REIMAGINE IP OVER DWDM WITH JUNIPER CORA

Tap into a new generation of converged packet-optical innovations to simplify the network, lower costs, and unleash new business flexibility

White Paper

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EXECUTIVE SUMMARY

What if you could combine the flexibility of IP networking with the capacity of coherent optical transport—at practically any distance, in any network location? What if you could use packet-optical convergence to update legacy protection schemes and free up massive amounts of bandwidth? And what if you could do it using standardized pluggable optics that interoperate with multiple vendor equipment? Suddenly, you'd have a world of new options to add capacity and reach practically anywhere—at a much lower cost than traditional optical transport systems.

That's the promise of IP over DWDM, and it's poised to help Communication Service Providers (CSPs), cloud providers, enterprises, and other large network operators redefine the economics of their business. Juniper® Converged Optical Routing Architecture (CORA) is leading the way. CORA combines groundbreaking Juniper Networks® JCO400-ZR/ZR+ pluggable optics with an industry-leading portfolio of 400GbE-capable routing and switching platforms, and multilayer visibility from Juniper® Paragon Automation. With these capabilities, CORA provides the flexibility to unleash massive bandwidth everywhere it's needed across metro, edge, and core networks. This new architecture is about to change everything we thought we knew about network and service design.

Introduction

In principle, IP over DWDM is straightforward: using coherent DWDM pluggable optics in IP routers and switches, operators can directly interconnect ports to a DWDM line system. Ideally, IP-optical convergence should deliver a long list of benefits, allowing operators to tap into 400GbE capacity and beyond for more applications, while eliminating the need for costly external transponder infrastructure.

Despite all this potential, however, multiple technical and operational barriers have prevented IP over DWDM from delivering on its promise. Oversized pluggables that reduced density of the router line card and stranded bandwidth, as well as siloed vendor-proprietary management, high costs, and other issues have relegated IP over DWDM to mostly a niche solution. Today, after steady advances in standardization, Digital Signal Processor (DSP) technologies, and optical subcomponents, IP over DWDM can be cost-effectively applied to a large, growing range of use cases. What's changed to make converged packet-optical networking a viable solution?

- **Industry standards:** Until recently, coherent DWDM solutions were proprietary. Now, open standards such as Optical Internetworking Forum (OIF) 400ZR, Open ZR+, and OpenConfig can bring true interoperability to pluggable optical transceivers, eliminating vendor lock-in and the need to manage IP and optical as separate, siloed domains.
- **Compact pluggable form factors:** New pluggables can deliver power-efficient DWDM signaling in the same QSFP-DD form factor as grey optical transceivers. You no longer have to choose between maximizing platform density or converging IP and optical.
- **Cost efficiencies:** New networking systems and ASICs can support high-capacity optics using less power and space. Meanwhile, standardized coherent pluggable optics eliminate the need for external optical transponders in many applications. Together, these innovations unlock huge capital and operational savings.
- **Massive growth in 400GbE transport:** With widespread adoption of 400GbE-capable routers and switches, more organizations are in position to deploy and benefit from IP over DWDM in many more network locations.

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These advances are driving an inflection point for converged IP-optical technology. For the first time, IP over DWDM is a real option for a range of metro, regional, and core use cases. And it's about to revolutionize the way we design and operate transport networks.

The Convergence Advantage

To understand why IP over DWDM is so advantageous, compare yesterday's transport networks with what's possible today with IP over DWDM. As Figure 1 illustrates, traditional optical networks require costly external transponder systems (typically closed and proprietary) and dedicated operations. With IP over DWDM, configurable optics in IP routing and switching platforms can hand off coherent DWDM signals directly to the line system or directly connect with another router, eliminating traditional transponder infrastructures and their associated costs.

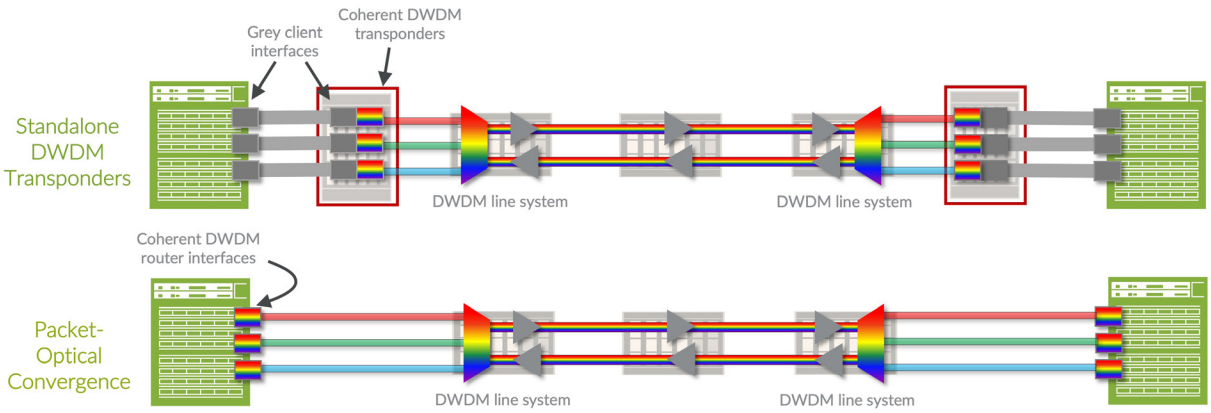

Figure 1. IP-optical integration eliminates hardware components, increases reliability, reduces costs and power consumption, and simplifies operations.

This model offers a more effective, economical way to address the huge increases in customer demand. By shifting to converged optical routing architectures—and using JCO400-ZR/ZR+ pluggables in router and switch ports—providers can increase link capacity and extend fiber reach at the same time. They gain the capacity to support exponential traffic growth, plus the architectural flexibility to bring 400GbE transport (and beyond), wherever it's needed, at a much lower cost.

Juniper conducted an in-depth TCO analysis that compared a converged configuration of Juniper PTX Series Routers using JCO Series Coherent Optics, versus one using traditional transponders (Figure 2). By eliminating the need to buy and maintain the transponders, IP over DWDM reduced CapEx by more than 40%. It reduced OpEx even more, requiring 54% less power and 77% less space, and generating 55% less carbon emissions. In all, the Juniper IP-over-DWDM solution delivered greater than 45% TCO savings.

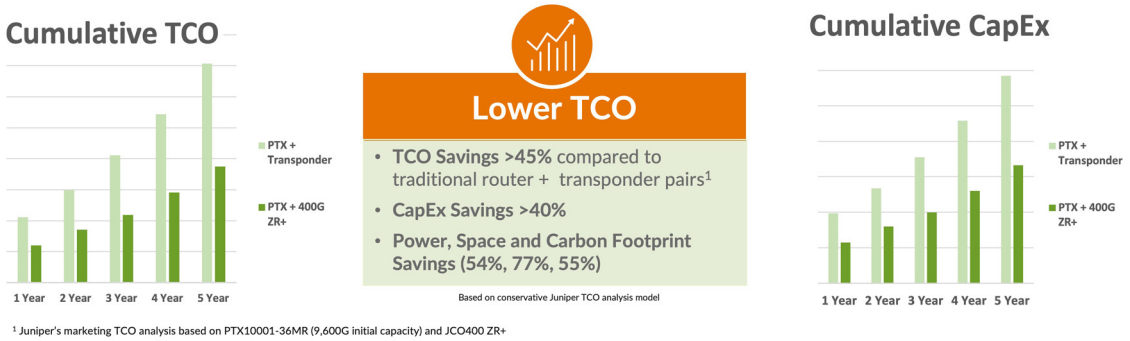

Figure 2. An IP-over-DWDM architecture delivers significant capital and operational savings.

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With CORA, Juniper can help you bring the benefits of IP-optical convergence to your most demanding use cases (Figure 3).

Using Juniper IP-over-DWDM technologies, you can meet next-generation capacity demands with a converged packet-optical network and accomplish so much more. You can:

- Address a range of greenfield and brownfield use cases
- Use interoperable solutions from multiple vendors
- Simplify network operations across IP and optical domains
- Meet insatiable customer demand for bandwidth with a more versatile, power-efficient network, at a much lower cost

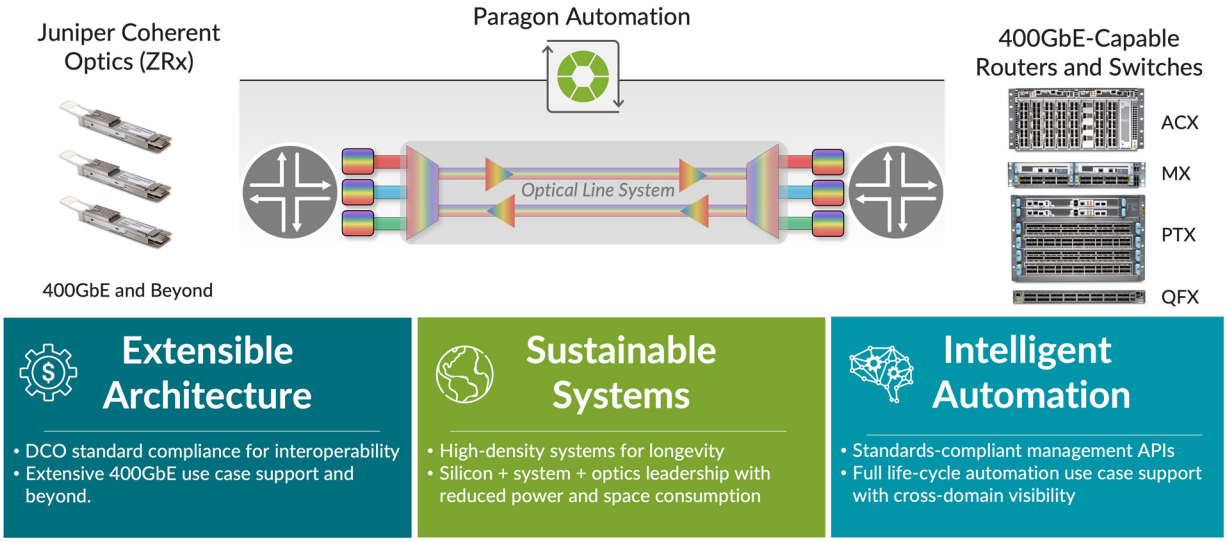

Figure 3. The Juniper CORA IP-over-DWDM solution provides an extensible architecture, sustainable systems, and intelligent automation

Juniper CORA delivers:

- **Extensible architecture**: Groundbreaking Juniper Coherent Optics JCO400-ZR/ZR+/0-dBm pluggables open a world of new possibilities for network and service design. With interoperable, standards-compliant QSFP-DD DWDM pluggables, you can mix and match optics to support different reaches and bit rates, even within the same line card. You can use converged mesh architectures, IP-based bandwidth optimization, and service-layer protection to free up huge amounts of protected bandwidth.
- **Sustainable systems:** The Juniper portfolio of 400GbE-capable routers and switches sets the standard for system capacity and longevity. Juniper ACX, MX, PTX, and QFX platforms lead the market in silicon and system innovation, continually driving higher performance in smaller, more power-efficient footprints. The ongoing optical innovations position you to take full advantage of 400GbE transport capacity today, and 800GbE and beyond in the future.
- **Intelligent automation:** The Juniper Paragon Automation suite can help you tap into the power of IP-optical convergence while simplifying network operations. It can automate full life-cycle network operations across multiple use cases, with multilayer visibility. CORA solutions also feature standards-compliant management APIs to interoperate with third-party management software in multivendor environments.

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Unlock New Flexibility with CORA

For decades, "optical" was synonymous with "proprietary." Today, vendors and industry groups have made huge gains in delivering interoperable optical technologies—and Juniper has been a leading voice in these efforts. Juniper is a longtime, active board member of the OIF and other industry groups. We've played a central role in defining multiple optical standards, including OIF400ZR, OpenZR+ Multi-Source Agreement (MSA), QSFP-DD MSA, and Common Management Interface Specifications (CMIS). Our solution also supports OpenConfig/YANG models for vendor-agnostic configuration and management of ZR/ZR+ optics.

Juniper doesn't just help define standards; we conduct rigorous interoperability testing to ensure that our IP-over-DWDM solutions work seamlessly in multivendor environments. That includes an extensive CORA testing and validation program with our ecosystem partners, as well as participation in public "plugfests," where we demonstrate real-world multivendor interoperability for 400GbE optics. Juniper is continuing this commitment as the industry moves towards 800GbE and beyond. Although 800GbE ZR/ZR+ standards are still being solidified, Juniper is once again leading standardization efforts. At the same time, we're making sure we're ready to deliver 800GbE coherent optics for our customers, as well as providing a portfolio of 800GbE-ready metro access, edge, and core routers to support them.

Why such a strong commitment to open standards? Openness fuels innovation. With multivendor interoperability, you can avoid vendor lock-in and choose best-of-breed solutions to meet different needs. That flexibility leads to more competitive pricing, and it enables a more resilient supply chain and the ability to tap into new optical innovations when you choose.

We're already seeing this process in action with IP over DWDM, as 400ZR and OpenZR+ dramatically accelerate adoption. Juniper is cultivating an ecosystem of standards-aligned partners across optical sub-components, silicon, and modules to deliver these benefits (Figure 4). We also protect customer investments by supporting Juniper co-developed and Juniper-branded coherent optics with Juniper routers and switches as a unified solution, with unified Juniper technical support.

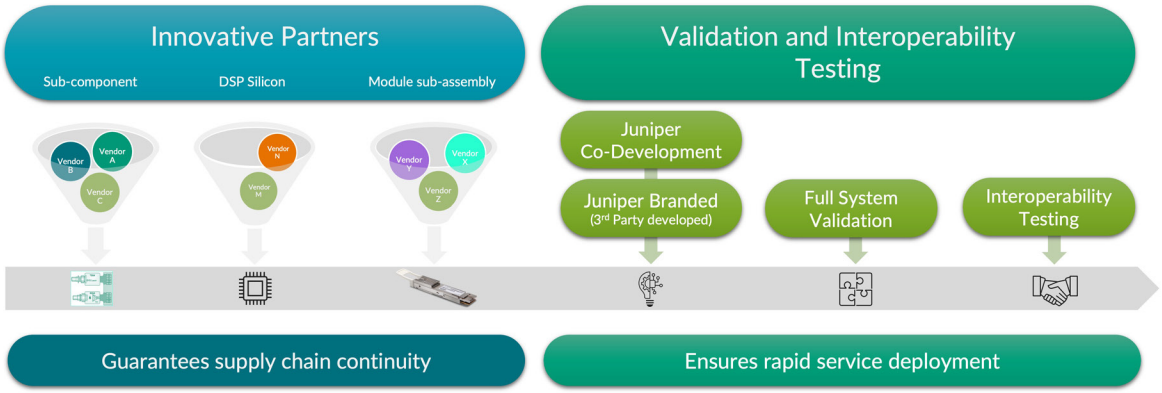

Figure 4. Juniper fuels multivendor innovation from an ecosystem of partners

Increasing Architectural Extensibility

Among CORA's many pioneering capabilities, the one likely to have the most far-reaching impact is the increased flexibility it brings to optical networking. Juniper JCO400 ZR+ optics support all OpenZR+ MSA-defined channelization modes, including 1x400, and 4x/3x/2x and 1x100GbE. These flexible modes enable you to mix and match 400G ZR/ZR+ optics—even within the same platform—to bridge longer distances and support diverse greenfield and brownfield use cases (Figure 5).

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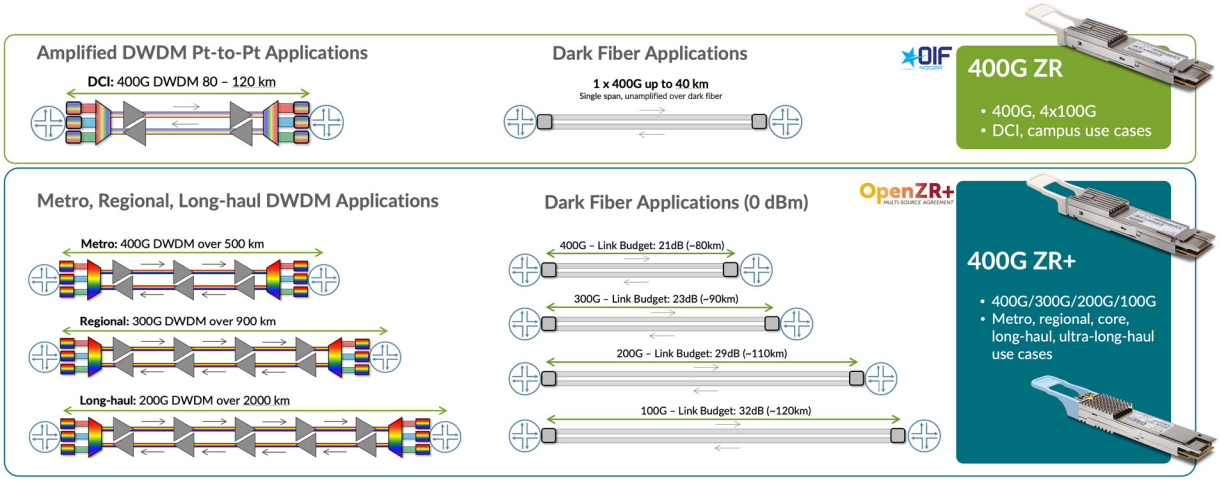

Figure 5. Juniper JCO Series supports diverse IP-over-DWDM use cases

For example, many CSPs currently use 400GbE optics in metro networks for dark fiber use cases less than 40km. With Juniper 400GbE ZR+ solutions, you can take advantage of more powerful optics and channelization options to serve longer distances depending on the desired bitrates. JCO400 optics can support metro 400GbE DWDM links over 500km, regional 300GbE DWDM links over 900km and long-haul 200GbE DWDM links over 2,000km depending on the line system and amplification employed. In addition to operating in 400GbE standard optical channel spacing, our 400G ZR+ solution also supports legacy 50GHz channel spacing, so it can interoperate with incumbent line systems in brownfield deployments. Both 400G ZR and ZR+ transceivers also have built-in FlexGrid capability, which allows you to configure a variable spectral width for the signal to occupy, in increments of 6.25GHz.

With new OpenZR+ 0-dBm optics with enhanced output performance, you can deploy coherent pluggables even in "lossy" networks or those using lower-quality fiber, including reconfigurable optical add/drop multiplexer (ROADM) infrastructures spanning hundreds of kilometers. New 0-dBm coherent optics can also link two network devices over 120 km without amplification—an unreachable distance with previous-generation optical technologies.

It all adds up to a vast improvement in network design and deployment flexibility compared to traditional transport. It's now possible to architect almost any metro, regional, core, or long-haul network using whichever combination of optics you need. And that flexibility extends into the future, long after initial deployment, with the ability to reconfigure channelization modes via the ASICs and firmware in Juniper optics. You could deploy a CORA solution today to connect a 400GbE short-reach optical link to interconnect metro data centers. But if requirements change tomorrow, you can reprogram those optics to provide a 2,000-km 200GbE long-haul link for a different use case.

Collapsing Network Layers for Flexibility and Scale

Legacy protection approaches to optical networking come with significant inefficiencies. IP and optical layers are frequently engineered independently, with separate teams to maintain and operate them—one group handling the optical line system, the other focusing on Layer 3 and above—using separate control planes and siloed management. Of even greater concern, traditional optical transport systems frequently use a 1:1 physical protection scheme which, by definition, reserves an entire lambda for every active circuit—meaning up to 50% of the network's wavelength-division multiplexing (WDM) capacity may be idle. With operators looking at 2x, 3x, 4x, or even greater traffic increases in the coming years, keeping that much capacity in reserve gets very expensive.

With CORA, those tradeoffs largely disappear. CORA allows you to converge siloed network layers into a unified mesh architecture with a single, packet-based control plane. You can bridge IP and optical operations, and empower teams to engineer the network cooperatively, with multilayer visibility. Your IP routers have visibility into the health of optical links thanks to integrated DWDM transceivers and can detect and react to L1 impairments. Most important, you can handle protection at the services layer instead of L1 and protect critical traffic with a fraction of the bandwidth.

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Transform Network Efficiency and Longevity with Sustainable Systems

Legacy routing and switching platforms simply couldn't provide the power necessary to support reliable 400GbE coherent optics—much less different optical interfaces in the same line card—without driving up power, rack space, and operating costs to unsustainable levels. Now, JCO coherent optics, along with advanced Juniper ASICs and networking systems, can deliver those benefits and more in smaller, greener, and power-efficient platforms.

CORA solutions enable:

- **Sustainable optics:** JCO400-ZR+ transceivers deliver 7% to 12% better power efficiency than competing coherent optics under typical and max load.
- **Sustainable systems:** Juniper MX, PTX and ACX systems deliver leading capacity and performance, with the industry's smallest carbon footprint. The Juniper ACX7000 series, for example, uses adaptive power innovations to reduce energy consumption up to 77%, while new MX and PTX platforms deliver huge gains in power efficiency (71% and 59%, respectively) over previous generations.
- **Sustainable economics:** By eliminating the need for external transponders, CORA reduces power consumption up to 54% compared to traditional deployments. Using less equipment also translates to improved overall system reliability, increased operational efficiency, and reduced carbon footprint.

Transform Network Operations with Intelligent Automation

Unleashing the potential of IP over DWDM requires more than new technology; you have to rethink operations too. That's why CORA solutions support best-in-class, vendor-agnostic, multilayer network management with Paragon Automation.

Paragon Automation actively and passively monitors multilayer network and service performance, collecting network telemetry data from Juniper and other standards-compliant devices across both IP and coherent pluggable optics. It enables active data plane monitoring and proactive testing to help you understand and optimize customers' real-world experiences. And it delivers advanced traffic engineering intelligence, with the ability to optimize network paths and traffic management in converged networks—using either RSVP-Traffic Engineering (RSVP-TE) or Segment Routing-Traffic Engineering (SR-TE). Together, these capabilities simplify life-cycle management, lower costs, and help you consistently assure excellent customer experiences.

Enabling MultiLayer Visibility

Juniper IP-over-DWDM elements expose standards-compliant management APIs to enable multilayer visibility and single-pane-of-glass support. Juniper optics, for example, feature programmable open interfaces (including RESTCONF and NETCONF/YANG) to expose optical telemetry. CORA elements interwork with Paragon Automation and any multidomain controllers that use these open interfaces (Figure 6). As a result, you can:

- Fully converge packet and optical networks, including configuring embedded optical transceivers alongside IP routing
- Simplify and accelerate network operations with the ability to collaborate and consolidate IP-optical management tasks, using the controllers and traffic engineering tools you prefer
- Break free from vendor lock-in by reducing reliance on proprietary optical management, so you can use best-of-breed hardware and software components across your network

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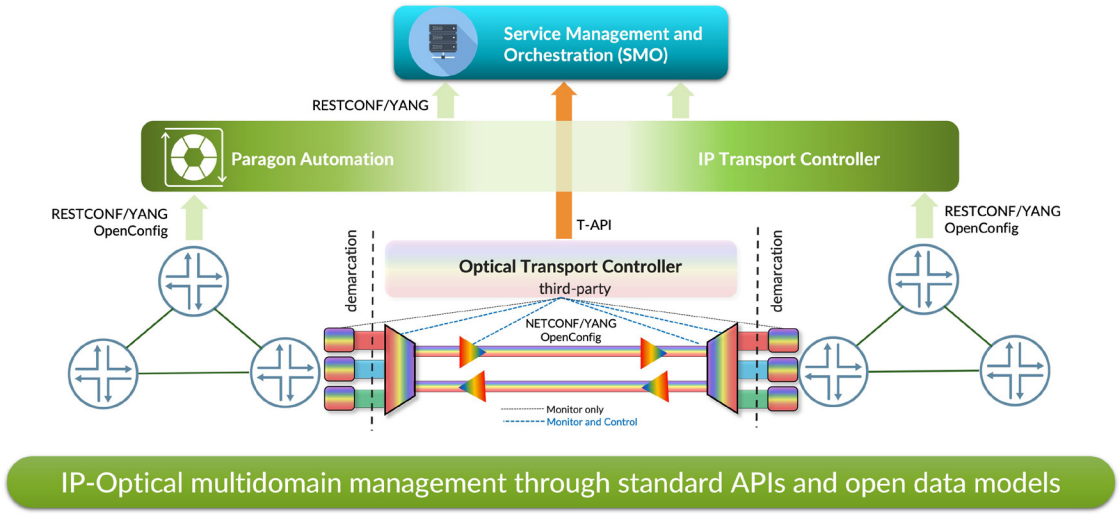

Figure 6. Paragon Automation enables multilayer visibility and support

While Paragon Automation is primarily an IP controller, CORA enables multilayer visibility through transceiver management and control functions, as well as Paragon Automation applications, to make converged network management possible. At the same time, CORA uses unique IP software control stacks, allowing engineers in both IP and optical groups to access, modify, and test their networks as they always have, while collaborating easily when needed.

Simplifying Life-cycle Operations

The use case-driven automation applications in Paragon Automation can help you perform life-cycle management tasks more quickly, and consistently deliver better business outcomes. Paragon Automation use cases include:

- **Assured device onboarding:** Reduce onboarding errors and service quality issues by testing the data plane and validating service quality before activating new CORA devices or configurations
- **Device life-cycle management:** Test optical elements across the end-to-end network with simulated traffic and identify issues before they affect customers
- **Autonomous capacity optimization:** Use automated path computation to increase average link capacity utilization by 20%
- **Automated optical link rerouting**: Leverage optical transceiver telemetry for preemptive re-routing in response to degrading conditions in the underlying optical network, such as bit error rates (BER) caused by anticipated power threshold crossings

A Powerful Combination: Juniper Systems and Juniper Coherent Optics

At Juniper, open standards and interoperability are part of our DNA. When vendors compete on an open playing field, customers win: They get more innovation, more quickly, at a better price. It's why Juniper leads multiple standardization efforts and validates our solutions to operate in multivendor environments. At the same time, we've built the fruits of that competitive innovation into the new generation of Juniper Coherent Optics. Combine them with our leading 400GbE-capable routing systems (and soon, 800GbE and beyond), and you have a solution that delivers incredible value and performance.

When you partner with Juniper for both optics and systems, you get:

- **Validated solutions:** Juniper Coherent Optics aren't just thoroughly tested and pre-integrated with Juniper platforms; in many cases, they're validated by the same engineering teams that defined the standards in the first place. We validate every aspect of end-to-end system operation—thermal, electrical, and more—to deliver reliably excellent performance.

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- **One-stop support:** Across the life cycle of your IP-over-DWDM deployment—procurement, maintenance, ongoing technical support—you can work with a single vendor, with a single point of contact for the entire solution. With no need to juggle different workstreams and support organizations from different vendors, you can resolve issues more quickly and cost effectively.
- **Competitive pricing:** In many cases, organizations choose third-party optics based almost entirely on price—even when that means taking on higher risk of integration and supply chain issues. Because Juniper co-develops our optics with an ecosystem of partners, we combine the best of single- and multivendor worlds. We keep prices competitive, while maintaining the supply chain, support, and quality advantages of a single-vendor solution.

Conclusion

The advantages of IP over DWDM for simplifying networks, reducing costs, and unleashing new converged use cases are no longer theoretical. With Juniper's CORA, they're a concrete reality.

When you choose Juniper for IP over DWDM, we deliver:

- **Unprecedented extensibility:** CORA solutions give you new freedom and flexibility to bring high-capacity coherent optical transport wherever you need it—across metro, regional, edge, and core use cases. You can continually keep pace with customer demand for more bandwidth and help bring new services to market faster. And with Juniper standards-based optics, you can continually reprogram coherent pluggables to serve different needs, without forklift overhauls.
- **Industry-leading power-efficiency and economics:** Juniper optics and systems deliver consistently better performance, with less power than competing technologies, at a lower cost. Juniper leads the industry in sustainable solutions that reduce carbon footprint and OpEx. By eliminating the need for external transponder systems, CORA solutions dramatically reduce overall TCO.
- **Commitment to open standards and interoperability:** Juniper has led industry efforts towards openness for years. We can help you break free from vendor lock-in, so you can use best-of-breed innovations across your network and reduce supply chain risk. With our rigorous interoperability testing and unified support, you can deploy CORA solutions in multivendor environments with confidence.
- **Simplified operations:** Juniper's CORA solutions streamline and simplify the network, reducing operational complexity and costs. Drawing on Paragon Automation multilayer visibility and testing capabilities, you can accelerate life-cycle management tasks, optimize capacity, and assure consistently excellent customer experiences.

For more details about CORA and the revolutionary Juniper solutions that enable it, visit: www.juniper.net/us/en/solutions/converged-optical-routing-architecture-cora.html

About Juniper Networks

At Juniper Networks, we are dedicated to dramatically simplifying network operations and driving superior experiences for end users. Our solutions deliver industry-leading insight, automation, security and AI to drive real business results. We believe that powering connections will bring us closer together while empowering us all to solve the world's greatest challenges of well-being, sustainability and equality.

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