Secure Real-Time Communications

Unifying Coherent Routing with Optical Transport in an Intelligent Middle Mile

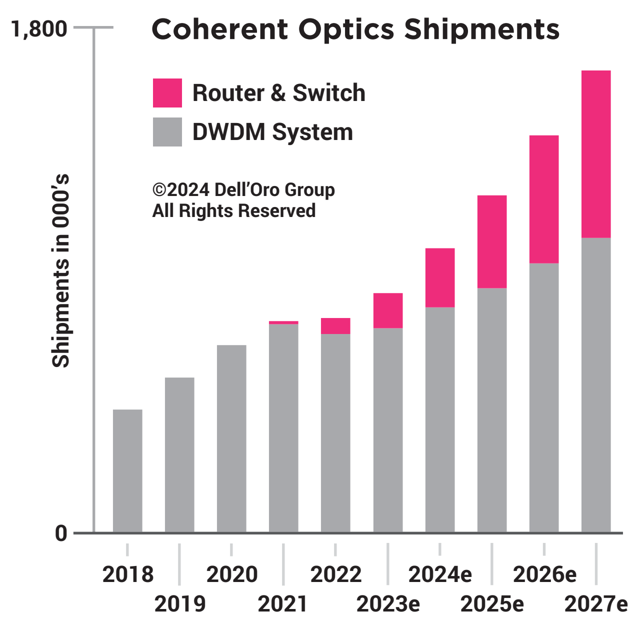
Network Evolution, not Revolution

> In today's rapidly evolving digital landscape, the demand for efficient, high-capacity, service-aware networking solutions is more pressing than ever. IP Routing and Optical Transport are key pillars in addressing these needs.

An essential building block of these networks is coherent transceivers, which provide high-capacity wavelengths that carry massive flows of digital traffic at the lowest cost per bit. For the first time, these transceivers are now available in small, pluggable form factors that can be integrated directly into routers. This development significantly impacts optical transport, which has traditionally been the exclusive domain of coherent transceivers.

But what is interesting is that forecasts indicate that the use of coherent transceivers will grow not only in routers and switches but also in Dense Wavelength Division Multiplexing (DWDM) optical transport systems. According to Jimmy Yu of Dell'Oro, while the $15B DWDM Systems market is under change, the impact is more evolution than revolution[1].

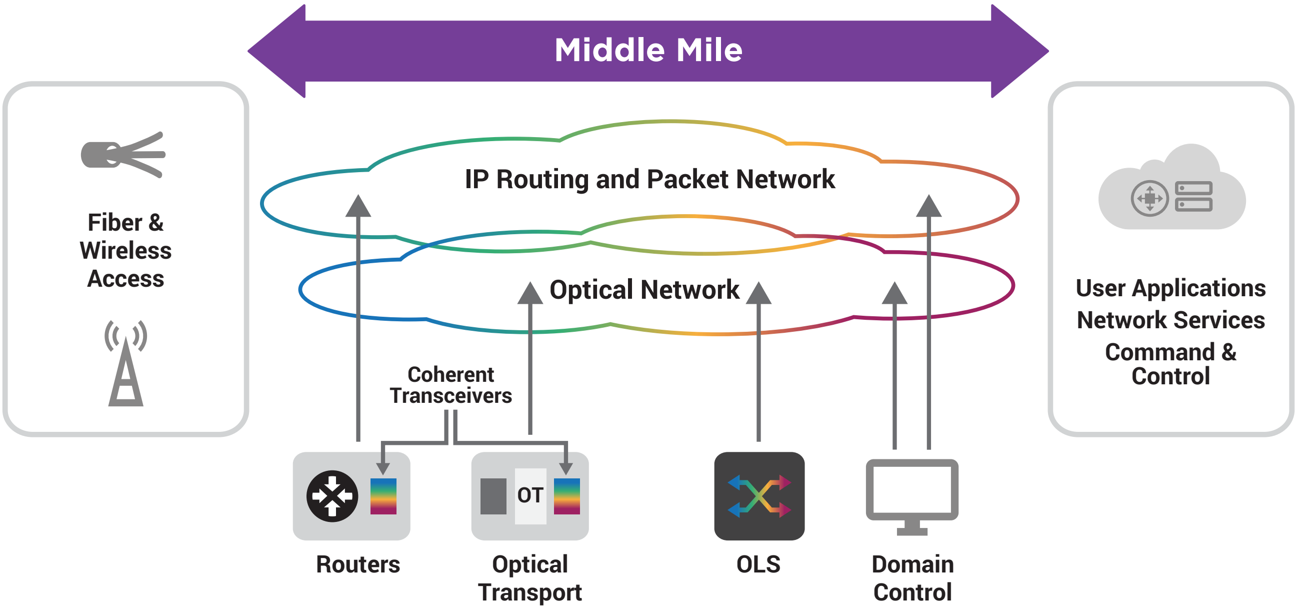
In this paper, we discuss how advances in optical transceiver technology and small form factor pluggables have enabled Coherent Routing (also referred to as IPoDWDM), and how this can work symbiotically with Optical Transport.



[1] Lightwave Webinar, May 15, 2024, Coherent Routing and Optical Transport – Getting Under the Covers.

Middle Mile Building Blocks

The context for the discussion is "middle mile" networks. Spanning tens to several thousands of kilometers, these networks provide the essential connective tissue bridging last-mile access networks with core services and applications. The main elements of the Middle Mile are:



- **Routers:** These aggregate traffic from multiple access networks with various interface rates and route the traffic to meet each service's performance SLA. Client interface rates range from 64Kbps or lower for legacy services up to 25Gbps for 5G cell sites. Line-side interface rates are primarily 100Gbps, with many networks moving to 400Gbps.
- **Optical Transport:** Transponders and muxponders provide high-capacity low latency traffic transport at the lowest cost per bit, with line interfaces today up to 1.2Tbps.
- **Optical Line Systems (OLS):** ROADMs and amplifiers route wavelengths across the network in DWDM pipes. The most important requirement for an OLS is the ability to route any wavelength with any bandwidth from any router, switch, or optical transport terminal.
- **Domain Control:** Controls both the routing and optical elements of the middle mile. It optimizes network design and path computation to ensure the right resources are used to minimize TCO while meeting all service delivery requirements. It also provides the agility to evolve the network as services and service needs change.

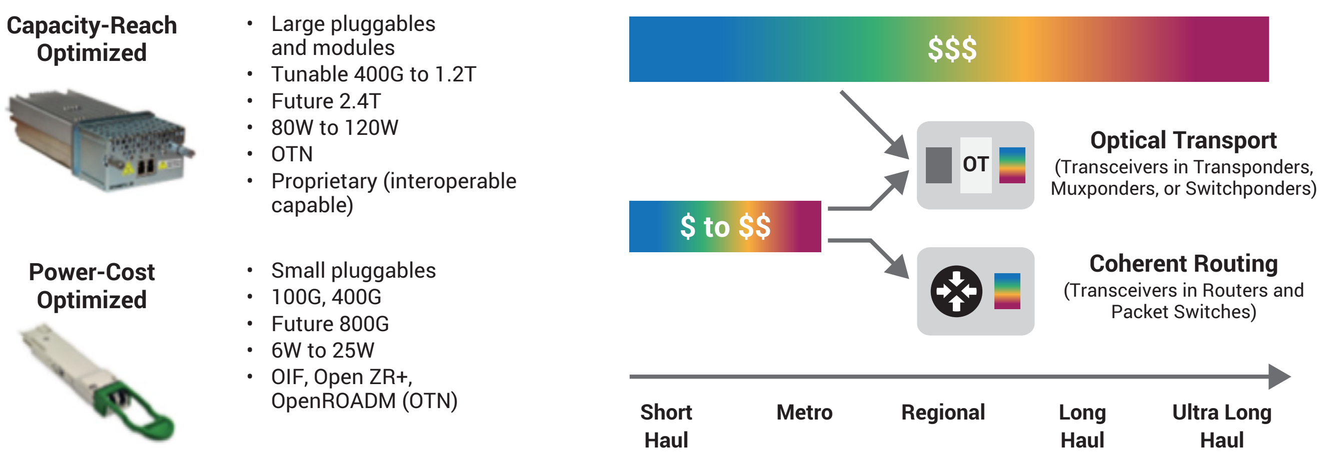
Key sub-elements, which are the focus of our discussion, are the coherent transceivers that generate and receive traffic-carrying wavelengths. Previously used exclusively by optical transport, new small form factor transceivers can now be plugged directly into routers. This gives network architects the flexibility to place these transceivers where they are most needed.

Two Types of Coherent Transceiver Optimization

There are two main categories of coherent transceivers:

1. **Capacity-Reach Optimized Transceivers:** These transceivers push the performance envelope of wavelength capacity and reach, only bounded by practical constraints on size, power, and cost. Currently, they support up to 1.2T wavelengths for short-haul applications and promise even greater capacities in the future. They cover regional distances at 800G for 1200km and have virtually unlimited reach at 400G. While these transceivers rely on proprietary technology and lack standard form factors, they can be interoperable at a system level, as demonstrated by Ribbon at OFC 2024.
2. **Power-Cost Optimized Transceivers:** These transceivers focus on power efficiency and cost-effectiveness, catering to extended metro applications. They adhere to standard small pluggable form factors like QSFP-DD and QSFP28 and are based on industry standards from organizations such as OIF, OpenZR+, and OpenROADM.

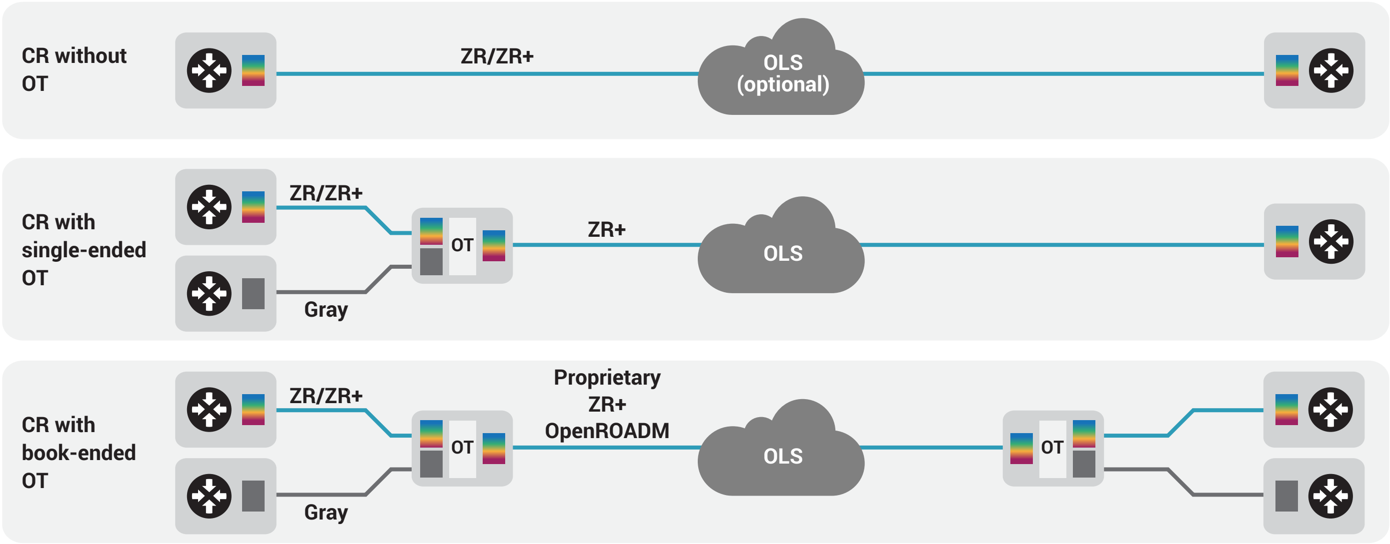
It is important to note that routers and switches will use only these compact, power-optimized pluggables, while optical transport systems will leverage both types of transceivers.



Network Architectures

Coherent Routing (CR) and Optical Transport (OT) work together within three basic architectures.

1. **Coherent Routing without Optical Transport:** In this approach, routers and switches communicate directly with each other using coherent transceivers. For simple point-to-point applications up to about 100km, this can be achieved using economical and ultra-low power 100ZR or 400ZR pluggables without relying on an Optical Line System (OLS). For longer distances and more complex networks, this pure CR approach typically uses higher powered 100GZR+ and 400GZR+ pluggables and often relies on an OLS.
2. **Coherent Routing with Single-Ended Optical Transport:** This approach makes interesting use of the ZR+ standard. Routers communicate with optical transport using ZR/ZR+ and gray wavelengths. The OT device then aggregates or regenerates the wavelengths and communicates directly via ZR+ with an end router. We explore some exciting applications for this in the use cases below.
3. **Coherent Routing with Book-Ended Optical Transport:** This is the traditional approach with a complete separation of concerns between the routing and transport layers. Here, the optical transport layer is not constrained in what transceivers it uses and can employ the highest-powered proprietary modules for maximum capacity and reach.

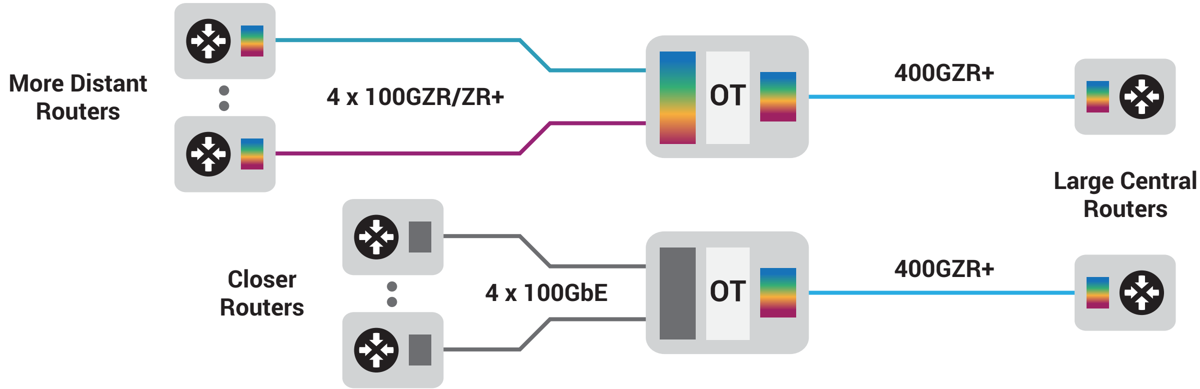


CR and OT Working Together Use Cases

CR with Single-Ended OT for Traffic Aggregation

In many cases, multiple smaller routers need to communicate with a single larger router using 100G interfaces. However, routing multiple individual wavelengths and using multiple ports on the larger router can be costly. Single-ended optical transport aggregates these wavelengths from coherent and gray optics, consolidating the traffic onto a single 400GZR+ wavelength, which terminates on the larger router.

This approach takes advantage of a ZR+ feature that must be supported by the larger router to segregate the traffic into four 100GbE services. This method is very useful for aggregating traffic from smaller routers, saving on the number of wavelengths in the network, as well as reducing the number of router ports needed.

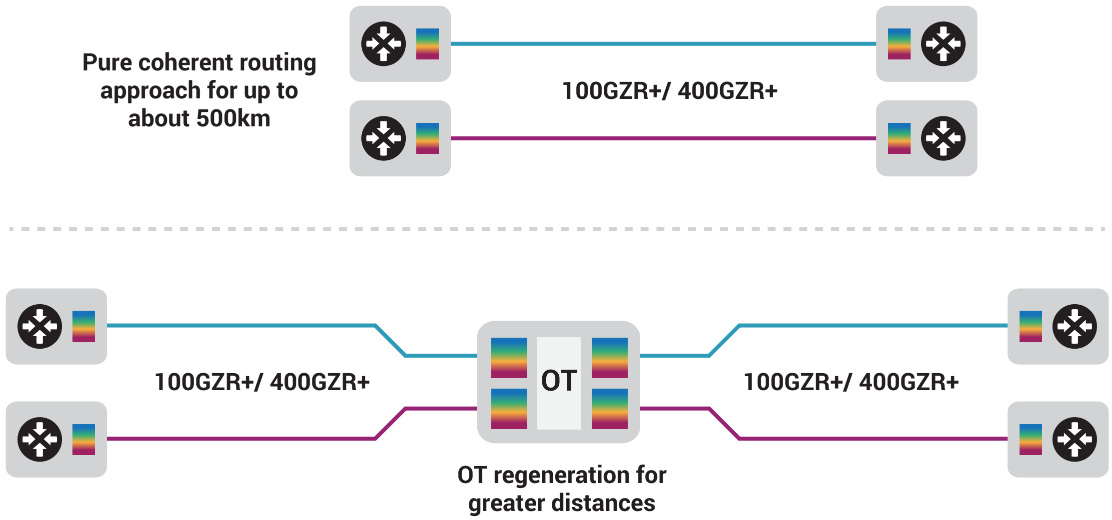


CR with Single-Ended OT for Regeneration

A great advantage of ZR+ is its higher power and longer reach, extending up to about 500km for extended metro applications. This makes ZR+ particularly beneficial for a pure CR approach, as shown in the upper configuration in the diagram.

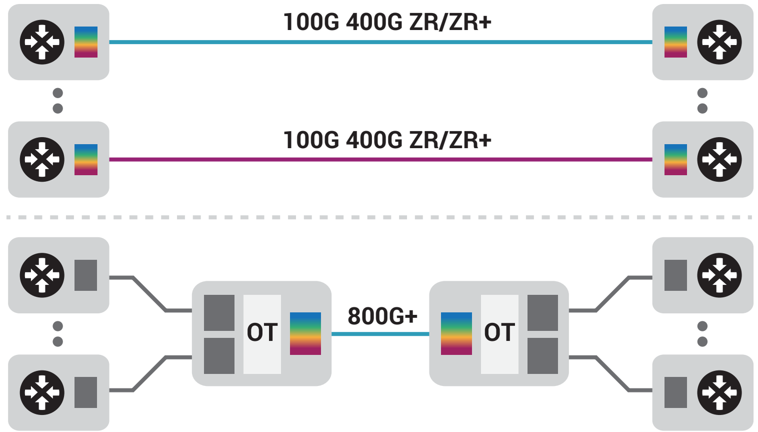
But what happens when an even longer reach is required? Inserting another router is expensive if routing functionality is not needed and adds delay. Instead, it is more effective to terminate and regenerate the signal using OT, as shown in the lower configuration.

It should be noted that in both this and the previous use case, OT utilizes the same small form factor, power-and-cost optimized ZR+ coherent transceivers used by the routers.



CR with Book-Ended OT for High-Capacity Short Haul

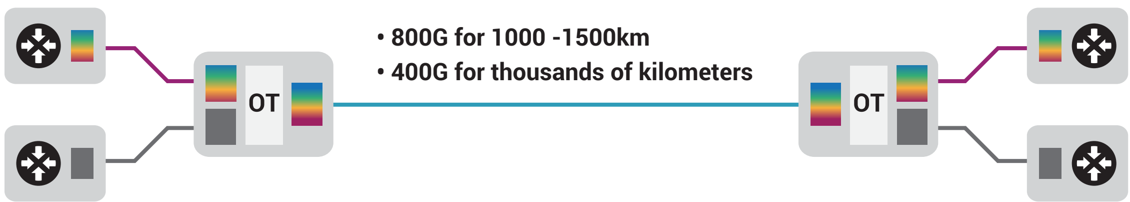
This use case, along with the following one, relies on a full OT network with high-powered, capacity-and-reach optimized transceivers. The first use case, for high traffic density short-haul applications, takes advantage of the transceivers' ability to provide wavelengths of up to 1.2T today, with even higher capacities expected in the future. The OT layer consolidates multiple connections onto significantly fewer wavelengths, resulting in cost savings.



CR with Book-ended OT for Long Haul and ULH

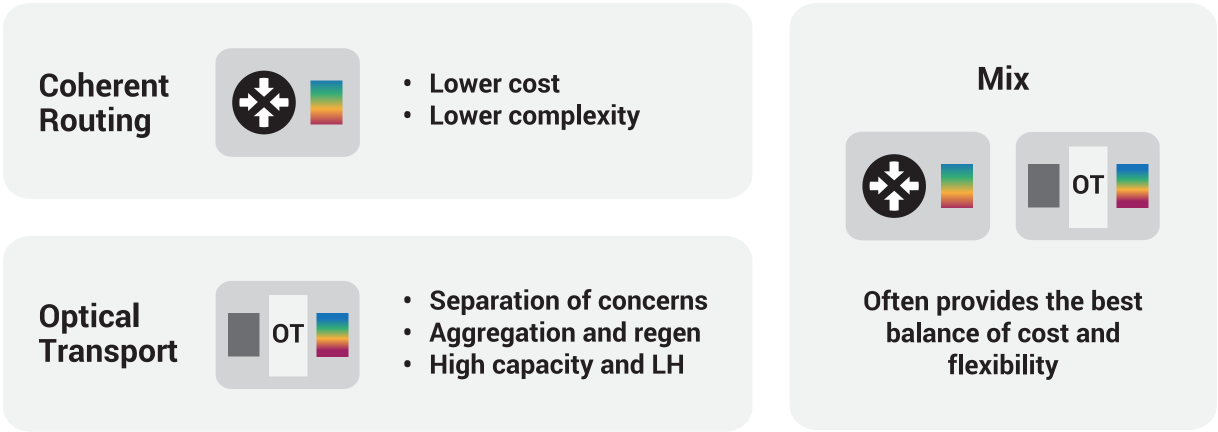
This situation is analogous for regional and long-haul applications, which are beyond the reach of lower-powered ZR+ technology. Here, OT can consolidate multiple wavelengths at 800G for regional applications and at 400G with practically unlimited reach.

For example, Ribbon demonstrated an 800G connection between Amsterdam and Geneva, spanning 1650km, with SURF, the Dutch research and education network. We transported two 400GbE services over a single wavelength 800G link, and exceptionally, achieved this over old G.655 fiber.

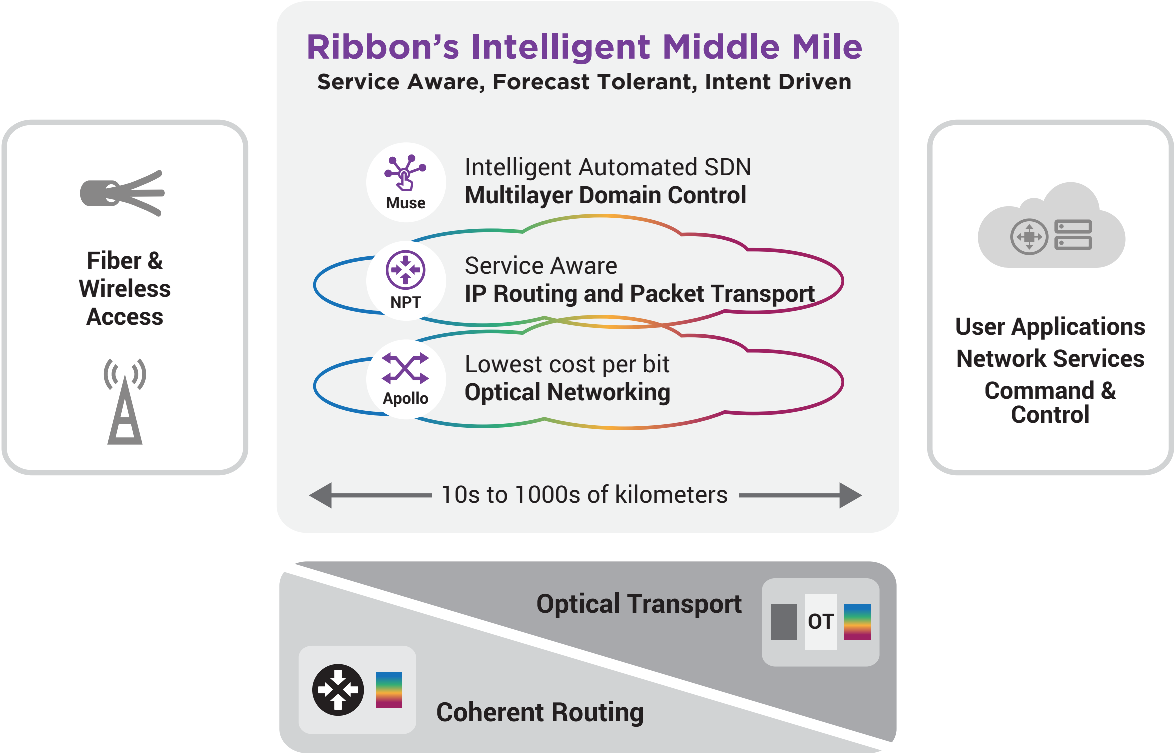


Summing Up – A CR/OT Mix is Often Best

As we mentioned at the start, small coherent receivers should be regarded as driving network evolution rather than revolution. Pure coherent routing offers lower costs and less complexity. Alternatively, optical transport provides a separation of concerns between the service and transport layers and can fill the gap for aggregation, regeneration, high capacity, and long haul. Practically, network architects usually require a full toolkit of Coherent Routing and Optical Transport approaches to achieve the best results when designing their networks.



Ribbon is leading the charge in unifying coherent routing and optical transport. This is a fundamental principle of our Intelligent Mile solutions, which are service-aware to ensure that services meet their performance needs, agile to evolve as services and service requirements grow and change, and optimized to minimize total cost of ownership.



Full toolkit for your Middle Mile needs

Contact Us Contact us to learn more about how Ribbon Unifies Coherent Routing with Optical Transport to implement Intelligent Middle Mile Solutions

About Ribbon

Ribbon Communications (Nasdaq: RBBN) delivers communications software, IP and optical networking solutions to service providers, enterprises and critical infrastructure sectors globally. We engage deeply with our customers, helping them modernize their networks for improved competitive positioning and business outcomes in today's smart, always-on and data-hungry world. Our innovative, end-to-end solutions portfolio delivers unparalleled scale, performance, and agility, including core to edge software-centric solutions, cloud-native offers, leading-edge security and analytics tools, along with IP and optical networking solutions for 5G. We maintain a keen focus on our commitments to Environmental, Social and Governance (ESG) matters, offering an annual Sustainability Report to our stakeholders. To learn more about Ribbon visit rbbn.com.