Passive optical LAN versus copper-based Ethernet

A Bell Labs financial analysis of the value of POL in a next-generation digital enterprise

Strategic White Paper

In the continuing effort to improve competitiveness, many enterprises now realize that distributed legacy LAN networks are no longer capable of meeting communications requirements. A centralized passive optical LAN (POL) architecture eliminates the networking limitations imposed by copper-based Cat 5/Cat 6 cabling. This paper presents the value of an enterprise POL based on a Bell Labs economic analysis. It examines the financial benefits of an optical network compared to traditional copper-based Ethernet architectures. Also discussed in this white paper is why a POL provides the most cost-effective option to meet the gigabit speed networking challenges of a future digital enterprise.

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Introduction

Most enterprises operate multiple communication and information networks with separate cabling for voice, video, data, surveillance, access control, security and Wi-Fi services. These complicated, copper-based infrastructures and their associated independent management systems must be continuously monitored, maintained, and upgraded to support the needs of demanding employees with new devices, advanced applications, and increasing expectations for always-on access to corporate networks. The ongoing operations and maintenance costs associated with these networks put a strain on corporate budgets and continuous upgrades leave enterprises in a never-ending cycle of increasing capital expenditures (CAPEX).

This paper presents the value of an enterprise passive optical LAN (POL) based on a Bell Labs economic analysis. It examines the financial benefits of an optical network compared to traditional copper-based Ethernet architectures. The paper also explains why a POL provides the most cost-effective option to meet the gigabit speed networking challenges of a future digital enterprise.

Benefits of a POL

In the continuing effort to improve their competitiveness, many enterprises now realize that distributed legacy LAN networks are no longer capable of meeting communications requirements. The performance and physical characteristics of the copper-based Cat 5/Cat 6 cabling that was designed to primarily support 10/100Mb/s services impose a number of limitations on an enterprise LAN. To support greater mobility, provide higher bandwidth, and deliver multi-gigabit Ethernet connectivity at the endpoints the existing enterprise LAN must evolve.

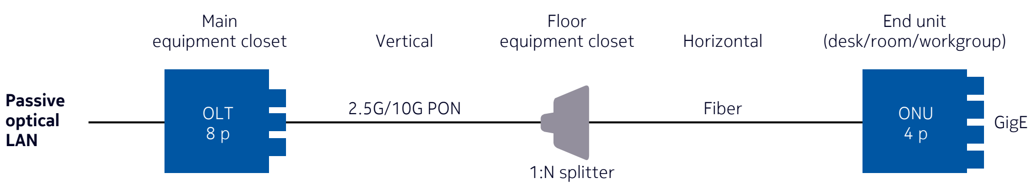
Passive optical LAN technology eliminates the networking limitations imposed by traditional copper-based Ethernet. It addresses the evolving service demands of enterprises with fiber optic cabling that delivers all services on one efficient, high-capacity centralized network. Deployed as a replacement for copper or as a new installation, it can enhance the service experience, improve mobile connectivity, reduce costs and deliver value for decades.

An economic analysis conducted by Bell Labs revealed that enterprises opting for a POL architecture rather than a copper-based Ethernet architecture will see significant financial benefits in CAPEX, operating expenditures (OPEX) and total cost of ownership (TCO).

Networking options

The analysis was based on the assumption that an enterprise would consider alternative networking options either because an existing network had a significant bottleneck and could not support Gigabit Ethernet (GigE) services, or because it was a brand new enterprise looking for an optimal network solution. The new network would be Cat 5, Cat 6, Cat 6a or fiber. For the purposes of the analysis and to highlight the key differences between the different architecture options, the economic model was built for a single enterprise building with 2,000 endpoints on 10 floors. This allowed for a comparison of three typical network architectures, one of which was a POL (see Figure 1).

Figure 1. POL architecture considered for the Bell Labs analysis



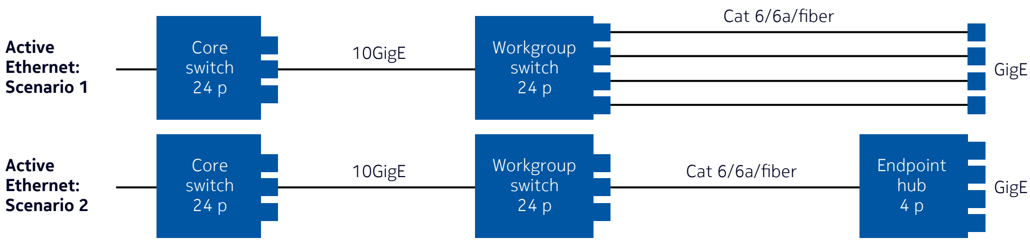
As with all POL architectures, the POL network configuration included a passive splitter on each floor to provide aggregation of multiple optical network terminals (ONTs) connected with fiber. As the splitters in a POL are passive (no power), they can be deployed relatively easily in a floor equipment closet or in the ceiling on each floor. The splitters are connected to a central optical line terminal (OLT) located in a main equipment closet. A typical four-slot OLT shelf can support 4,096 endpoints in a typical enterprise scenario (assuming one PON port is split to the 64 Ethernet ports, using splitters and multiport ONTs). This makes the POL architecture very scalable and future-ready for growth in endpoints.

The centralized architecture of this POL is enabled by Gigabit Passive Optical Network (GPON) technology, which has been deployed successfully worldwide for residential, business and mobile backhaul applications. It has been designed for long reaches from 20km to 40km compared to copper cabling, which is limited to approximately 30m to 100m, depending on the cable type used and the bit rates offered. This makes POL a more efficient option for small, medium and large enterprises.

For the active Ethernet architectures in this model, two possible configuration scenarios based on typical copper-based Ethernet deployments (see Figure 2) were assumed. Scenario 1 assumed that each floor would require a workgroup switch to aggregate multiple GigE endpoints over Cat 6 cabling.

For Scenario 2, it was assumed that an additional level of aggregation would be provided by a managed Ethernet endpoint hub switch on each floor. Scenario 2 was somewhat equivalent to the POL scenario in terms of aggregation of the endpoints. And for both active Ethernet scenarios, a core switch would be located in the main equipment closet to aggregate traffic from multiple workgroup switches.

Figure 2. Traditional copper-based Ethernet network configurations considered in the Bell Labs study



For the three network options it was assumed that traffic would be handed off from the main equipment closet to a wide area network (WAN) for connectivity outside the enterprise. Given the focus of the analysis on determining the benefits of POL and the active Ethernet, WAN networking costs in the model were excluded.

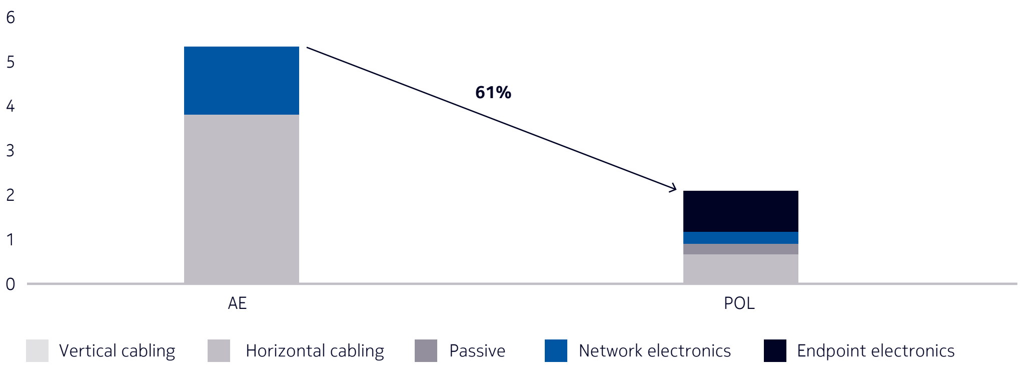
CAPEX savings

The CAPEX in this economic model includes the material and labor costs associated with:

- Cabling (horizontal and vertical)
  (Note: The costs of the vertical cabling are relatively small compared to the cost of the horizontal cabling.)
- Passive components (splitters/splices)
- Electronics (OLT, ONT, Ethernet switches).

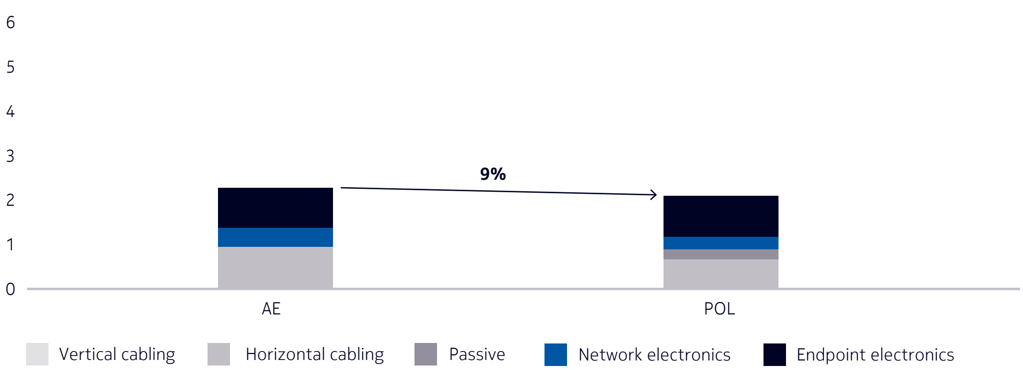
Based on this approach, the analysis revealed that a POL architecture provides a significant capital cost savings of 61 percent compared to a copper-based Ethernet architecture like that of Scenario 1 (see Figure 3). The primary savings are realized in horizontal cabling costs. Compared to copper cabling, a fiber-based POL offers a 77 percent saving in horizontal cabling. This is because of the aggregation provided by the multiport ONTs (four in this example) compared to an active Ethernet architecture. With ONTs, fewer cables are required to enable the network elements. Therefore, in this model, four times fewer fiber cables were required compared to the number of cables needed to provide the same capacity with Cat 6 cabling in an active Ethernet network.

Figure 3. Relative CAPEX associated with active Ethernet compared to POL (Scenario 1)



A POL enterprise network will also provide CAPEX savings when compared to active Ethernet architectures like that of Scenario 2, albeit a lot lower (see Figure 4). The analysis revealed that the CAPEX savings for a POL are reduced to 9 percent when compared to that configuration. This is because an active Ethernet architecture like Scenario 2 requires less horizontal cabling compared to Scenario 1 because of the aggregation provided by the Ethernet hub endpoint. Therefore, the overall cost of cabling is similar to that of a POL. Furthermore, fewer workgroup switches are required. It should be noted that these savings in electronics costs are offset by a large increase in endpoint electronics costs for the managed Ethernet hub switches.

Figure 4. Relative CAPEX associated with active Ethernet compared to POL (Scenario 2)



The analysis also revealed that a POL provides an overall savings in OPEX and TCO compared to the active Ethernet configuration, as discussed in the next section. In addition, Scenario 2 considers relatively “dumb” Ethernet hubs, which cannot be remotely managed. If switches capable of management are used to match the capability of the ONTs in a POL, and with no other change, the CAPEX associated for equipment in this type of active Ethernet solution rises significantly. As a result, the CAPEX savings with a POL will increase to as much as 55 percent compared to the active Ethernet configuration.

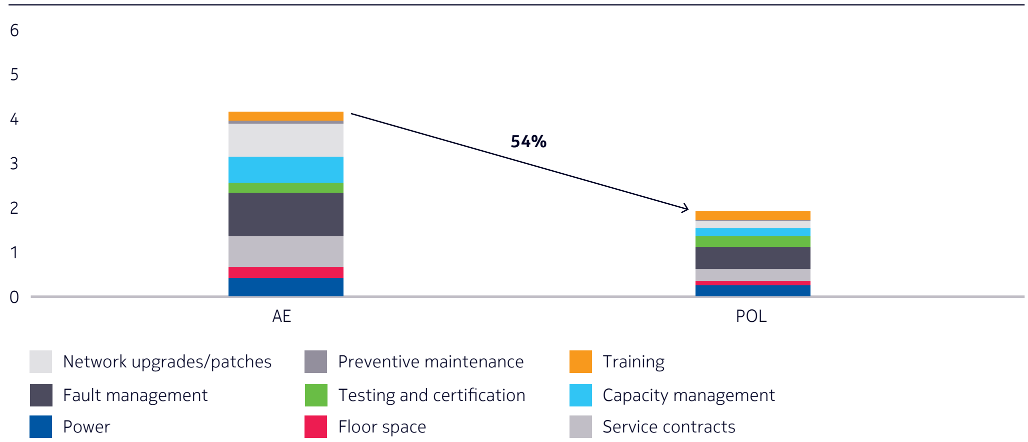
OPEX savings

For the OPEX comparison, the typical recurring costs associated with maintenance and operation of an enterprise LAN were considered:

- Power
- Floor space
- Service contracts
- Fault management
- Testing and certification
- Capacity management
- Network upgrades/patches
- Preventive maintenance
- Training.

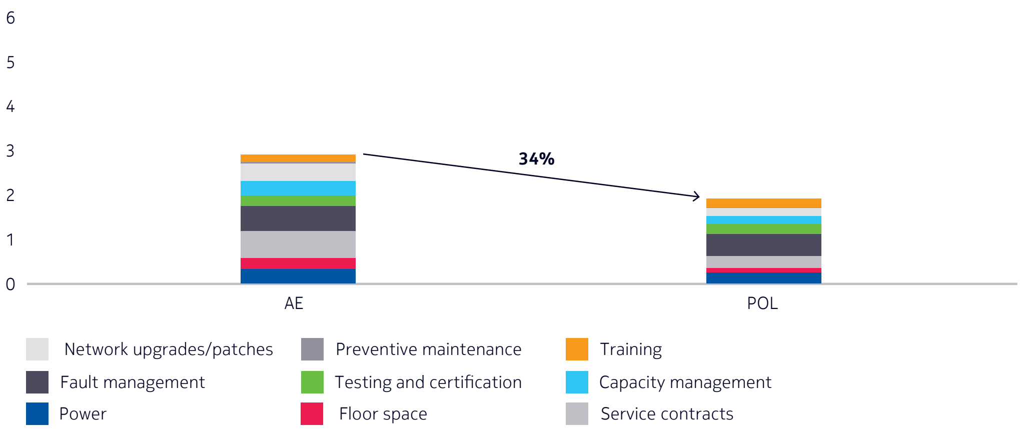
Based on these recurring expenses, the Bell Labs analysis revealed that a POL architecture provides 54 percent OPEX savings when compared to the active Ethernet option offered by Scenario 1 (see Figure 5).

Figure 5. Relative OPEX associated with active Ethernet compared to POL (Scenario 1)



The analysis also showed that a POL offers a 34 percent OPEX savings when compared to Scenario 2 (see Figure 6).

Figure 6. Relative OPEX associated with active Ethernet compared to POL (Scenario 2)



A breakdown of the savings is presented in Table 1.

Table 1. Breakdown of OPEX savings for a POL compared to active Ethernet scenarios

	Active Ethernet Scenario 1	Active Ethernet Scenario 2
Power	38%	21%
Floor space	60%	60%
Service contracts	61%	56%
Fault management	49%	13%
Testing and certification	0%	0%
Capacity management	68%	41%
Network upgrades/patches	75%	54%
Preventive maintenance	95%	85%
Training	0%	0%

Note:
- Scenario 1 assumes that each floor will require a workgroup switch to aggregate multiple GigE endpoints over Cat 6 cabling.
- Scenario 2 assumes that an additional aggregation level will be provided by a managed Ethernet endpoint hub switch on each floor.

Power

For the power expenses, the relative power costs needed for a POL versus the costs required for an active Ethernet, without including any power over Ethernet (PoE) delivered at the endpoint, were compared. These costs also include the power consumed by the uninterruptible power supply (UPS) and the heating, ventilation and air conditioning (HVAC) that are necessary for the Ethernet switches and the OLT.

The results show that a POL is relatively power efficient compared to an active Ethernet architecture. It provides savings ranging from 21 percent to 38 percent. This is because the active Ethernet architectures require multiple distributed switches (workgroup and core), which makes these architectures less energy efficient compared to a POL.

The analysis also revealed that the power consumption of the multiport Ethernet hubs in Scenario 2 compared to the ONTs in a POL is similar. And, because less aggregation switches are needed in Scenario 2, there is a savings in power overall between the two active Ethernet options.

Finally, it should be emphasized that the costs compared for this analysis are based on configurations with non-PoE switches, which have a lower baseline power consumption compared to PoE capable switches. If PoE capable switches are used in the network and compared with PoE capable ONTs, a POL would show even greater savings.

It was noted that the power and energy efficiency gained with a POL would enable enterprises to meet and exceed green initiatives such as Leadership in Energy and Environmental Design (LEED) certification.

Floor space

The analysis showed that the centralized high-density OLT platform in a POL enables a smaller network footprint compared to multiple distributed Ethernet switches in active Ethernet architectures. This results in a 60 percent savings in floor space costs with a POL compared to both copper-based Ethernet network options.

Service contracts

As shown in Table 1, the cost of service contracts is also lower for a POL compared to the two Ethernet options (56 percent to 61 percent) because significantly lower maintenance is required for electronics in a POL.

Service contract costs will be higher for copper-based Ethernet architectures as shown in Scenario 2 if managed switches are used. Consequently, the savings with a POL solution would be higher.

Fault management

The analysis showed that a POL architecture has lower fault management costs because the fiber in POL architecture is passive and does not contain any active signal generating properties. Compared to the active architecture built on workgroup and core switches in Scenario 1, a POL offers a savings of 49 percent in fault management costs. Whereas, compared to Scenario 2, which has fewer workgroup switches, the relative savings with a POL are 13 percent.

Once again, if managed Ethernet hub switches are used for a copper-based Ethernet LAN, the savings in workgroup switches is more than offset by the added complexity of managing and configuring all the hub switches. This will make the overall costs and savings of a POL solution almost the same as that of Scenario 1.

Capacity management, upgrades and preventive maintenance

As shown in Table 1, the overall costs for capacity management, upgrades and preventive maintenance are significantly lower with a POL. A POL solution leverages a high-density OLT platform in a centralized location versus the hundreds of switches distributed throughout an enterprise in an active Ethernet solution, similar to those offered by Scenario 1 and Scenario 2.

Testing, certification and training

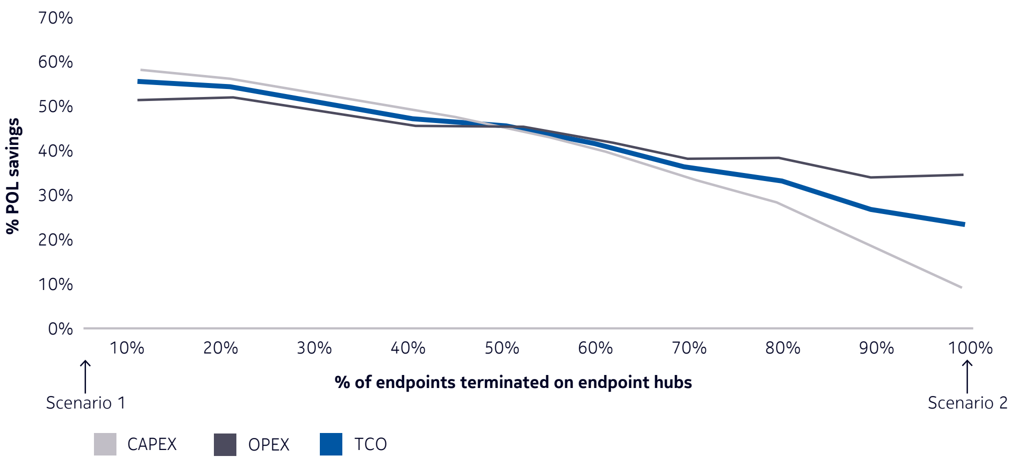
The analysis concluded that, given the significant maturity of PON technology, the costs associated with testing, certification and training would be comparable for both a POL and a copper-based active Ethernet LAN.

Total cost of ownership

Bell Labs looked at the five-year TCO for the three network architecture options, based on the CAPEX and OPEX calculations outlined earlier. For this part of the analysis, it was assumed all three options would be affected by price erosion in the electronics components based on current industry trends. It also factored in inflation costs for labor and installation.

Figure 7 illustrates the savings with a POL architecture compared with the savings that could be expected from both of the active Ethernet options based on a percentage of endpoints terminated on endpoint hubs.

Figure 7. Comparison of TCO for POL and active Ethernet



Note: The 0% corresponds to the active Ethernet Scenario 1 and 100% corresponds to active Ethernet Scenario 2.

The analysis shows that a POL solution provides TCO savings of at least 23 percent, and up to 58 percent compared to active Ethernet LAN deployments. If managed switch hubs are used, the TCO savings would vary between 40 percent and 58 percent, which would provide relatively stable savings of POL against active Ethernet over a range of ports and architectures varying between 100 percent termination on hubs and no termination.

Interestingly, the analysis showed that while it is possible to lower the CAPEX of an active Ethernet solution by better aggregating the endpoints (that is, with the use of Ethernet managed endpoints and reducing cabling costs), the resulting OPEX is not reduced significantly and would plateau out.

Summary

Multi-gigabit bandwidth requirements will soon be a reality for enterprise networks. Small, medium and large enterprises will need to upgrade their legacy networks and invest in next-generation LAN technologies. Given the potentially significant CAPEX required it is critical that enterprises select the most efficient network architectures and technologies that provide the optimal combination of CAPEX and OPEX in a future-ready solution. This decision will protect their network investments for decades.

The Bell Labs comparison of traditional copper-based Ethernet LANs and a passive optical LAN shows that over five years a POL will provide:

- 9 percent to 61 percent CAPEX savings
- 34 percent to 54 percent OPEX savings
- 23 percent to 58 percent TCO savings.

Furthermore, these savings can increase significantly over the longer term (10–20 years). Once deployed, a POL has a longer life span (50+ years) compared to copper-based Ethernet LANs. Plus, deploying a POL architecture today enables an enterprise to evolve its network easily from 2.5Gb/s with GPON today to 40Gb/s per system with Next-Generation Passive Optical Network 2 (NG-PON2) tomorrow. This makes the investment in a POL network future-proof.

In summary, based on the associated savings and given the high capital investment involved with deployment of enterprise LANs, a POL will deliver a significant value to an enterprise. Thus, POL architecture is highly recommended for enterprise network upgrades and greenfield deployments.

Acronyms

AE	active Ethernet
CAPEX	capital expenditures
GigE	Gigabit Ethernet
GPON	Gigabit Passive Optical Network
HVAC	heating, ventilation and air conditioning
LAN	local area network
LEED	Leadership in Energy and Environmental Design
NG-PON2	Next-Generation Passive Optical Network 2
OLT	optical line terminal
ONT	optical network terminal
ONU	optical network unit
OPEX	operating expenditures
PoE	power over Ethernet
POL	Passive Optical LAN
TCO	total cost of ownership
UPS	uninterruptible power supply
WAN	wide area network

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About Bell Labs

Bell Labs, a research division of Nokia, collaborates closely with the company's customers and product development teams to create the technologies that are transforming the way people connect with each other and with the information around them.

Its researchers are continually expanding the capabilities of communications networks with breakthrough technologies to make them faster, smarter and greener. Recognized by many of the world's most prestigious technology organizations, Bell Labs scientists have received numerous awards including eight Nobel Prizes.

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