The Economic Benefits of Routed Optical Networks for DCI, Metro, and Long-Haul Applications

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EXECUTIVE SUMMARY

Cisco Routed Optical Networking, an integral part of the Cisco Converged SDN Transport architecture, represents a transformative approach in modern networking. Routed optical networking is an architecture that simplifies the traditional DWDM layer by leveraging pluggable coherent optics that deliver coherent wavelengths directly from router ports. As routing infrastructure is upgraded to support increasingly scalable capacity, the IP layer can be used to more efficiently aggregate services onto coherent wavelengths delivered with pluggable technology.

Introduced several years ago, Cisco Routed Optical Networking has been deployed by more than 100 customers in 400G metro and data center interconnect (DCI) applications. These customers have benefited from increased capacity, reduced energy consumption, and lowered network costs, complexity, and footprint. For example, infrastructure provider Colt Technology Services, has seen 69% CapEx savings and 2X reduction in rack space and power consumption, resulting in improved sustainability. Arelion, the provider with the world's #1 ranked IP backbone, saved 64% in CapEx and 76% in OpEx by streamlining its architecture.

The detailed analysis reveals a TCO savings of up to 48% for DCI, 56% for metro, and 62% for long haul. The adoption of Routed Optical Networking architecture reduces environmental expenses (power and facilities costs) by up to 83% across all three scenarios.

With Routed Optical Networking widely deployed and advances in pluggable coherent optics technologies, this whitepaper examines the total cost of ownership (TCO) benefits of leveraging these newer technologies for DCI short-haul, metro medium-haul, and long-haul applications, as opposed to traditional networking models that require multiple layers of IP and optical switching as well as complex coordination.

Key highlights include the elimination of transponders, the integration of advanced coherent pluggable optics technologies, and the adoption of Private Line Emulation (PLE). These

innovations reduce the need for optical transport network (OTN) equipment and additional router ports, resulting in substantial CapEx and OpEx savings. Cisco's Crosswork Network Automation and Cisco Provider Connectivity Assurance (formerly Accedian Skylight) enhances TCO by streamlining network management through automation, orchestration, and assurance.

The five-year TCO comparison across various network scenarios, underscores the financial advantages. The detailed analysis reveals a TCO savings of up to 48% for DCI, 56% for metro, and 62% for long haul. The adoption of Routed Optical Networking architecture reduces environmental expenses (power and facilities costs) by up to 83% across all three scenarios. The TCO savings are driven by reductions in network CapEx as well as reductions in power consumption, space requirements, and labor costs, making Cisco Routed Optical Networking a compelling choice for network operators.

Routed Optical Networking Overview

Routed Optical Networking is an architecture designed to deliver improved operational efficiencies and simplicity. The solution, depicted in Figure 1, works by merging IP and private line services onto a single layer, where all the switching is done at Layer 3 with IP routers, such as the Cisco 8000 Series Routers. This approach contrasts with traditional networking models that separate IP and optical layers, requiring multiple layers of switching and complex coordination between them.

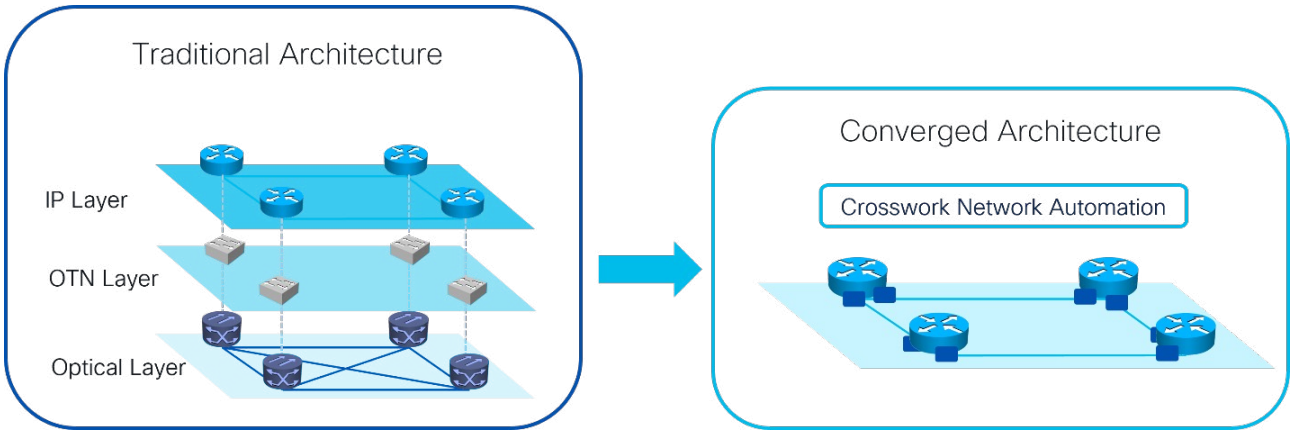

Figure 1. Traditional Network Compared to a Converged Routed Optical Network

Elimination of Transponders

One of the key benefits of Routed Optical Networking is the elimination of transponders required in optical transport systems. Traditionally, the optical network and the IP network have been separate

networks. IP networks interface to the optical networks using transponders in optical transport systems to convert signals to Dense Wavelength Division Multiplexing (DWDM) colored optics. In a Routed Optical Network, the pluggable optics in the router provide DWDM colored optics, eliminating the need for transponders and other optical equipment. This architecture provides the ability to integrate amplifiers into the router using pluggable optics, further reducing the need for some external amplifiers. By converging the layers of the network, Routed Optical Networking reduces network TCO.

> "Our new Cisco infrastructure uses less electricity, includes more high-capacity ports, and requires less space than our previous system. It is highly scalable and can handle enough bandwidth to accommodate our projected growth. When you pair these benefits, it is clear we found the right partner in Cisco.[1]"
>
> Odd-Eirik Grottheim, CEO, NTE Telekom AS

Advances in Coherent Pluggable Technology

With cloud and AI network traffic demands continuing to grow rapidly, high-performance pluggable modules have become an important tool for network operators to cost-efficiently scale their networks. As routers increase I/O port speeds to 800G, coherent pluggable optics leveraging silicon photonics-based designs and advances in digital signal processors (DSP) technology are enabling twice the connectivity speed as well as longer reaches with the potential to replace traditional transport equipment across a greater range of infrastructure. Key developments in the Cisco portfolio of coherent pluggable optics are enabling new use cases for Routed Optical Networking:

- Cisco 400G ZR+ QSFP-DD High-TX Power: This technology enhances existing ZR+ modules with increased optical transmit power that enables high-capacity data transmission over long distances without the need for regeneration.
- Cisco QSFP-DD Pluggable Open Line System (QSFP-DD OLS): Provides a flexible and efficient means of managing optical signals delivered in a QSFP-DD pluggable form factor.
- Future coherent QSFP-DD 800ZR, QSFP-DD 800G ZR+, and QSFP-DD 400G Ultra-Long Haul: These emerging technologies promise even greater capacities and longer reach, further enhancing network performance and efficiency.

Private Line Emulation

Routed Optical Networking significantly simplifies the network by converging IP and optical functions into a single router network. In a Routed Optical Network, traditional wavelength

[1] Minimizing Cost and Maximizing Growth with a Routed Optical Network, https://upshotstories.com/stories/minimizing-cost-and-maximizing-growth-with-a-routed-optical-network

services can use private line emulation (PLE), eliminating the need for complex and costly optical transport network (OTN) equipment. PLE enables non-Ethernet type services such as SONET/SDH and Fibre Channel to be carried over the same IP network, maintaining service-level agreements and characteristics such as guaranteed bandwidth and persistent bidirectional paths. This is achieved with Ethernet Virtual Private Network extensions for setup and control and circuit emulation for bit transparency. Figure 2 provides a comparison of an optical network using OTN to transport private line circuits, such as OTU, TDM, Fiber Channel, Ethernet, and SONET, with PLE services over a converged IP network. In the diagram, the present mode of operation requires a significant amount of OTN equipment as well as interfaces in and out of the optical network and routing network. This additional equipment as well as the interfaces drives up network TCO. The converged IP network with PLE does not require these multiple interfaces and equipment at every hop of the network. Instead, a simple PLE CPE is required at each end of the connection, and circuit emulation is used to carry traffic across the IP network. An intermediate step is also possible in which existing ROADM equipment can be used to transport the wavelengths coming from routers with Ethernet/IP and PLE services.

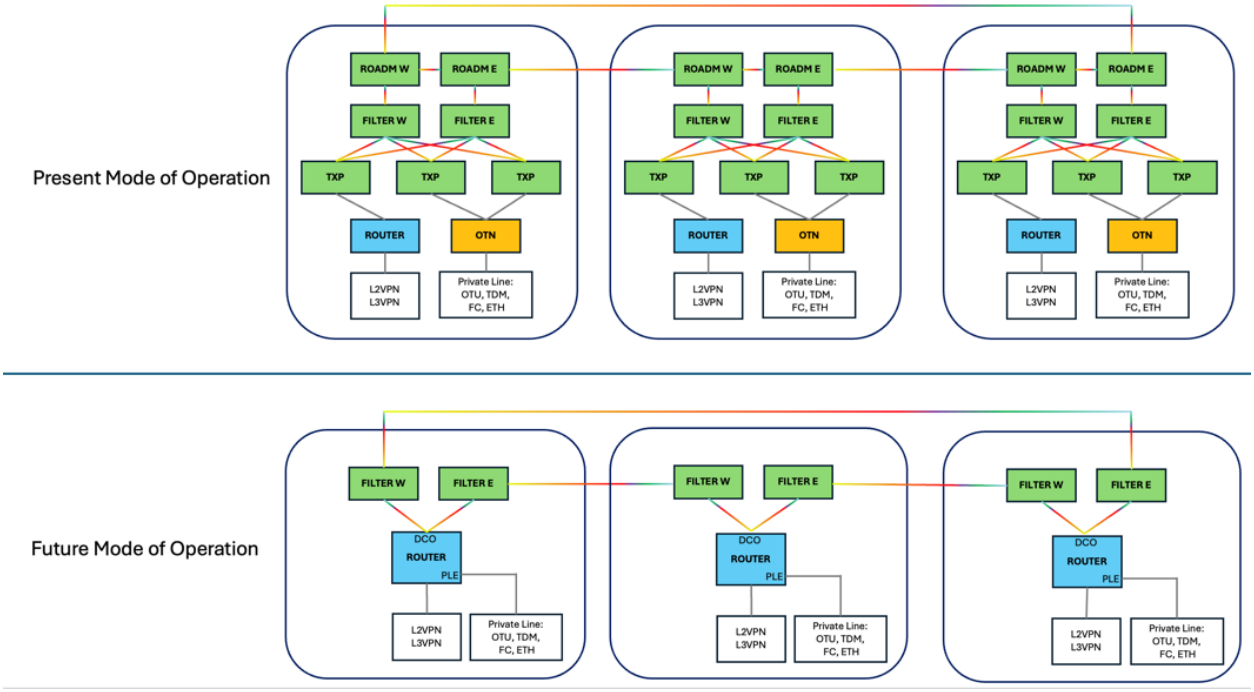

Figure 2. Comparison of PLE over an Integrated IP Network with OTN over an Optical Transport Network
DCO: Digital Coherent Optic (Cisco Coherent Pluggable Optic for Routed Optical Networking)

PLE is fully automated through Cisco Crosswork Network Automation, which provides bandwidth reservation, bidirectional path optimization, service assurance, and orchestration for private line services, ensuring visibility from the service layer down to the fiber.

Management, Automation and Assurance

Cisco Crosswork Network Automation enhances the TCO with advanced automation and assurance capabilities. Crosswork is an industry-leading automation platform that simplifies and accelerates network planning, design, and implementation. It allows operators to proactively optimize the network and ensure high-quality services, making it a crucial component in achieving the efficiencies promised by Routed Optical Networking.

- **Cisco Crosswork Network Automation** manages the simplified network as well as brownfield and multilayered siloed networks through a single pane of glass.
- **Crosswork Automated Assurance** pairs advanced network automation with high-resolution performance monitoring for continuous visibility on end-to-end service quality and automated remediation of issues before end-users are impacted.
- **Cisco Provider Connectivity Assurance** (formerly Accedian Skylight) delivers proactive service assurance built on precise sub-second testing and service monitoring to optimize digital experiences. It simplifies operations and troubleshooting with a single view of granular performance metrics across multiple network layers helping large enterprises and network operators accelerate mean-time-to-resolution.

> "Colt has migrated more than 50 percent of their EU core network traffic to 400G ZR/ZR+ optics in Cisco routers to address the benefits of the Routed Optical Networking Solution. The smaller footprint and lower power reduced our operational complexity resulting in a TCO savings of up to 69% so far.[2]"
>
> Vivek Gaur, Vice President Networking Engineering, Colt

Key Savings and Benefits

Routed Optical Networking architectures deliver significant savings and benefits, including:

- **Reduced CapEx and OpEx:** Integrating IP and optical layers reduces the need for separate equipment and simplified network management.
- **Sustainable Power and Space Savings:** Consume less power and require less rack space, contributing to improved sustainability.
- **Reliability in Production Networks:** Mature technology that has been widely adopted, demonstrating reliability and effectiveness in real-world scenarios.

[2] "Cisco Helps Service Providers Build a Sustainable Internet for the Future with Advancements to Its Converged Network Solution to Lower Costs, "https://newsroom.cisco.com/c/r/newsroom/en/us/a/y2022/m06/cisco-helps-service-providers-build-a-sustainable-internet-for-the-future-with-advancements-to-its-converged-network-solution-to-lower-costs.html

Routed Optical Networking TCO Model Framework

Total Cost of Ownership is a critical metric for evaluating the financial efficiency of network architectures. This section compares the TCO of two scenarios: one utilizing Routed Optical Networking and one without it. The Routed Optical Networking scenario uses Cisco coherent pluggable optics, Cisco Crosswork Network Automation, and Cisco Provider Connectivity Assurance software. The metro and long-haul applications simplify the network architecture further by integrating OTN services with PLE. The second scenario uses traditional optical transport with separate IP and optical/DWDM and OTN switching layers.

The comparisons are made across DCI, metro, and long-haul applications to demonstrate the tangible Routed Optical Networking benefits in various networking use cases.

TCO Comparison Use Cases

The Routed Optical Networking TCO comparison use cases are presented in Figure 3 and summarized:

1. DCI short-haul connecting two data centers (800ZR QSFP-DD coherent modules with 4 nodes).
2. Metro medium-haul networks with 40 nodes (400G ZR+ High-Tx Power and 800ZR+ QSFP-DD coherent modules <1000km) with PLE and OTN.
3. Long-haul networks with 80 nodes (400G QSFP-DD coherent module for ULH only) with PLE and OTN.

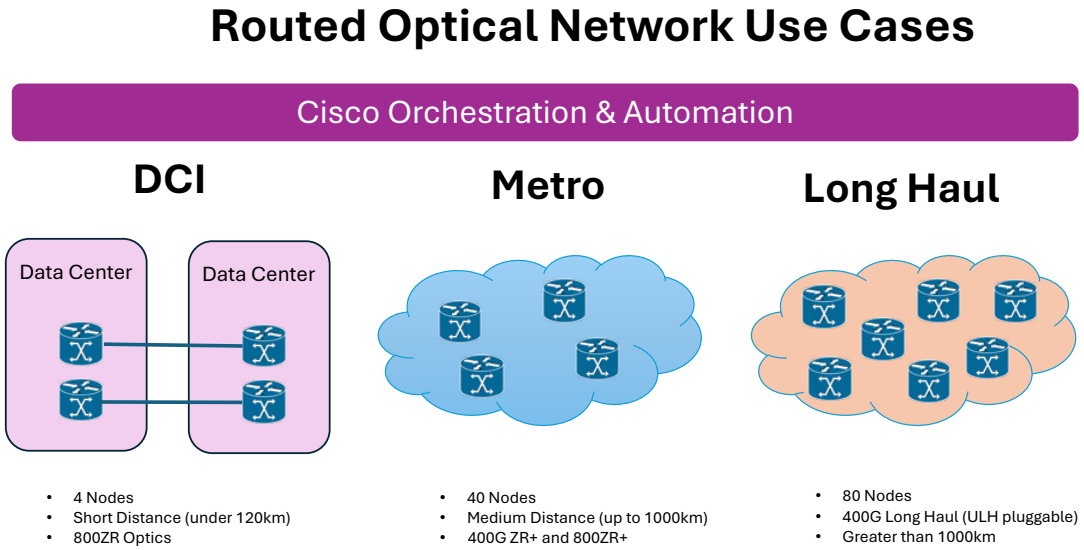

Figure 3. Routed Optical Networking TCO Use Cases

Key Areas of Network Simplification and TCO Savings

Routed Optical Networking offers substantial simplifications and cost savings by integrating IP and optical layers into a single cohesive architecture. The following are key areas where Routed Optical Networking provides TCO advantages:

1. **Elimination of Optical Transponders**
   - **Cost Reduction:** By eliminating the need for separate optical transponders, Routed Optical Networking reduces CapEx.
   - **Power Savings:** Fewer transponders mean reduced power consumption, contributing to OpEx savings.
   - **Space Efficiency:** Less hardware leads to a smaller physical footprint, saving valuable rack space in data centers and network facilities.
2. **Reduction of OTN Equipment with PLE**
   - **Simplified Infrastructure:** PLE reduces the need for OTN equipment and additional router ports interfacing with DWDM and OTN gear.
   - **Cost Efficiency:** This simplification results in lower CapEx and OpEx due to reduced hardware and power requirements.
   - **Space Efficiency:** Fewer components lead to significant space savings in network setups.
3. **Integrated Open Line System with Cisco QSFP-DD OLS**
   - **Pluggable line system and amplification:** The Cisco QSFP-DD OLS includes an amplifier and line system functionality within the QSFP-DD form factor, reducing the necessity for external line systems and amplifiers.
   - **Financial Savings:** Integrating line systems and amplification directly into the router decreases CapEx by eliminating costs.
   - **Operational Efficiency:** Reducing external components lowers power consumption and saves space, enhancing overall network efficiency.

TCO Savings with Cisco Crosswork Network Automation and Provider Connectivity Assurance

The Cisco Crosswork Network Automation and Provider Connectivity Assurance platforms play a crucial role in realizing TCO savings by providing comprehensive automation, orchestration, and assurance capabilities. Significant reductions in labor expenses can be achieved. Key areas of savings include:

- **New Customer Additions**
  - **Efficiency:** Automation streamlines the process of onboarding new customers, reducing time and labor costs.
  - **Scalability:** The ability to quickly add new customers without significant manual intervention enhances scalability.
- **Incident Resolution**
  - **Proactive Management:** Automated monitoring and troubleshooting reduce the time required to resolve incidents, leading to lower operational costs.
  - **Reliability:** Faster incident resolution improves network reliability and customer satisfaction.
- **Change Requests**
  - **Simplified Processes:** Automation simplifies the handling of change requests, reducing the need for manual adjustments and associated labor costs.
  - **Consistency:** Ensuring consistent implementation of changes across the network enhances operational stability.
- **Maintenance Windows**
  - **Optimized Scheduling:** Automated systems can schedule and execute maintenance tasks more efficiently, minimizing downtime and labor requirements.
  - **Reduced Interruptions:** Efficient maintenance reduces the impact on network operations, maintaining higher service levels.

These savings are summarized in Figure 4. This data came from Cisco study on the benefits of automation and orchestration. The team analyzed the individual tasks for each of the categories of labor highlighted above and determined:

- Percentage of time spent on a particular task
- Percentage of operational improvement for each task provided by Cisco Crosswork automation

Using this data and data for the level of effort required for network engineering and planning, we developed a labor operations TCO model that is applied to each Routed Optical Networking use case.

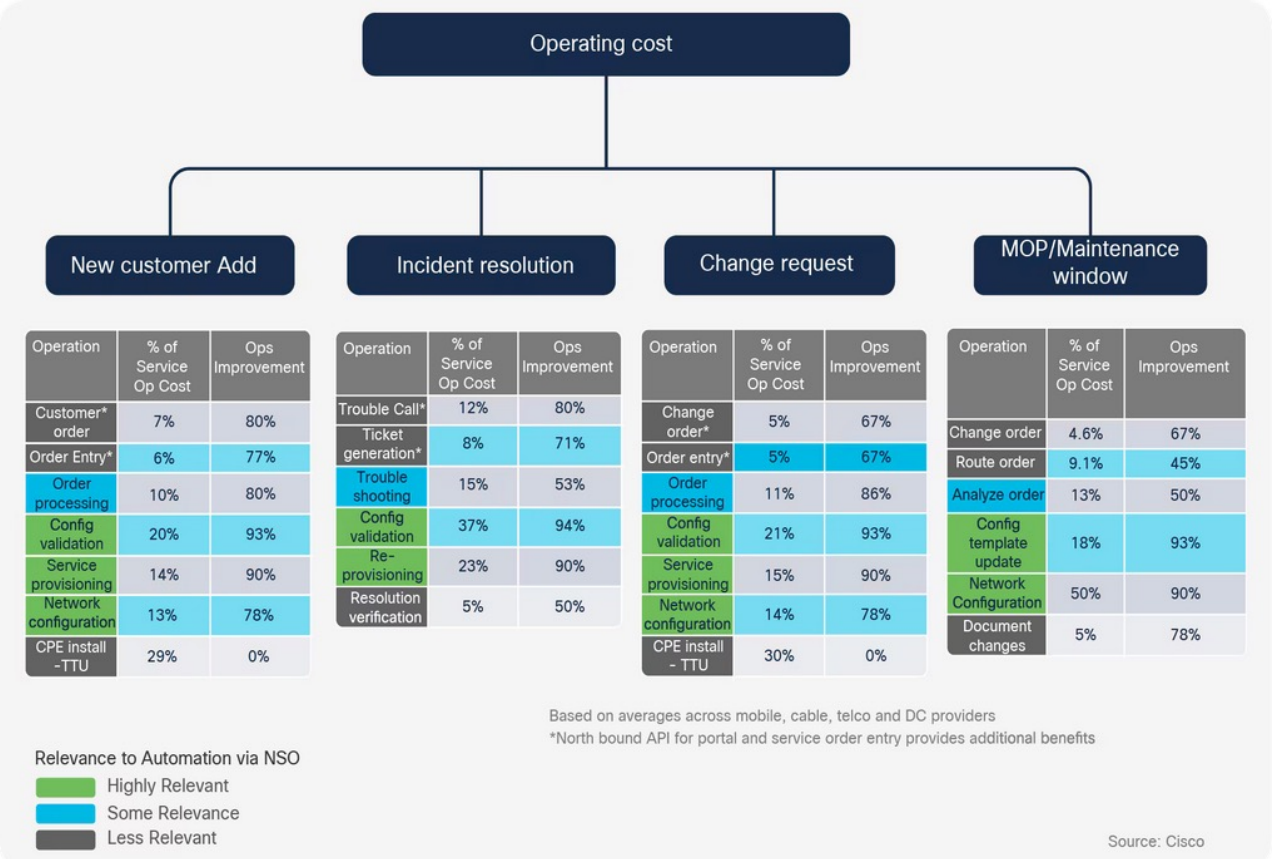

Figure 4. Key Operational Savings Achieved by Crosswork Automation and Orchestration

TCO Results

For each of the use cases we assume an average annual traffic growth rate of 15%. The five-year cumulative TCO savings for Routed Optical Networking for each use case are presented in Table 1, and the cumulative CapEx, OpEx, and TCO for each use case are presented in Figure 5–Figure 7. The Routed Optical Networking architecture provides significant savings due to the numerous benefits described earlier in the paper.

	DCI Savings	Metro Savings	Long-Haul Savings
CapEx	60%	50%	58%
OpEx	39%	67%	68%
TCO	48%	56%	62%

Table 1. Five-Year Cumulative Routed Optical Networking TCO Savings

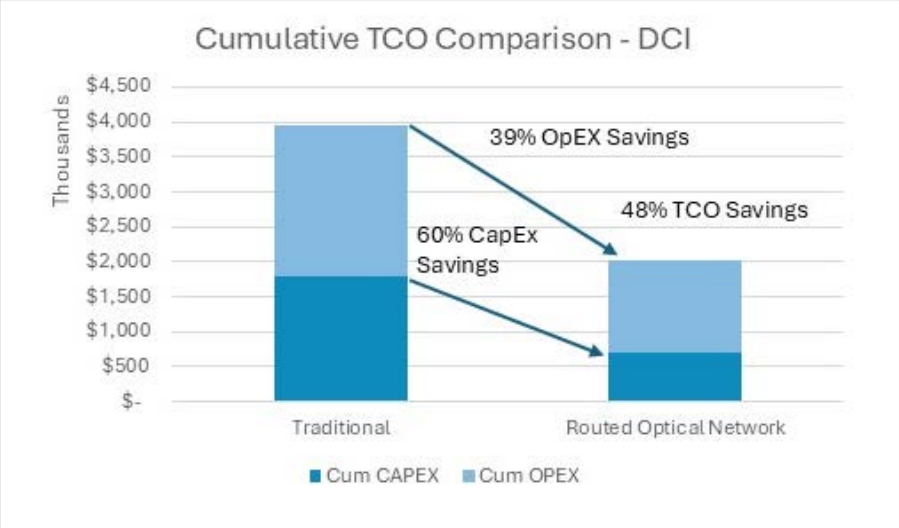

Figure 5. Five-Year Cumulative TCO for DCI Use Case

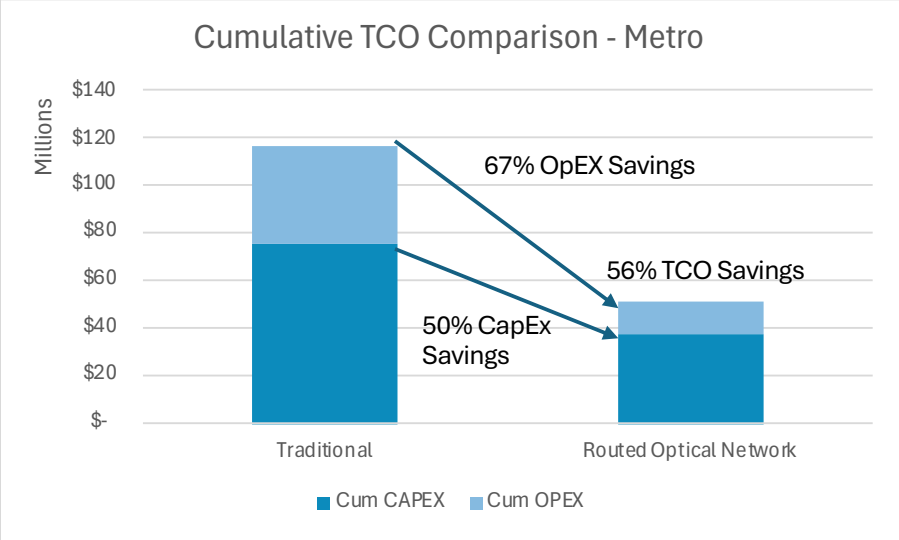

Figure 6. Five-Year Cumulative TCO for Metro Use Case

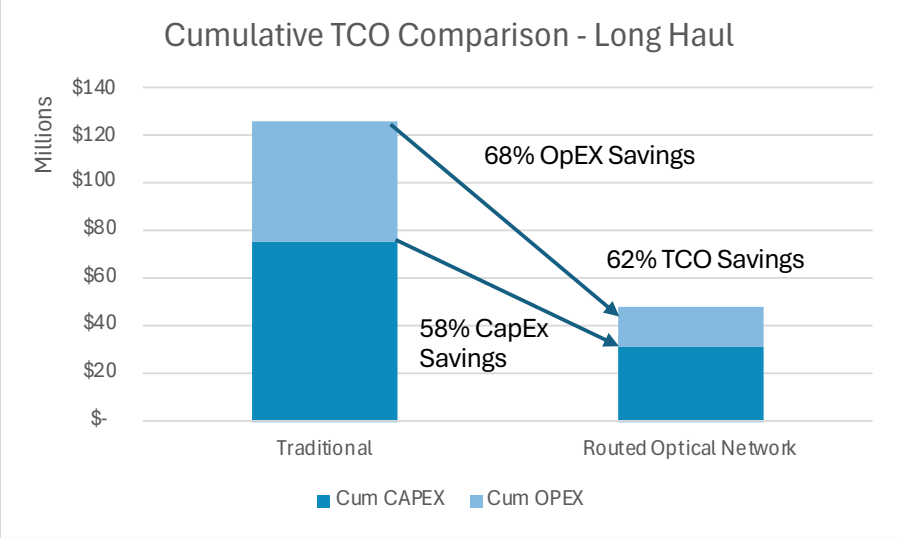

Figure 7. Five-Year Cumulative TCO for Long-Haul Use Case

A comparison of five-year cumulative environmental expenses for each use case are presented in Figure 8–Figure 10. Environmental expenses consist of power, cooling, and floorspace. The key drivers to reducing environmental expenses are reducing the amount of equipment and associated power costs for:

- Transponders
- OTN CPE
- OTN Muxponders
- OTN Cross-Connects

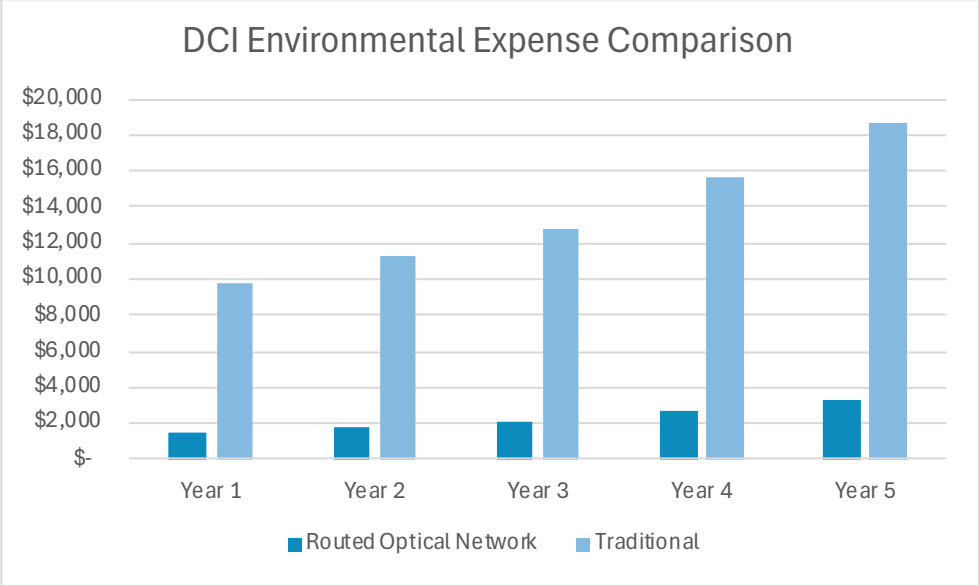

Figure 8. DCI Environmental Expense Comparison

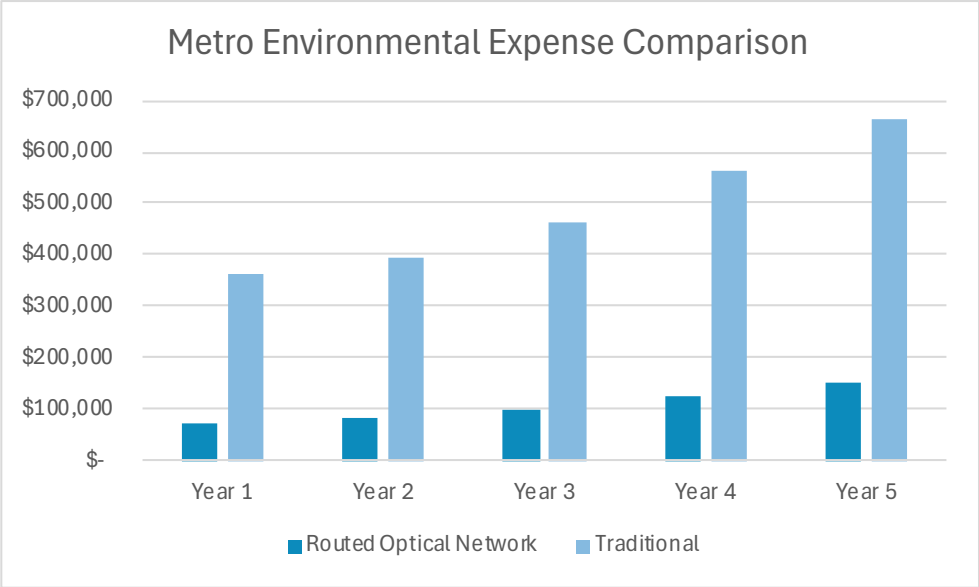

Figure 9. Metro Environmental Expense Comparison

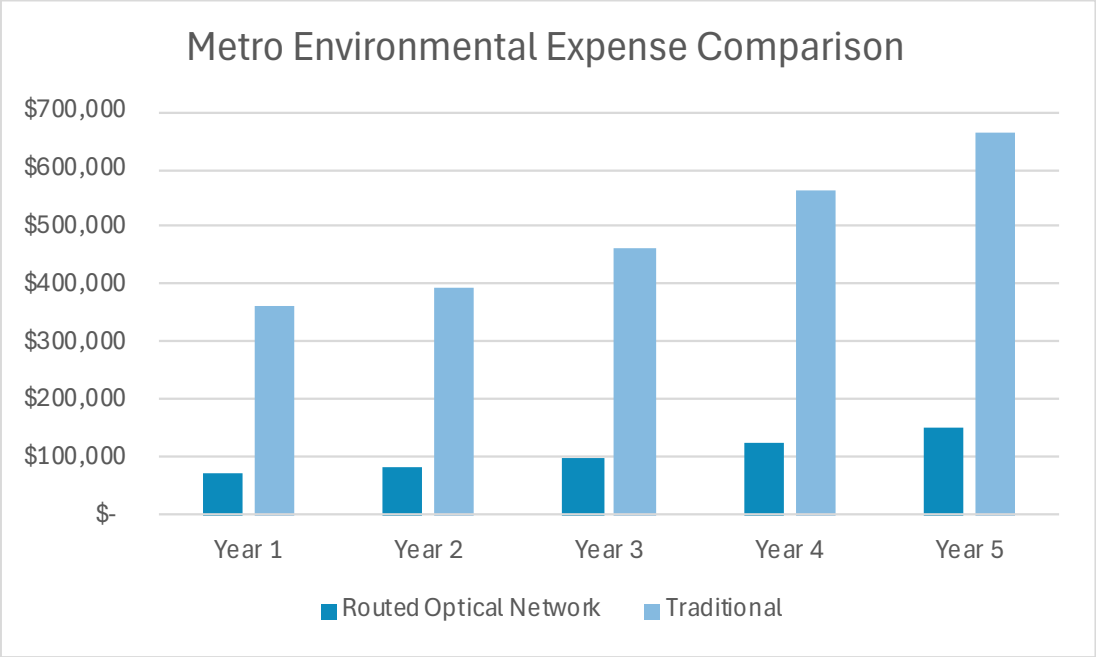

Figure 10. Long Haul Environmental Expense Comparison

Annual breakdowns for labor expenses for each use case are presented in Figure 11–Figure 13. The estimates for labor expenses with and without a Routed Optical Networking network architecture are based on a Cisco study on the benefits of automation and orchestration.

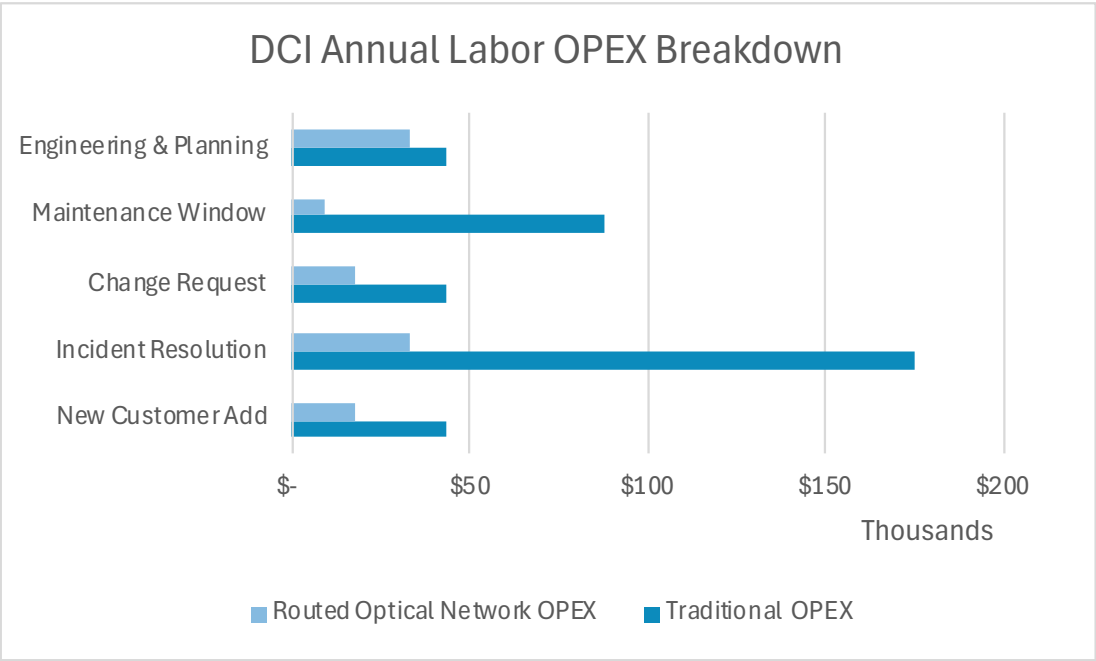

Figure 11. DCI Annual Labor OpEx Breakdown

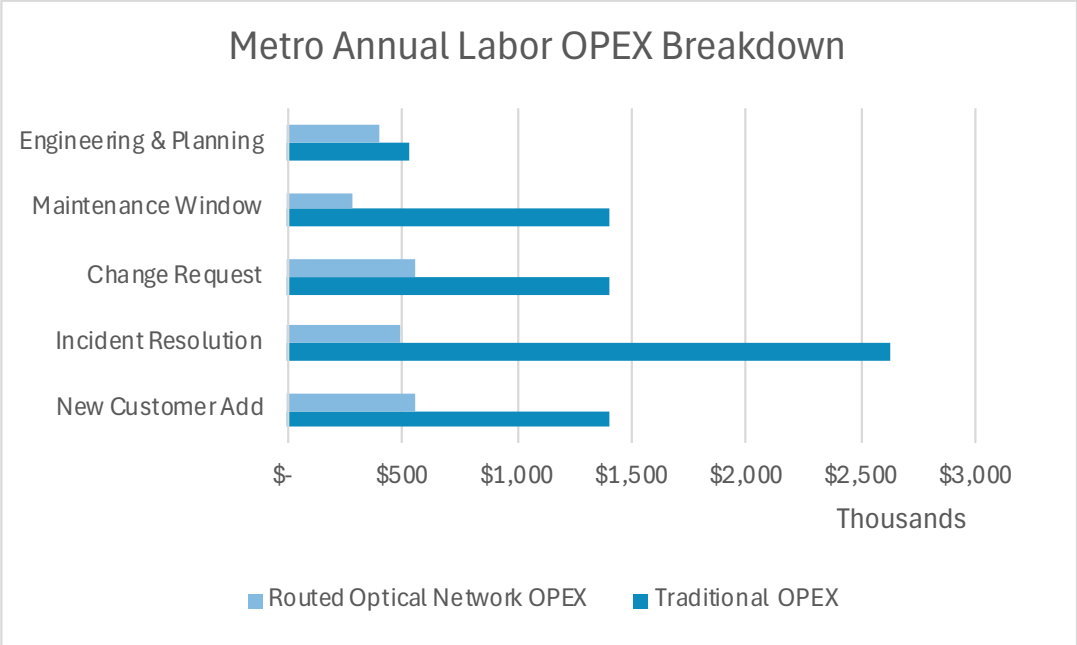

Figure 12. Metro Annual Labor OpEx Breakdown

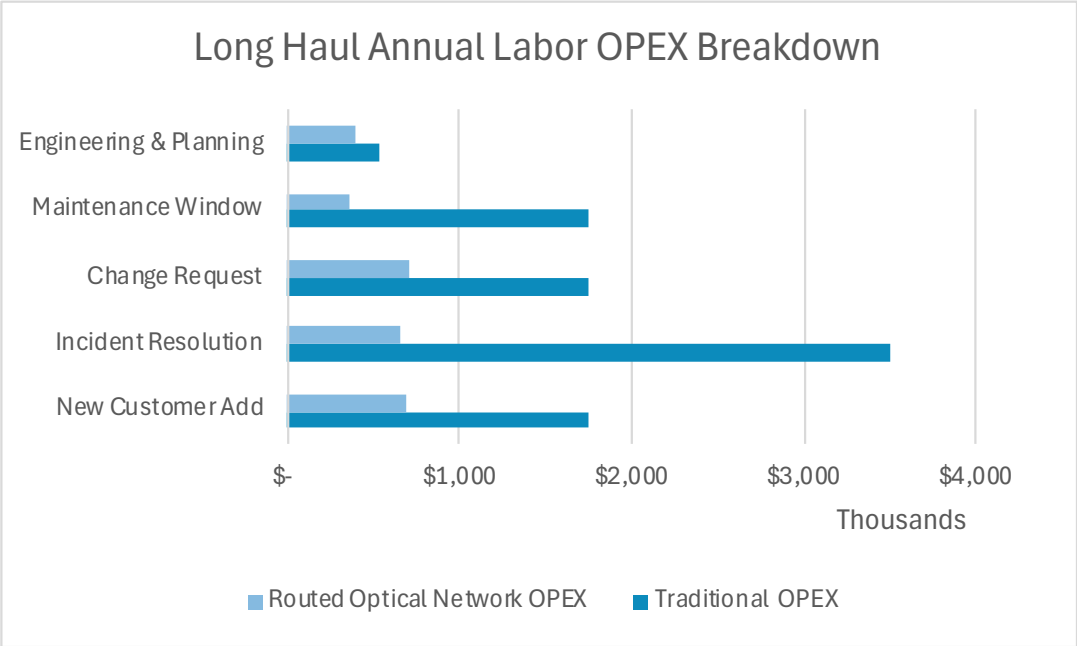

Figure 13. Long-Haul Annual Labor OpEx Breakdown

Conclusion

Routed Optical Networking stands out as a pioneering solution that addresses the complexities and inefficiencies of traditional network architectures. By integrating IP and optical layers, it not only simplifies network design but also delivers significant cost savings and operational benefits. The elimination of transponders, reduction of OTN equipment, and integration of amplification within routers are key drivers of these savings.

The use of Cisco Crosswork Network Automation and Cisco Provider Connectivity Assurance further enhances the value proposition by providing comprehensive automation and orchestration capabilities. This leads to reduced labor costs, improved network reliability, and enhanced scalability.

The TCO analysis presented in this whitepaper demonstrates the substantial financial and operational advantages of adopting Routed Optical Networking across different network applications. With proven benefits in real-world deployments, it emerges as a mature and widely adopted solution that is able to meet the evolving needs of modern network infrastructures. For network operators looking to future-proof their networks and achieve significant cost efficiencies, Routed Optical Networking offers a robust and forward-looking choice.

> "Thanks to game-changing innovations that span across silicon, optics, and routing systems, complex layers can finally converge into a simpler and more scalable architecture.[3]"
>
> Staffan Göjeryd, CEO, Arelion

For more information on Cisco Routed Optical Networking, visit www.cisco.com/go/ron

[3] Converging IP and Optical Network Layers, Arelion Blog, https://blog.arelion.com/2023/10/03/converging-ip-andoptical-network-layers/

Related Resources:

- The Business Benefits of Automation and Orchestration White Paper;
- Unlocking the benefits of converged IP and Optical Transport Webinar
- Cisco Provider Connectivity Assurance Overview
- Cisco Optics Overview

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