The Economic Benefits of a Super-Converged Multi-Access Edge Network

Peter Fetterolf, Ph.D.

EXECUTIVE SUMMARY

Traffic demand in access networks is growing at a rapid rate and this growth is expected to continue for the next five years. The key drivers are:

- Transition from 4G to 5G in mobile networks
- Massive fiber rollout for Gigabit access
- Evolution to the cloud
- Bandwidth-intensive applications in residential PON networks
- Bandwidth-intensive applications in businesses

As a result of traffic growth access networks will be upgraded from 10GE to 100GE. As service providers roll out higher capacity they have the opportunity to converge their Access Edge to create a super-converged multi-access edge which supports:

- Mobile backhaul
- Residential broadband backhaul
- Business services
- PON infill
- SONET/SDH

ACG Research has developed a total cost of ownership (TCO) model that compares the capital expense (CapEx) and operations expense (OpEx) over five years for separate service access networks versus a converged access network. The model projects traffic growth over five years. Our results show CapEx savings of 33%, OpEx savings of 60%, and TCO savings of 46%.

Market Dynamics

Today, many service providers operate separate access networks for different services as depicted in Figure 1. Specifically there are separate:

- Mobile access networks
- Business services access networks
- PON residential fiber access networks
- SDH/SONET TDM access networks

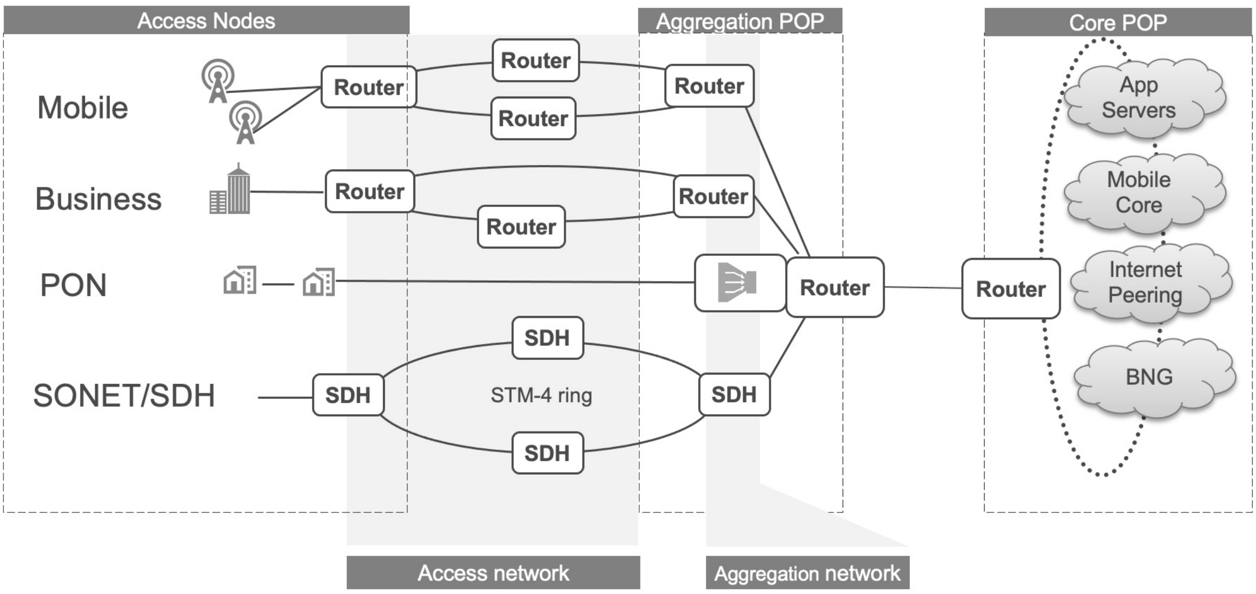

Figure 1. Many Network Operators Run Parallel Access Networks for Different Services

These networks are being challenged by innovative technologies and applications that are driving tremendous traffic growth. This growth in traffic is propelling the need to upgrade access network capacity.

Mobile traffic growth is being driven by the transition from LTE to Dynamic Spectrum Sharing (DSS) and 5G. These innovative technologies are also enabling new bandwidth-intensive applications that, in turn, are driving the need for additional network capacity. We estimate that the LTE migration to DSS is increasing average cell site traffic from an average of 300 Mbps to 700 Mbps. As mobile migrates to 5G we expect average cell site traffic to increase to 2.8 Gbps.

Business traffic is also growing rapidly. This increase is driven by bandwidth-intensive applications:

- Applications are increasingly housed in the cloud
- Increased video conferencing
- Video training
- AR/VR and other new applications

Residential traffic continues to grow because of the mass roll-out of fiber supporting high-bandwidth applications:

- Video streaming
- 4K/8K TV
- Work at home with video conferencing applications
- Cloud gaming
- High-speed upstream bandwidth for many applications

As a result, access networks need to be upgraded from 10 GE to 100 GE to support the new traffic requirements, providing an opportunity for service providers to introduce a super-converged multi-access edge, Figure 2. These networks use Multi-Access Edge Routers (MAER) to converge different network services.

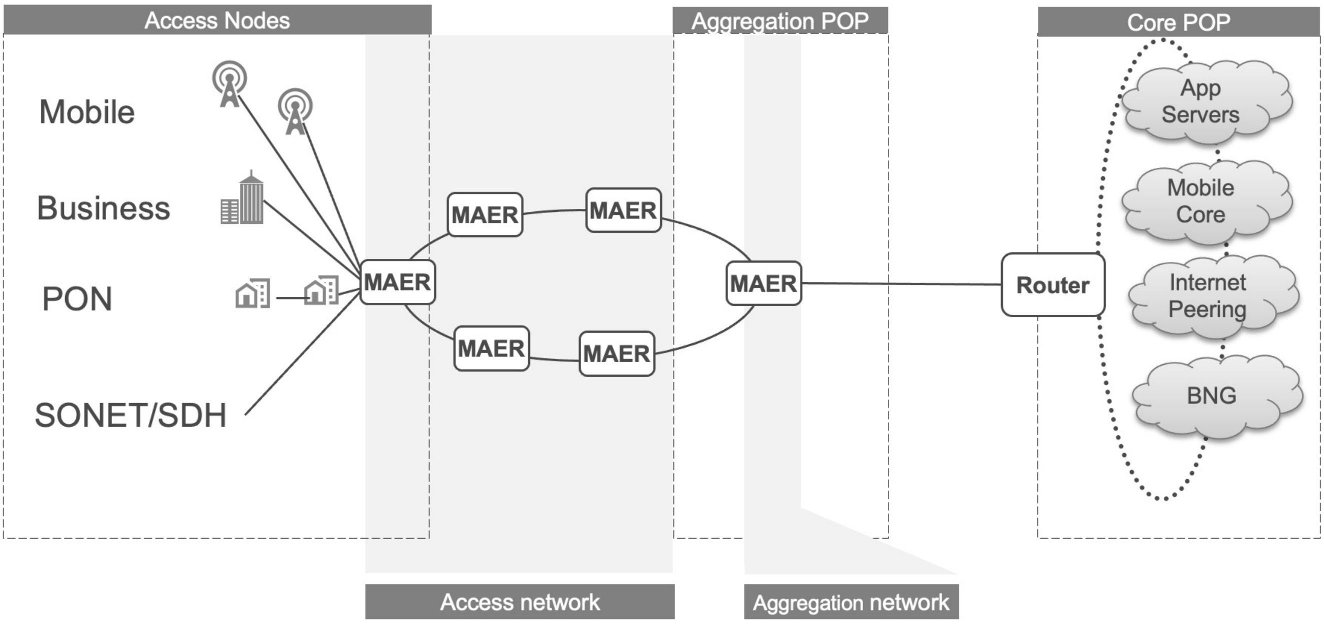

Figure 2. Super-Converged, Multi-Access Edge Network for Mobile, Business, Residential, and SONET/SDH Transport Services

Converged networks have fewer network elements to purchase, maintain, and operate, and as a result there is a reduction in both capital expense (CapEx) and operation expense (OpEx). The example in Figure 2 shows how these networks are converged. Edge multi-access routers are configured in a 100GE access ring. Services are connected to the Edge multi-access routers:

- Mobile base stations are connected with 10 GE interfaces
- Business services are connected with 1 GE or 10 GE interfaces
- PON networks are connected to the router with an OLT line card
- SONET/SDH connectivity is provided with circuit emulation

The following sections of this paper define the requirements and key benefits of a super-converged multi-access edge network and provides an overview of a total cost of ownership (TCO) model to quantify the cost savings of these networks.

Super-Converged Multi-Access Edge Network

A super-converged multi-access edge network is a network that provides MPLS transport over a metro access and aggregation network using a Multi-Access Edge Router. MAER routers have evolved to support carrier-grade transport with support for convergence of mobile, business, PON, and SONET/SDH transport services. The flexibility of an IP/MPLS network allows service providers to take advantage of packet transport statistical multiplexing gain while also providing quality of service to bandwidth- and latency-sensitive applications. Some of the requirements for such networks are:

- IP/MPLS router providing packet transport
- Converged support of Ethernet, MPLS, OTN, and WDM
- Support 100 GE ring and mesh networks
- Integrated PON OLT interfaces
- Temperature hardened platform
- TDM circuit emulation supporting SONET/SDH, T1, and E1 services
- Ring protection and restoration
- Timing and synchronization for mobile base stations

TCO Model Framework and Assumptions

ACG Research has developed a five-year TCO model to compare both the CapEx and OpEx of the present mode of operations (PMO) with the future mode of operations (FMO). The PMO represents an operator with separate parallel access networks for mobile, business, PON, and SONET/SDH services (Figure 1). The FMO converges these services into a single access network (Figure 2). Key assumptions for both the PMO and FMO are:

- Mobile, business, and residential PON traffic is growing over the five-year model period
- SONET/SDH traffic is static during this period but support for these services must continue
- Networks need equipment upgrades to support new capacity requirements

The model uses traffic growth projections to estimate the capacity and cost of both the PMO and FMO networks. The assumptions used to project capacity requirements are presented in Table 1. The network architecture assumptions are presented in Table 2. We assume that access rings will be upgraded from 10 GE to 100 GE and also that the average number of nodes per access ring will be reduced from eight to five to support more capacity per access node. The model computes the capacity requirements of the access nodes from the demand and then determines the configuration and cost of the access nodes using the demand assumptions.

Demand Assumptions	Year 1	Year 2	Year 3	Year 4	Year 5
Number of base stations per access node	6	6	6	6	6
Mobile traffic per base station (Mbps)	300	800	2800	2800	2800
Number of business services per access node	2	2	2	2	2
Business service traffic (Mbps)	200	240	288	346	415
Number of PON subscribers (ONTs) per access node	200	200	200	200	200
Average traffic per PON subscriber/ONTs (Mbps)	3.0	3.6	4.3	5.2	6.2
Number of STM stations per access node	6	6	6	6	6
Number of E1s per STM station	4	4	4	4	4

Table 1. Demand Assumptions

Network Assumptions	Year 1	Year 2	Year 3	Year 4	Year 5
Number of MAERs per access ring	8	8	5	5	5
Number of access rings per aggregation node	2	2	4	4	4
Number of aggregation nodes per network	30	30	30	30	30

Table 2. Network Assumptions

OpEx Assumptions

One of the key benefits of network convergence is OpEx savings. Operating separate networks for business, mobile, PON, and SONET/SDH services results in duplicated tasks and separate organizations. It is harder to automate and optimize operations with separate networks, technologies, and vendors.

ACG Research has developed an OpEx model that considers fixed labor expenses and variable labor expenses. Labor is measured in Full-Time Equivalents or FTEs. Fixed FTEs are not directly driven by the size of the network but are driven by the responsibilities and tasks required for an FTE. For example, test and certification of new hardware and software is not dependent on the number of routers in the network but is driven by the number of new software and hardware releases and the complexity of the system. Variable FTEs are driven by the size of the network; these are functions that increase as the size of the network increases. For example, the complexity of fault management and troubleshooting is more labor intensive in a large network.

The key functions considered in fixed FTE OpEx are:

- **Security management:** Managing security standards, accessing and remediating vulnerabilities, monitoring attacks, and ensuring configurations meet security standards
- **Test and certification:** All new hardware and software needs to go through a CSP's test and certification labs to ensure they meet the CSP's network and service requirements
- **Software upgrades:** Major, minor, and patch releases
- **Network engineering and capacity planning:** Planning for network capacity and router upgrades based on projected increases in network traffic

The functions in variable FTE OpEx are scaled for each network element. The individual variable FTE OpEx functions are:

- **Moves, adds, and changes:** These are generally router software configuration changes but also could involve physical changes to wiring and racks
- **Network installation:** New router hardware and software installation and testing
- **Service assurance and fault management:** Fault monitoring, correlation, troubleshooting, remediation, and help-desk trouble ticketing

Additionally, the OpEx model considers the cost of technical support services for the network. For the SONET/SDH network these support costs are extremely high because many of the ADMs are at end of life and support costs are growing 15% annually. The OpEx model also considers the cost of power and cooling expenses. Multiple networks have more network elements and therefore they consume more power.

CapEx Assumptions

Network CapEx is driven by growth in traffic and subscribers. As we discussed previously, the transition from 4G to 5G will dramatically grow mobile backhaul traffic. As operators continue to roll out PON, residential internet traffic will grow. Network upgrades and capital expenditures are required to support the traffic generated by these new services.

We have modeled a network based on the assumptions in Table 1 and Table 2. The model calculates the network configurations for both the PMO and FMO and uses hardware and software cost assumptions to calculate CapEx for both.

The PMO CapEx consists of:

- Routers, line cards, and pluggable optics
- PON OLTs chassis, OLT line interfaces, and 10GE line cards
- SONET/SDH is considered a sunk cost and not included in CapEx

The FMO CapEx consists of:

- Routers, line cards, and pluggable optics
- PON SFP (OLT on a chip)
- SONET/SDH circuit emulation

In the FMO scenario, CapEx is required for SONET/SDH convergence, but this investment reduces support expenses for SONET/SDH, which are extremely high.

TCO Results

As a result of converging business, mobile, PON, and SONET/SDH traffic into an integrated access network, we see 46% TCO savings over five years. Table 3 presents the high-level TCO results for the network specified in our demand and network architecture assumptions. Both the PMO and FMO networks are modeled using identical demand assumptions. The FMO architecture has a CapEx savings of 33% and OpEx savings of 60%. The key reason for this TCO savings is the convergence of multiple services on a single IP/MPLS network. It is always more cost-effective to run multiple services on a single IP/MPLS access network rather than operating multiple parallel networks.

	CapEx	OpEx	TCO
FMO	$ 59,457,600	$ 36,258,588	$ 95,716,188
PMO	$ 88,335,000	$ 89,821,042	$ 178,156,042
TCO Savings	33%	60%	46%

Table 3. Five-Year Cumulative TCO Comparison of the PMO and FMO

In our model the demand assumptions resulted in CapEx expenses in Year 1 and Year 3 as represented in Figure 3. Annual OpEx is presented in Figure 4, and annual TCO (CapEx + OpEx) is depicted in Figure 5. CapEx is not added every year because we are assuming a greenfield network where most of the network buildout is done in the first year. That buildout provides capacity for Year 1 and Year 2. Additional capacity is required in Year 3, which serves network demand through Year 5. The reduction in FMO CapEx is due to service convergence. Network OpEx is by definition an on-going set of expenses that continues to grow over time. The PMO OpEx is significantly higher than the FMO because it requires the operations and maintenance of multiple parallel networks as compared to a single converged network.

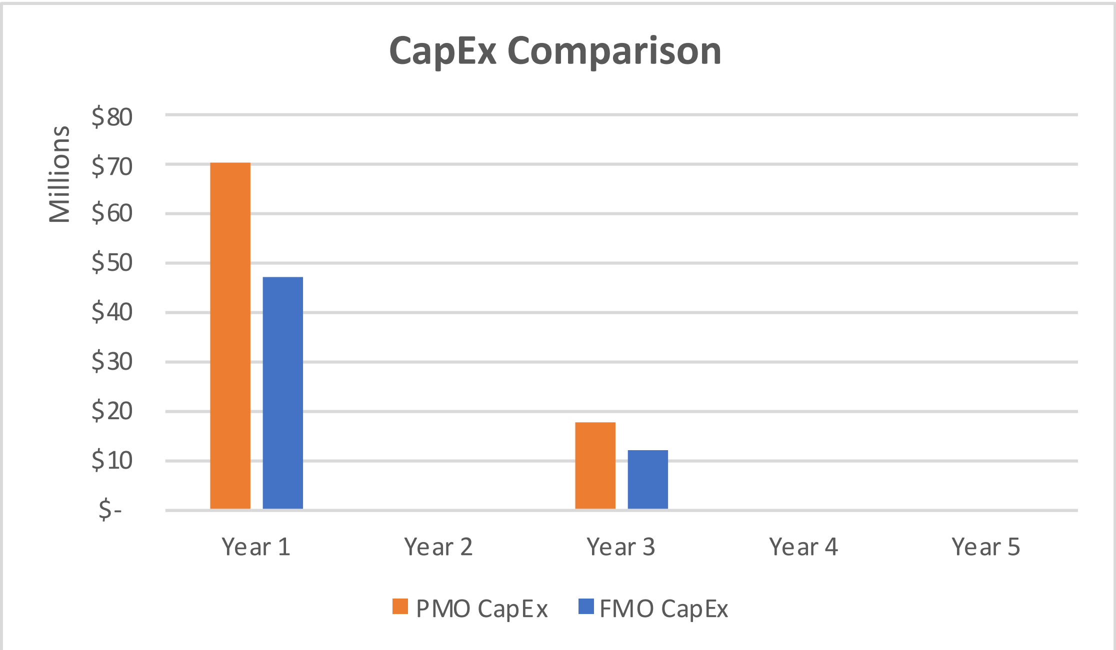

Figure 3. Year by Year CapEx Comparison of FMO and PMO

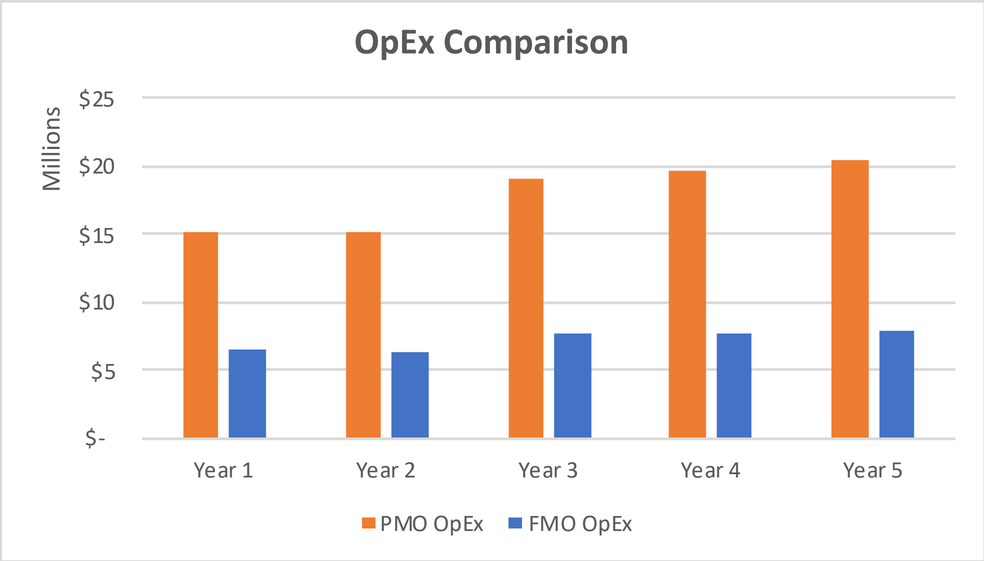

Figure 4. Year by Year OpEx Comparison of FMO and PMO

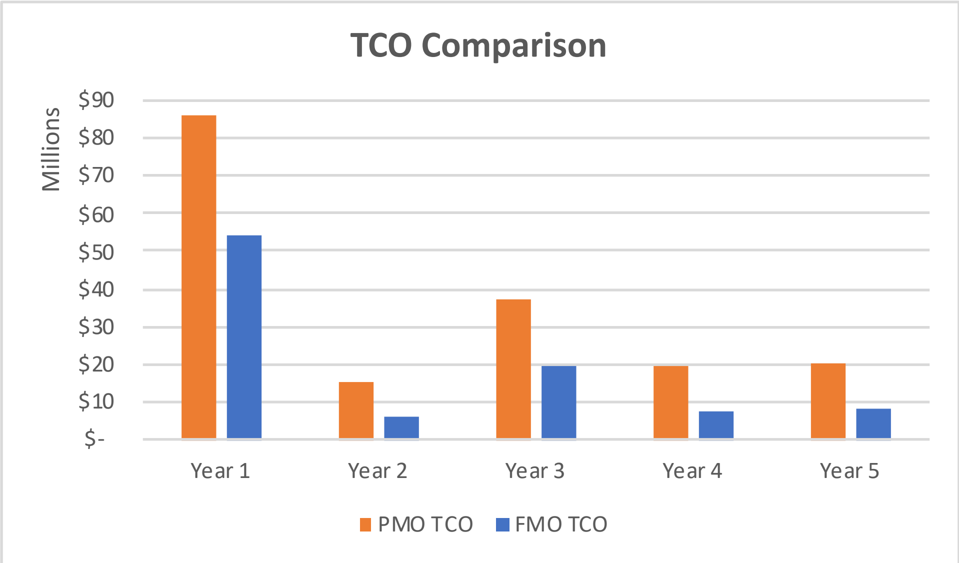

Figure 5. Year by Year TCO Comparison of FMO and PMO

The five-year cumulative CapEx breakdown for the FMO and PMO is presented in Figure 6 and Figure 7, respectively. In the FMO there are fewer components because it is a converged network. Most of the cost is for the routers, which provide the access rings. The PON SFP interfaces provide an OLT on a chip; therefore, PON is integrated directly into the access routers, which is more cost-effective than a separate PON OLT in an aggregation central office. Because the FMO solution integrates SONET/SDH into the IP network, there are some expenses represented in the line item for E1 interfaces. In the PMO CapEx breakdown separate network elements are required for mobile, business, and PON networks. We assume SONET/SDH is not growing so there is no CapEx required.

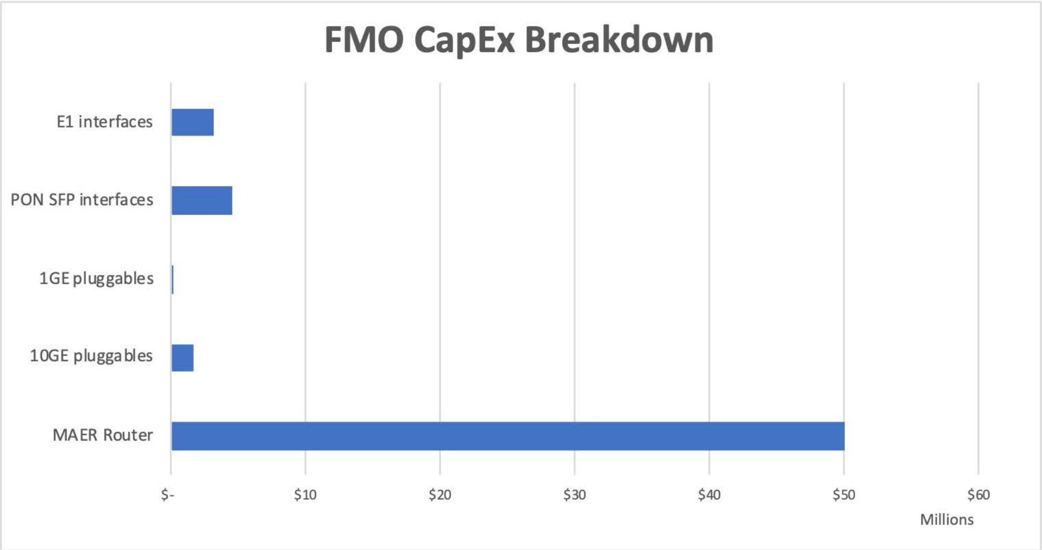

Figure 6. Five-Year Cumulative FMO CapEx Breakdown

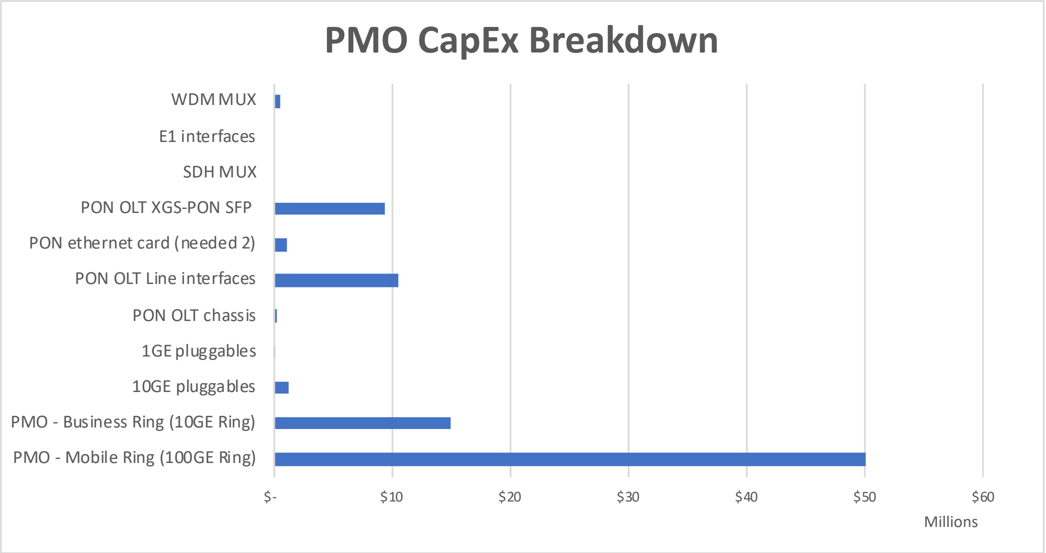

Figure 7. Five-Year Cumulative PMO CapEx Breakdown

A five-year cumulative OpEx breakdown is provided in Figure 8. The largest component of OpEx is technical support services for network hardware and software. Separate parallel networks require more network elements and therefore larger support expenses. SONET/SDH support expenses are continuing to increase as a result of network element end of life. Supporting parallel networks also results in higher labor expenses, especially around service assurance, move, adds, and changes, and network engineering and planning. Parallel networks also result in much higher power expenses.

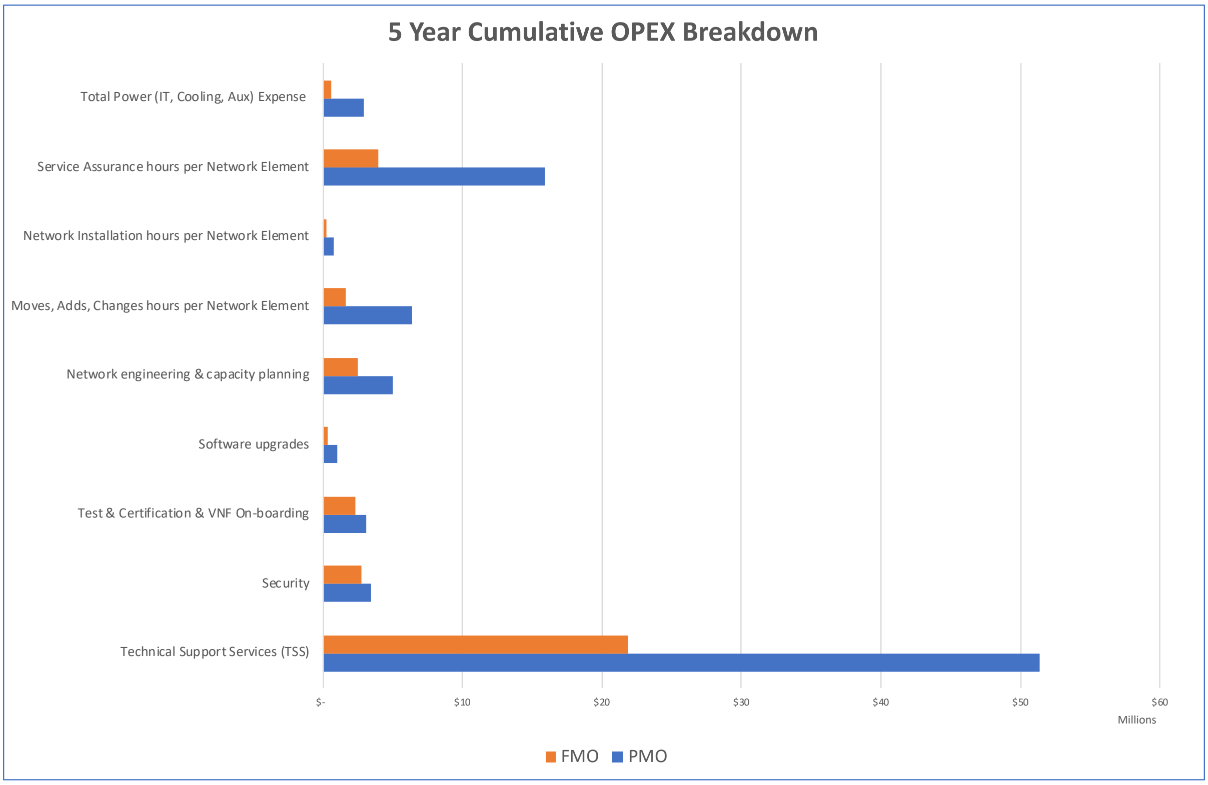

Figure 8. Five-Year Cumulative Comparison of PMO and FMO OpEx

Conclusion

Innovative technologies and bandwidth-intensive applications are driving tremendous growth in access networks. These include mobile network upgrades to 5G, PON buildouts, continued growth in video and gaming, and bandwidth-intensive business applications. This growth is driving the need for capacity upgrades. As networks are upgraded there is an opportunity to converge multiple services on a single, integrated access network. These services are:

- Mobile backhaul
- Business services
- PON
- SONET/SDH

A converged network should be based on next-generation IP/MPLS routers that provide carrier-class traffic engineering, quality of service, circuit emulation, and mobile backhaul services. By converging services on a single network the overall network is simplified, the number of network elements are reduced, and redundant labor tasks are eliminated. Our results show CapEx savings of 33%, OpEx savings of 60%, and TCO savings of 46% because of access network convergence.

Acronym Definitions

CapEx: Capital Expenses

CSP: Communications Service Provider

FTE: Full-Time equivalent

FMO: Future Mode of Operations

IP: Internet Protocol

MAER: Multi-access Edge Router

MPLS: Multiprotocol Label Switching

OLT: Optical Line Termination

ONT: Optical Network Termination

OTN: Optical Transport Networking

OpEx: Operations Expenses

PMO: Present Mode of Operations

PON: Passive Optical Networks

TCO: Total Cost of Ownership

WDM: Wave Division Multiplexing