THE ECONOMIC BENEFITS OF IP TRANSPORT AT 400G

Executive Summary

A new architecture is emerging, and it stands to disrupt the way networks have been built for the last 10 to 20 years. This new network architecture effectively removes the optical switching layer and puts the switching onus back onto the router layer, thus simplifying the management of the entire network. This is a new paradigm for many of the transport operators yet might provide the best overall total cost of ownership (TCO) seen in a while.

Traditional solutions build IP networks on top of an optical layer to increase capacity and reduce the number of expensive router ports. That was and is considered the router bypass option that included reconfigurable add/drop multiplexers (ROADMs). These router bypass networks leveraged the DWDM layer to liberate routers of the massive transit traffic on the network to reduce the cost of big, expensive routers.

400 Gbps routers, like the Cisco 8000, are delivering a massive increase in router scale and capacity, resulting in a significantly lower cost per bit router. At the same time, DCO optics have decreased in size and power consumption where 400G optics can now reside on a router card at much higher densities.

This begs the question, should we change the architecture to allow transit traffic to flow through the router layer and remove the complexity of the optical layer? This paper will examine both the capital expenditure (CAPEX) and operational expenditure (OPEX) savings to provide a total cost of ownership model.

Report Highlights

- 400G IP transport networks will be more operationally cost effective than typical router bypass networks.
- IP transport networks have 46% TCO savings, 57% OPEX savings, and 35% CAPEX savings over router bypass networks because of increased router capacity, lower price per Gbps and significant reductions in OPEX by simplifying the optical layer.

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IP NETWORK ARCHITECTURES

In a service provider's network, there are two approaches to network architecture:

1. Router bypass: Routers are interconnected via a DWDM ROADM network.
2. IP transport: Adjacent routers are directly interconnected with high-speed optics.

This study compares the economics of router bypass and IP transport networks that span core and metro networks with 400G interfaces. An overview of both architectures and an economic analysis comparing the approaches is presented.

Router Bypass

ROADMs have been the standard building blocks in DWDM networks. The advantage of ROADMs is to bypass routers, saving on fabric capacity and router interfaces. However, with the recent evolution of optics technology and integrated on-board Digital Signal Processors (DSP) for coherent DWDM transmission, the paradigm is shifting.

In a typical router bypass network, all routers with any significant amount of origin-destination traffic are directly connected over a ROADM based DWDM underlay network (Figure 1). This analysis assumes that in an 80 node network each router is connected on average to 40 percent of the other routers.

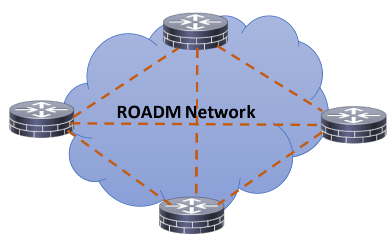

Figure 1. Router Bypass Network where Routers are Directly Connected through ROADMs

The network architecture used to implement router bypass is depicted in Figure 2. Client interfaces carrying traffic are connected to routers with 100G grey optics. These routers are connected to DWDM ROADM transponders using 100G grey optics. At intermediate transit nodes, wavelengths are either added and/or dropped or passed through the ROADM. This greatly reduces the transit traffic in the router. As the network scales, the optical infrastructure must add capacity, resulting in utilization of the C+L band or by dedicating a new fiber. In either case, there must be additional investment in the optical infrastructure.

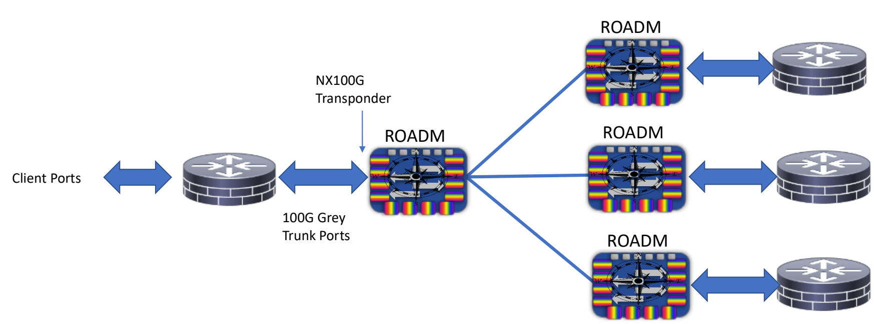

Figure 2. Router and DWDM ROADM Architecture

Key issues of the router bypass network are:

- IP layer riding on top of a DWDM underlay network is used to reduce transit traffic and router interfaces by putting it onto what is considered a lower-cost DWDM network. That lower-cost network requires full installation of ROADMs at a large entry-level cost.
- Separate network operations and management functions are required for the IP network and the optical network.
- DWDM ROADM layer has become more complex to plan, configure, provision, optimize, and operate.

IP Transport Network

The key attribute of the IP transport network is that 400G DCO optics are integrated into the router, and the router network now provides the routing and switching of all network traffic. This is a new architectural approach made possible with the recent evolution of silicon technology used in two major building blocks: Network Processing Units (NPU) used in Layer 3 routers and DSPs used in coherent transmission optical interfaces. Wafer-scale silicon, which follows Moore's Law[1], is accelerating the cost-per-bit reduction of these components faster than the reduction of cost of optical infrastructure building blocks, such as ROADMs.

NPU processing power has been exploding exponentially since 2017; the NPUs on next-generation Cisco routers, like the Cisco 8000, provide unprecedented throughput and scale. This also means that for the first time, packet processing/fabric capacity will not be the limiting factor when designing large IP networks. DSPs like NPUs have been undergoing an evolution. Node sizes have been reduced at each DSP generation: 28 nm (2nd generation), 16 nm (3rd generation) down to 7 nm, and there are already plans to move to 5 nm node size. Power consumption has been steadily declining to a point where the DSP function resides in the optical pluggable module.

Traditionally, optical infrastructure dominated the total cost of next-generation networks. However, in an IP transport network, routers are connected in a mesh with IP trunks. Client traffic traverses the routed network from node to node (Figure 3). This is an example of a typical mesh network where transit traffic that used to be switched at the DWDM layer now exists in the router mesh.

[1] Moore's Law asserts that the number of transistors on a microchip doubles about every two years, though the cost of computers is halved.

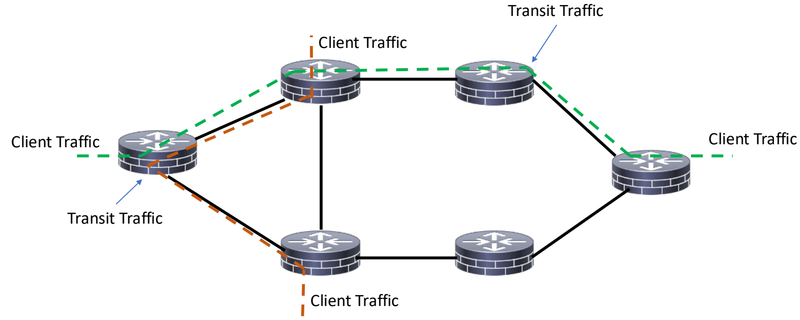

Figure 3. IP Transport Network Architecture

In this analysis, we consider routed networks with integrated 400G DCO optics. In many cases connections between adjacent routers require multiple 400G trunks. To conserve fiber, point-to-point DWDM optics and a simple multiplexer is used to insert multiple 400G colored trunks on a single fiber pair. This architecture is presented in Figure 4.

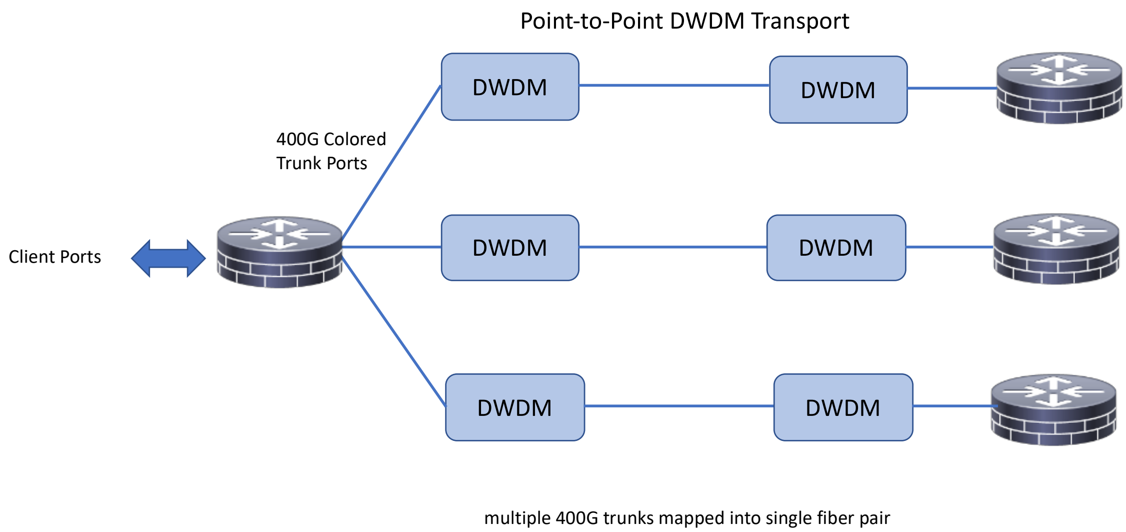

Figure 4. IP Transport Maps Multiple 400G Trunks into a Single Fiber Pair

Key benefits of the IP transport network:

- Simplifies the architecture and dramatically reduces network cost when the ROADM layer is removed.
- Simplified operation, maintenance and troubleshooting with single management layer as the analogue DWDM network is now confined to point-to-point links; failures are confined between adjacent routers.
- Enables network optimization, better fiber utilization.
- Eliminates the need for dedicated line card for optics.

Why IP Transport, Why Now?

Previous attempts at simplifying the optical layer leveraging routers have failed for several reasons. It required new router line cards and router slots which were simply too expensive. Today, the density and form factor of the optics have been reduced dramatically and can be inserted on a router line card at higher densities and bit rates than previously possible. The cost per port of routers, like the Cisco 8000, has dropped sufficiently, and the scale of those routers has increased dramatically. Operational challenges that keep organizations separate are shifting as network modernization to converge TDM over IP is driving disparate operational teams together as just one example.

Advantages of DCO optics are that they can be inserted into any router at 400G or whatever the next bit rate is, providing insurance for the previous challenge of routers and optics having different life cycles. Today, thousands of routers with DCO optics are being deployed in the access area for many of these reasons, including footprint and OPEX reduction. This simpler architecture will likely migrate to the metro and core when DCO optics become available in volume and decrease in cost.

Would a Hybrid Network Work?

It should be noted that it is possible to design a hybrid of the IP transport and router bypass network. In the metro, one could use IP transport with next-generation routers and optics to reduce CAPEX and OPEX because **the majority of the traffic today remains localized**. It is also possible to keep in place the routed and DWDM ROADM layered network for long-haul or subsea routes to leverage the investment made and gain savings by deploying IP transport networks in the metro and regional areas.

TCO MODEL FRAMEWORK AND ASSUMPTIONS

The TCO analysis compares the cost of an IP transport network with the typical DWDM ROADM network. The network architecture assumptions described in the previous section are used in the TCO model. The expenses include CAPEX associated with network equipment and OPEX associated with equipment maintenance and a service provider's operations expenses. The TCO analysis shows that at 400G scale in large networks, the IP transport network has a lower CAPEX and OPEX than a router bypass network. Note that the Cisco 8000 was used in both models; in the IP transport model, DCO optics are used, and in the router bypass model, traditional ROADMs are used.

The model utilizes the following assumptions:

- 80 node network.
- Routed traffic at metro nodes starts at 2.4 Tbps and grows annually at 15 percent.
- In the router bypass, 40 percent of the router nodes are directly connected to each other.

TCO RESULTS

All TCO results depend on network topology (number of nodes, distances between nodes) and traffic requirements; hence, a customer-specific TCO should always be created to evaluate specific savings. The results displayed in Figure 5 compare the five-year cumulative TCO of an IP transport to a router bypass network. Over five years there is a 35 percent CAPEX savings and a 57 percent OPEX savings, resulting in a 46 percent TCO savings. The CAPEX savings are a result of the economies of scale of 400G router interfaces, elimination of 100G transponders, and the simplification of the DWDM layer. Operation savings are a direct result of eliminating the cost and complexity of managing and supporting the optical underlay network.

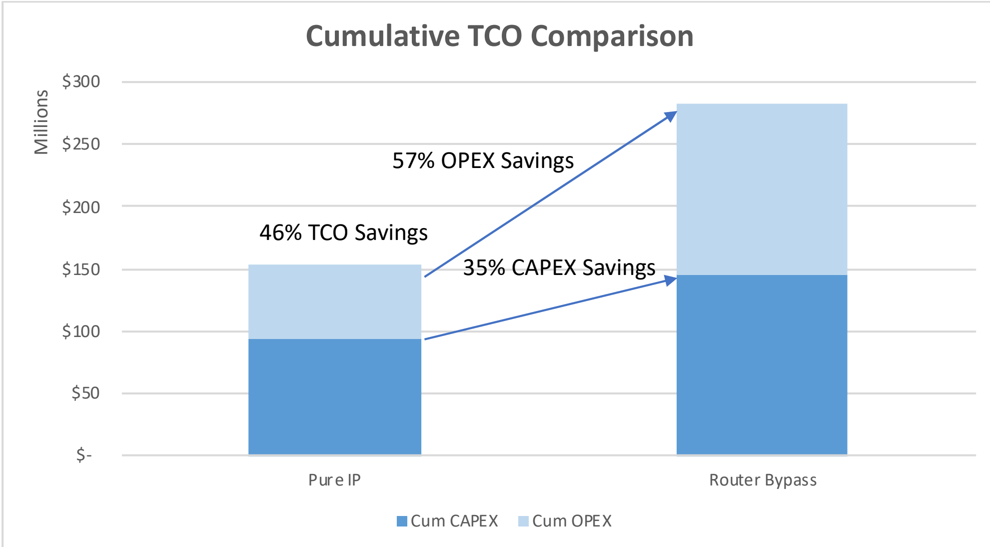

Figure 5. Five-Year TCO Comparison of IP Transport to Router Bypass

The cumulative CAPEX and OPEX over five years is presented in Figures 6 and 7. Note that the router bypass network requires the ROADM underlay to be fully installed day one. This is because the router bypass requires full connectivity between all nodes with routed traffic, exacting a large, up-front investment. The IP transport network grows to support increasing network traffic but is more flexible and can take advantage of the natural elements of routing like segment routing and traffic engineering to smooth capacity. The IP transport network also has a much lower cost of entry than the router bypass.

The cumulative OPEX differences are a direct result of the expenses of the two separate networks, where router bypass requires management of two network layers. These expenses will continue to diverge over time, because OPEX is a recurring expense, and management costs do not decrease unless a major architecture shift to IP transport can be done.

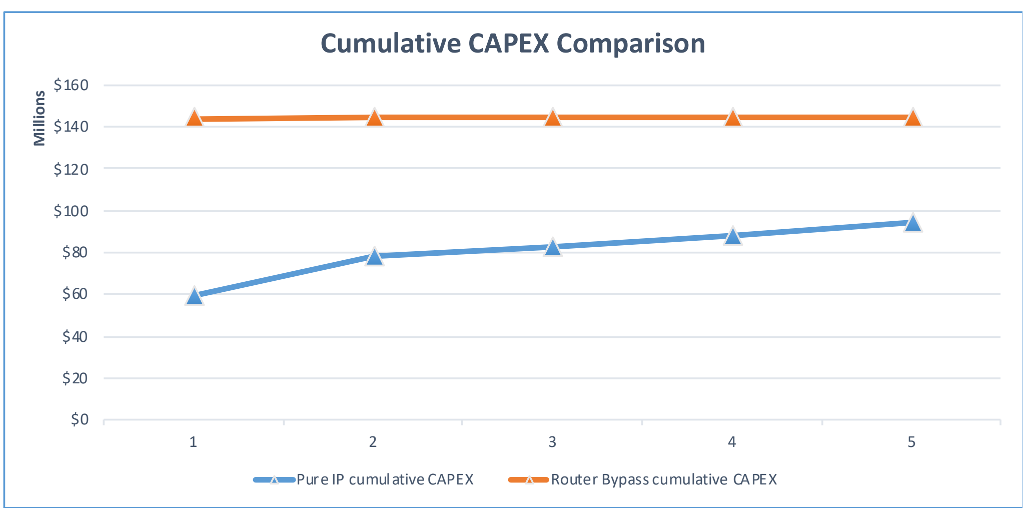

Figure 6. Five-Year Cumulative Capex Comparison of IP Transport and Router Bypass

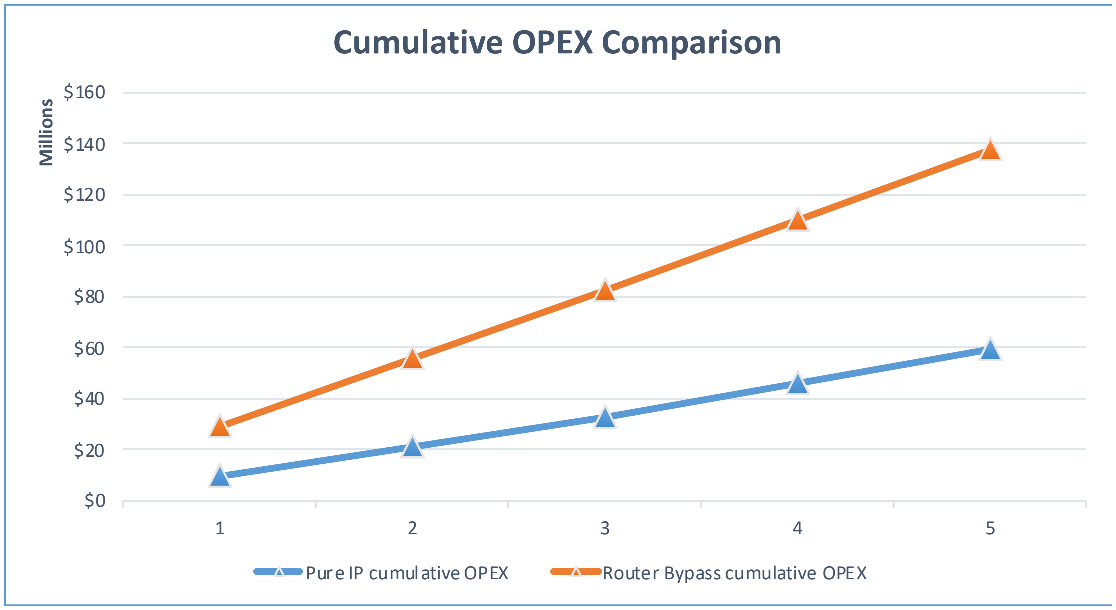

Figure 7. Five-Year Cumulative Opex Comparison of IP Transport and Router Bypass

Power consumption is also an important factor in network design. It is the primary contributor to environmental expenses (power, cooling, floorspace). An important consideration is that power and cooling in central offices and data centers are limited resources. Once the power or cooling capacity is exceeded, it may be impossible to add additional power. Figure 8 shows that the IP transport network has lower power consumption than the router bypass network.

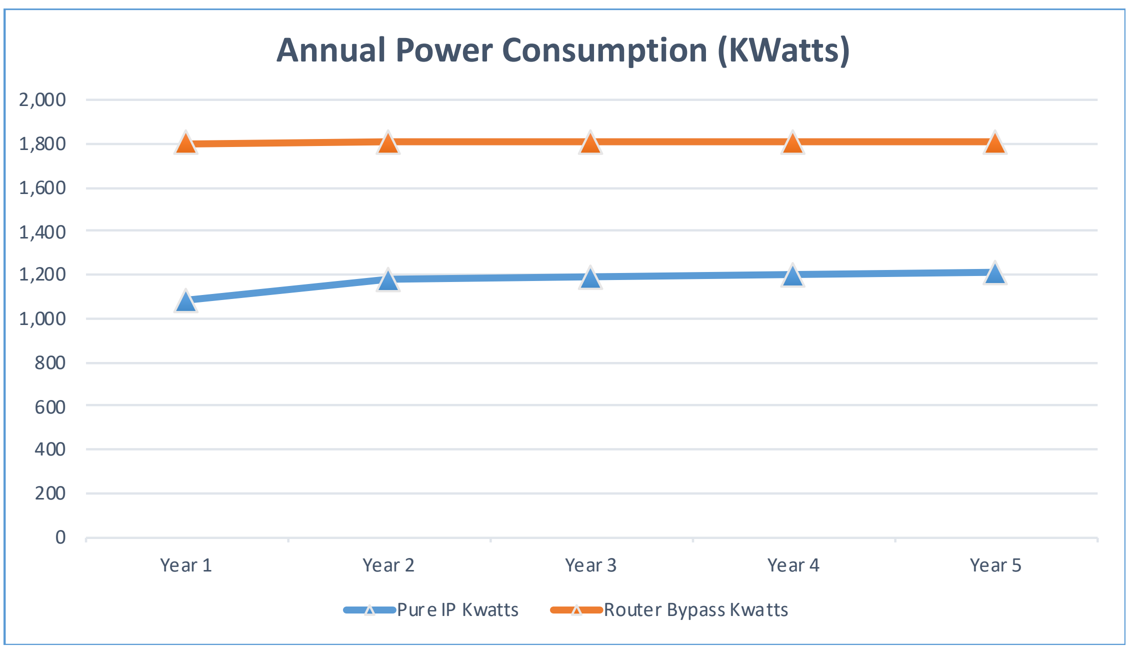

Figure 8. Five-Year Comparison of IP Transport and Router Bypass Power Consumption

OPEX Analysis Breakdown

Operation expense is the most important component of the TCO savings. Table 1 provides definitions for the categories of OPEX considered in this paper.

OPEX CATEGORY	DEFINITION
Tech Support Services	These are support expenses for hardware and software provided by the vendor.
Multi-Layer Fault Management	Sometimes it is not clear if the root cause is in the routing or optical layer. These are expenses for troubleshooting and fault management across the routing and optical network layers.
Security	Security management must be done for both the routing and optical network layers. This involves security monitoring and patching.
Test & Certification	Before any new hardware or software releases are deployed in production, they must go through a service provider’s test and certification process.
Software Upgrades	Network software upgrades require planning, monitoring, execution and possibly rollbacks. These are the labor expenses associated with software upgrades.
Network Engineering & Capacity Planning	Network engineering groups are responsible for network architecture, detailed design, resiliency analysis and capacity planning.
Moves, Adds, Changes	Network operation requires constant changes in configuration, tuning and management.
Network Installation	One-time installation expenses for network equipment installation.
Service Assurance Labor	Fault management, troubleshooting and repair activities.
Orchestration Software	Software expenses for network orchestration and management.
Fault Management Systems & Software	Software expenses for fault management systems.
Total Power (IT, Cooling, Aux) Cost per Kwatt/Hour	Power expenses for powering and cooling equipment.
Facilities (Floorspace, Land, Engineering) Cost per RU	All expenses related to central office and data center facilities.

Table 1. Definitions of OPEX Categories

The fundamental reason for the IP transport network OPEX savings is due to simplifying a complex layer of the network that needs to be managed and operated independently of the IP network. The biggest drivers of OPEX savings are service assurance and moves, adds and changes (Figure 9). This is directly a result of the requirement for fault management, troubleshooting, network repair and ongoing configuration activities on two parallel networks. A complicating factor is that the technology and skill-sets required for ROADM networks are orthogonal to IP router networks, requiring different sets of skills and departments.

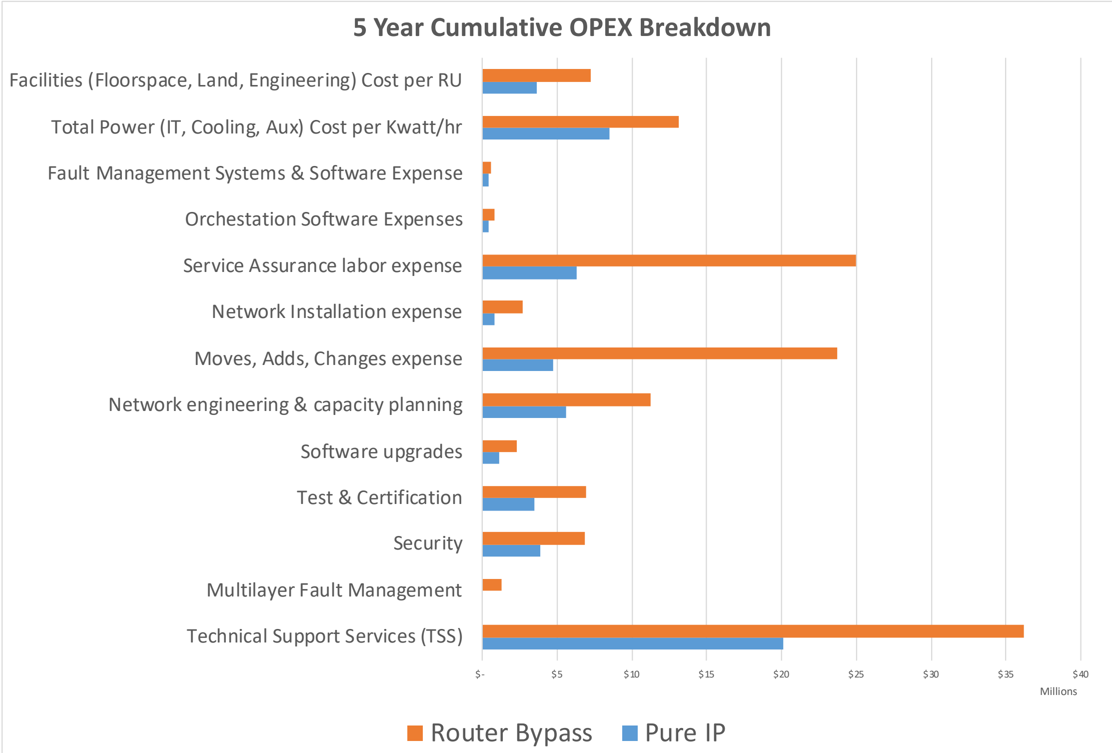

Figure 9. Five-Year Cumulative OPEX Breakdown

CONCLUSION

This TCO analysis demonstrates that any router, like the Cisco 8000 with 400G DCO pluggable optic, have both the price, performance, and scale to provide IP transport with a simplified DWDM optical layer. By simplifying the DWDM optical layer, service providers can dramatically decrease expenses associated with multilayer network operations and reduce capital expenses: TCO savings of 46 percent, OPEX savings of 57 percent and CAPEX savings of 35 percent over five years for an IP transport network versus a router bypass network.

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