 39% less for the POL than for the PMO in the single-building scenario and 41% less in the multiple-building scenario. OpEx is 52% less in the single-building scenario and 71% less in the multiple-building scenario.

The POL, in terms of TCO savings sources, is compared to the PMO in the next several paragraphs.

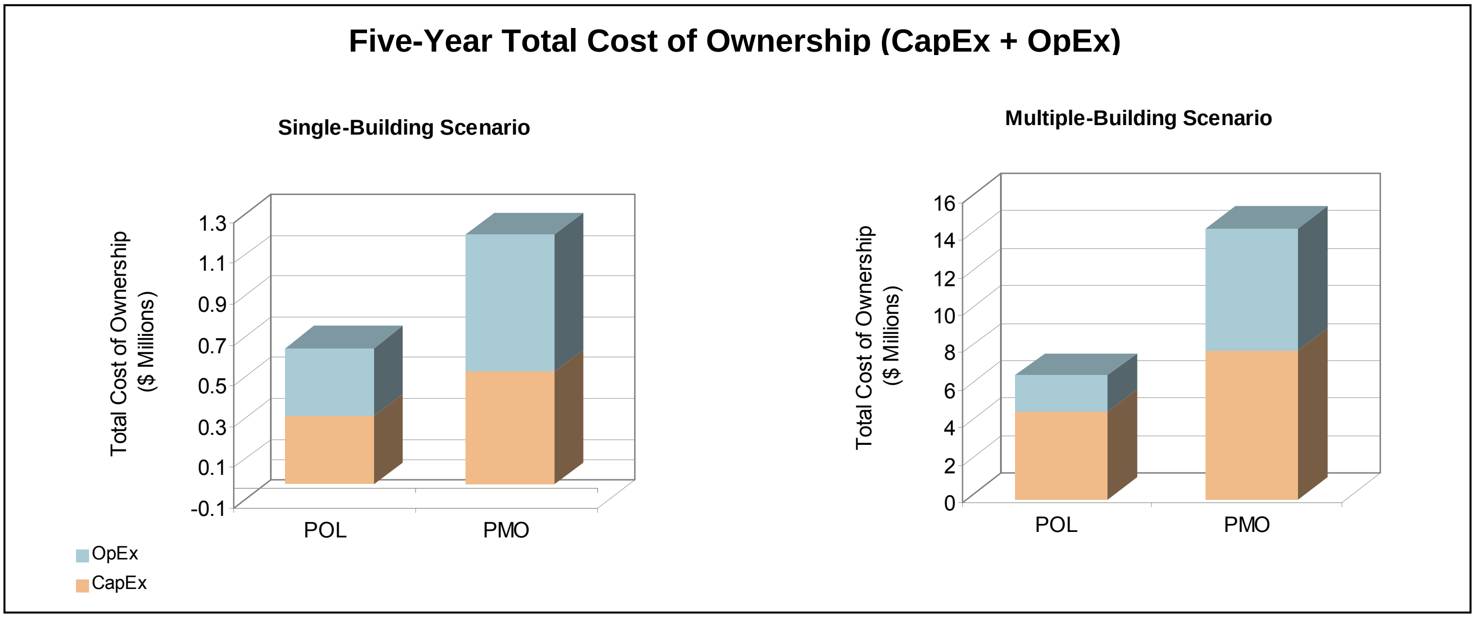

Figure 6. Five-Year Total Cost of Ownership Comparison

Figure 7 breaks out the capital expense for both scenarios between active and passive network elements.

Capital expense for active network elements is the major difference between the two solutions for both scenarios—as its name implies, the POL has lower active network element capital expense. However, it is perhaps surprising that the passive network element capital expenses are somewhat higher for the PMO. The PMO has slightly higher passive network element capital expenses than the POL due to its use of one CAT 6 lateral cable connection to every end-user port, while the POL employs one single-mode fiber between the riser closet and each WGT. Each WGT has four end-user ports.[3] This results in higher cost for the lateral cable runs in the PMO solution when compared to POL, even though the installed cost of each fiber drop is estimated to be $300 compared to $150 for the installed- per-drop cost of CAT 6 cable.

[3] Not all four ports are used on some WGTs; therefore, the actual advantage is somewhat less than one-fourth.

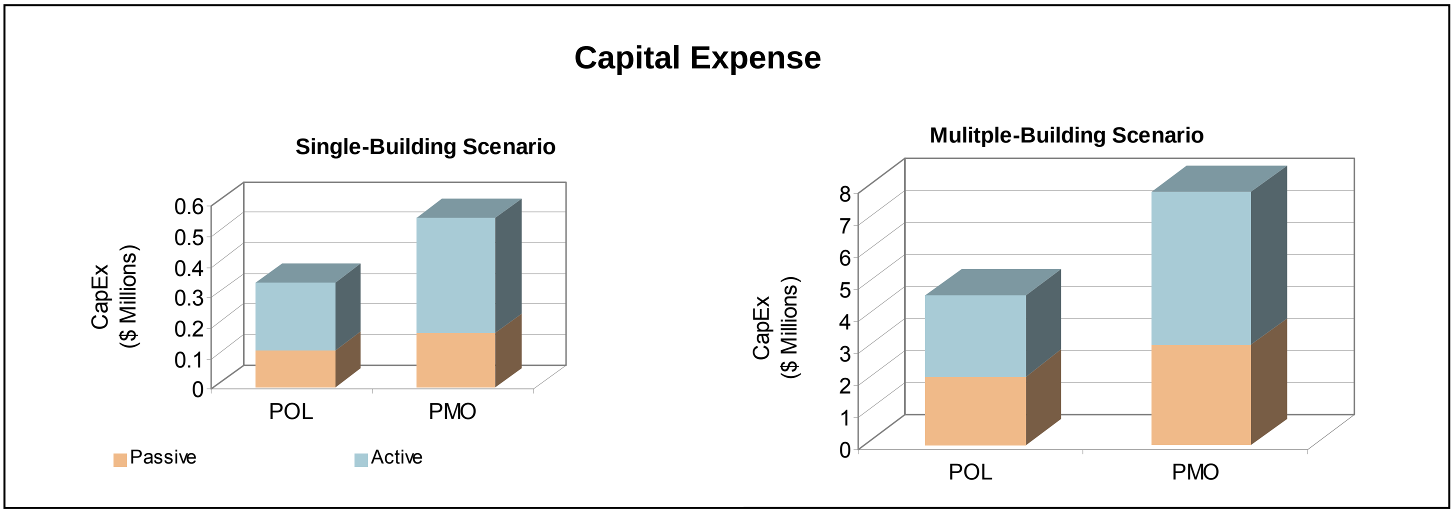

Figure 7. Active and Passive Capital Expense

Figure 8 breaks out capital expense by network element for both scenarios. Riser closet cost is the major difference in the capital cost of the POL solution versus the PMO. The PMO uses a workgroup switch with 1 Gbps Ethernet ports on the user side and 10GbE uplinks. Whether stackable or chassis-based workgroup switches are used, their costs run from thousands to tens of thousands of dollars per system. In contrast, POL uses passive optical splitters in the riser closets with an installed cost of $500 per splitter. This makes the riser closet expense a trivial part of the CapEx for the POL solution, while it is over half of the CapEx of the PMO solution. Lateral CapEx, consisting of the lateral single-mode cable and WGT for the POL solution and CAT 6 cable for the PMO, is higher for the POL solution. This provides only a modest offset to the dramatically higher riser closet CapEx of the PMO.

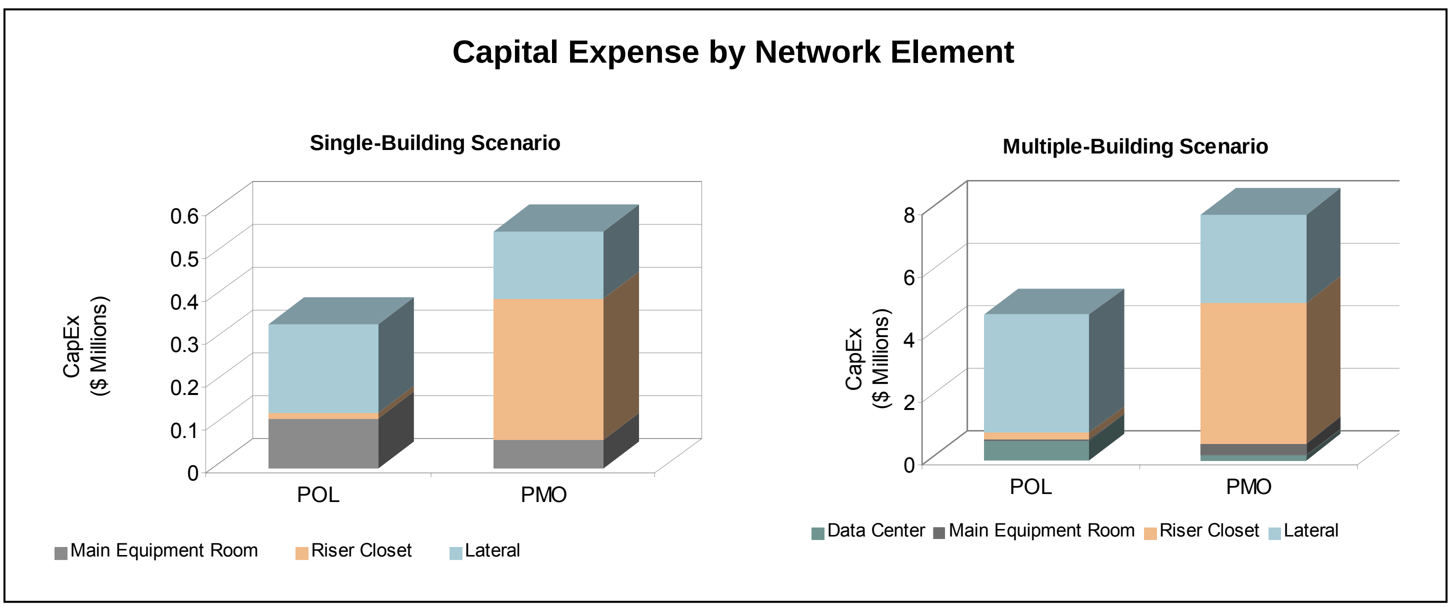

Figure 8. Breakdown of Capital Expense by Network Element

Figure 9 shows the first-year TCO for both scenarios. An immediate financial benefit is gained by moving to the POL solution. The first-year TCO is 40% less for the single-building scenario and 45% less for the multiple-building scenario for the POL when compared to the PMO.

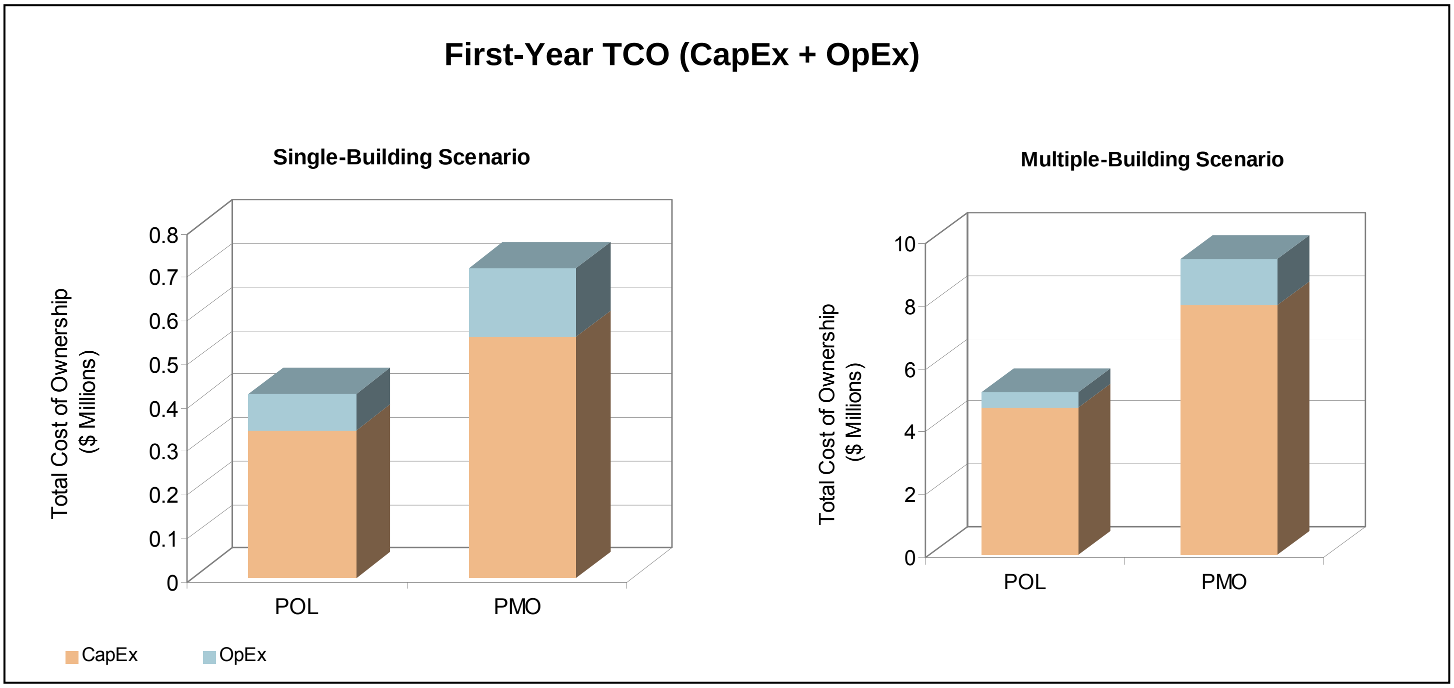

Figure 9. First-Year TCO Comparison

Operations Expense Comparison

Table 3 lists the components of operations expense and provides a definition for each component.

Table 3. OpEx Cost Components

Operation Expense	Breakdown of Expense
Engineering, Facilities, and Installation (EF&I)	Cost of engineering, facilities, and installation of network equipment.
Capacity Management	The engineering function of planning and provisioning additional network capacity.
Network Upgrades & Patches	Both hardware and software upgrades to the network.
Network Care	Network provisioning, surveillance, monitoring, data collection, maintenance, and fault isolation.
Testing and Certification Operations	Costs associated with the testing and certification necessary for all new hardware and software releases that go into the production network.
Testing and Certification Capital	Capital equipment required for the test lab.
Training	Initial training expenses as well as ongoing training expenses.
Network Management Equipment and Software	All hardware and software required to manage the network.
Service Contracts	Vendor service contracts required for ongoing support of network equipment.
Sparing Costs	Costs associated with line card spares.
Floor Space Cost	Costs associated with the floor space cost in equipment rooms, closets, and the data center.
Power Cost	Cost of the electric power used by active network elements.
Cooling Cost	Cost of the electric power used by HVAC systems as well as the prorated carrying cost of the HVAC equipment itself.

Figure 10 breaks down the individual elements of OpEx for each solution and each scenario. Vendor service contracts are the single largest source of the OpEx advantage enjoyed by the POL over the PMO. There are two underlying reasons for the POL's large advantage. First, vendor service contract costs are assessed according to the purchase price of each active network element. Since the CapEx of PMO active network elements is much larger than that of the POL service contract, costs are much larger. Second, enterprise Ethernet switches are very complex and require extensive manufacturer support and frequent in-the-field upgrades. In contrast, the POL uses GPON technology which has been designed for very large-scale (tens of millions of subscribers) residential deployments. Of necessity, GPON technology is designed to minimize both system vendor and end-user service and maintenance. The unit cost of POL service contracts is 55% less than for the PMO.

Network care and power cost are the next largest contributors to an OpEx advantage for POL in the multiple-building scenario. The source of this cost advantage is simply that POL has only five Ethernet switching systems (four AXS1800 EASs and one core switch/router) that require extensive network care and consume large quantities of electric power, while the PMO has 80 such systems.

Network upgrades, patches, and power cost are the next largest contributors to an OpEx advantage for POL in the single-building scenario. The power cost advantage in the single-building scenario is due to the POL's use of two Ethernet switching systems compared to thirteen Ethernet switching systems in the PMO. Network upgrades and patches cost more for the PMO than for the POL because many more patches and upgrades are needed for the enterprise-class equipment used by the PMO compared to the carrier-class equipment used by the POL.

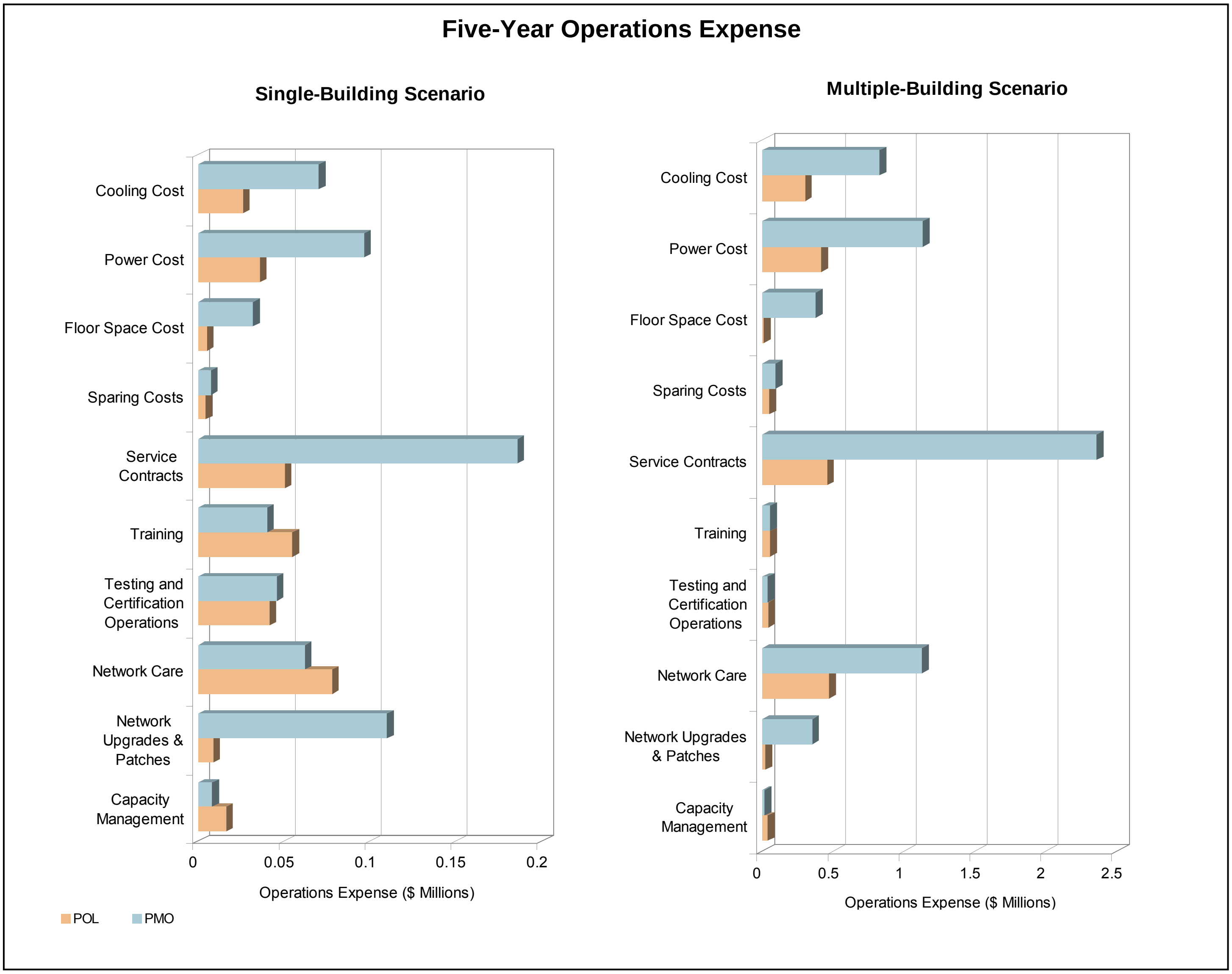

Figure 10. OpEx Breakdown Over a Five-Year Period

Conclusion

The rapid growth of bandwidth requirements and the changing role of enterprise networking are causing disruptive change to the enterprise LAN. Incumbent vendors are recommending upgrading Ethernet switches to 10GbE uplinks which typically require single-mode rather than multimode fiber optic cable and replacement of lateral CAT 5 cable with CAT 6 cable. Enterprises facing such disruptive change to either an existing enterprise site or a new enterprise site have the opportunity to dramatically reduce TCO by moving to a Motorola POL solution.

Table 4. Percent Savings: POL vs. PMO

Scenario	CapEx	OpEx	TCO
Single Building	39%	52%	45%
Multiple Buildings	41%	71%	54%

Single-building and multiple-building scenarios for upgrading the enterprise LAN were created and shown to produce TCO savings for the POL solution when compared to the PMO. Table 4 summarizes these results.

The primary source of savings for the POL when compared to the PMO is due to the elimination of the workgroup switch, an active network element, by the POL. This dramatically reduces capital expense and most categories of operations expense because a design with fewer active network elements uses less power and less floor space. It also reduces the work of maintaining, operating, and managing the enterprise LAN.

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