



Coherent Routing

Using the latest generation of coherent optics to build application-optimized IP-optical networks

NOKIA

Nokia coherent routing

Relentless demand for more capacity at a lower cost per bit is forcing network operators to constantly upgrade and optimize their IP-optical network designs. Coherent routing leverages a new breed of digital coherent optics (DCOs) that can be equipped in small pluggable form factors such as QSFP56-DD, to connect routers directly over DWDM wavelengths. Combined with compact optical line systems, ROADM capabilities and cross-domain IP-optical management coordination, it enables operators to optimize deployments for a wide range of applications and topologies.

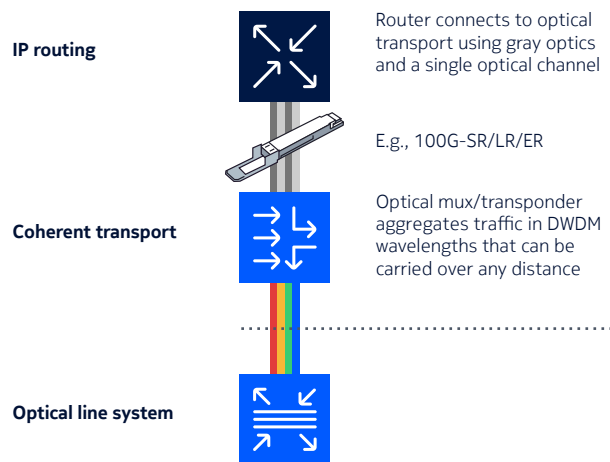
Nokia Coherent Routing provides all the building blocks operators need to build scalable and cost-optimized network infrastructures for 400GE and beyond, including:

- IP routers that are design-optimized to support a full suite of pluggable coherent optics in different form factors to optimize cost and connectivity requirements

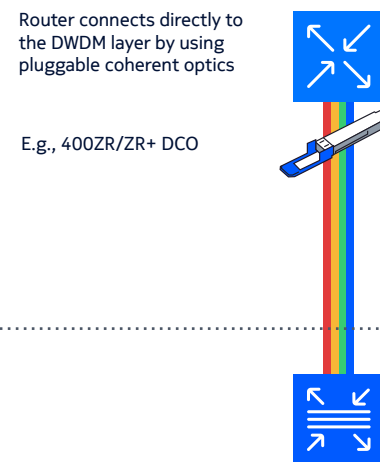
- Optical line systems and reconfigurable add-drop multiplexors (ROADMs) that efficiently connect routers and multiplex wavelengths on fiber links
- Cross-domain IP-optical management and control software for seamless, end-to-end operation through a single pane of glass.

Upgrading IP networks with pluggable coherent optics

Conventional IP network (gray optics)



Coherent routing (DWDM optics)



Coherent optics for any application

Most coherent routing applications require a careful balance of performance and profile due to dependencies on fiber availability, quality, reach, topology and service requirements. Flexibility and choice in transceiver types are essential for optimizing application requirements.

Nokia brings a full suite of vertically integrated capabilities to the coherent optics ecosystem, along with more than a decade of experience in coherent DSP innovation, silicon photonics and high-speed electronics design, and packaging expertise for high-speed DCOs.

Technology	400ZR	400ZR+	400G Multihaul	PSE Transponder
Bit rate	400Gb/s only	100 – 400Gb/s	100 – 400Gb/s	100 Gb/s – 1.2 Tb/s
Reach	40 – 120 km	400 – 750 km	500 – 750 km	Thousands of km
Modulation	16QAM	QPSK, 8/16QAM	QPSK, 8/16QAM	Shaped PCS
FEC	CFEC	CFEC+, oFEC	CFEC+, oFEC, NOK FEC	Nokia FEC
Tx power	-7 to -10 dBm	-7 to 0 dBm	~0 dBm	>0 dBm
Form factor	QSFP-DD	QSFP-DD	CFP2	Line card module
Interfaces	400GE	100GE, 400GE	100/400GE OTU4/OTUCn	100/400/800GE OTU4/OTUCn
ROADM bypass	No	Multiple	Multiple	Many
Application	Access/Metro DCI	Metro/regional	Metro/regional	Metro/regional/LH

Nokia offers a full range of 400G coherent optics that can be equipped in IP routing, WDM and OTN platforms:

- **400ZR** is a standardized interoperable 400G coherent interface specification offered in the router-pluggable QSFP-DD format in the Nokia 7250 IXR, 7750 SR and 7950 XRS router families. Developed by the Optical Internetworking Forum (OIF) and released in March 2020, 400ZR is profile-optimized for high-density access and point-to-point DCI applications. It can deliver 400 Gb/s up to 40 km over a single dark fiber span without external amplification. With external amplification, it can support up to 64-channel WDM in the C-band over distances up to 120 km.
- **400ZR+** expands the applications for router-pluggable coherent optics in QSFP-DD format in the Nokia 7250 IXR, 7750 SR and 7950 XRS router families. It provides higher optical performance over 400ZR using high-gain forward error correction (FEC), flexible 100G–400G line rates, and supports even longer reaches by leveraging multiple modulation types (16QAM, 8QAM and QPSK). In 400G/16QAM mode and depending on optical link characteristics, 400ZR+ can reach up to 600 km with external amplification, and even further by operating at sub-rates below 400G using QPSK or 8QAM modulation. 400ZR+ can also traverse a limited number of reconfigurable optical add-drop multiplexer (ROADM) nodes to enable efficient router bypass when needed.
- **400G Multihaul** pluggable DCOs integrate the fifth-generation Nokia PSE-V DSP in a CFP2 form factor. 400G Multihaul DCOs also support 100–400 Gb/s line rates using QPSK, 8QAM and 16QAM modulation. A higher launch power enables longer reaches up to 750 km, with the ability to pass multiple ROADMs hops. 400G Multihaul DCOs are ideal for metro/regional edge and core networks, either as a pluggable router interface to enable IP-optical integration in Nokia 7750 SR and 7950 XRS router families, or as a pluggable WDM transponder in the Nokia 1830 PSS and PSI-M families for multi-service aggregation and transport.



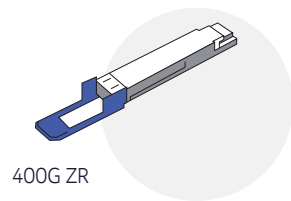
- Nokia's super-coherent Photonic Service Engines (PSE) complement pluggable coherent optics with transponder-based coherent optics in the Nokia 1830 PSS and PSI-M families, or as WDM line cards in the Nokia 1830 PSSx family of OTN switches. They use advanced features such as second-generation probabilistic constellation shaping

(PCS) and low-overhead, high-gain FEC to provide the ultimate in capacity-reach performance over the most challenging fiber spans. They are also capable of delivering 400 - 1.2 Tb/s wavelengths over thousands of kilometers across long-haul and subsea networks. Optical transponders are typically deployed in combination with

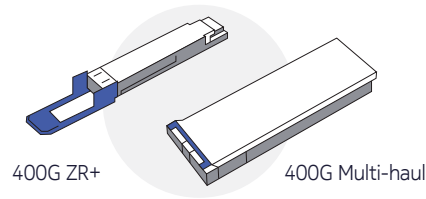
ROADMs to provide efficient optical switching, reconfiguration and wavelength bypass. Together, the range of digital coherent optics can enable 400G everywhere for applications such as point-to-point DCI, high-bandwidth access links, metro aggregation rings, metro/regional core networks and long-haul backbone networks

that span national, continental and transoceanic distances. Router-pluggable and transponder-based deployment options are available and can enable operators to optimally address different application connectivity needs.

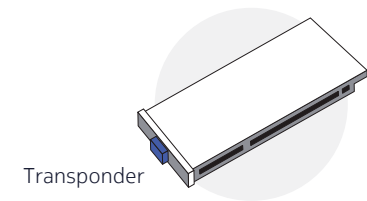
Metro DCI and access



Metro/regional aggregation



Long haul/subsea core



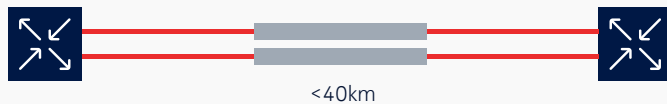
Optical line systems for coherent routing applications

Pluggable coherent optics enable routers to connect a single wavelength over short, point-to-point fiber links, such as metro access links. The Nokia

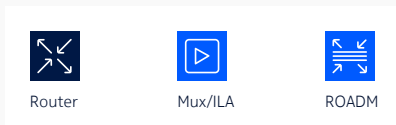
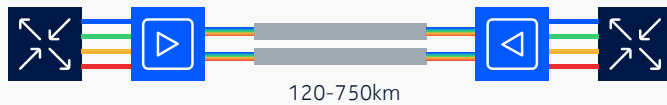
1830 family of optical line systems adds essential capabilities to enable 400G connectivity across a wide range of applications, as shown below

Application scenarios for optical line systems

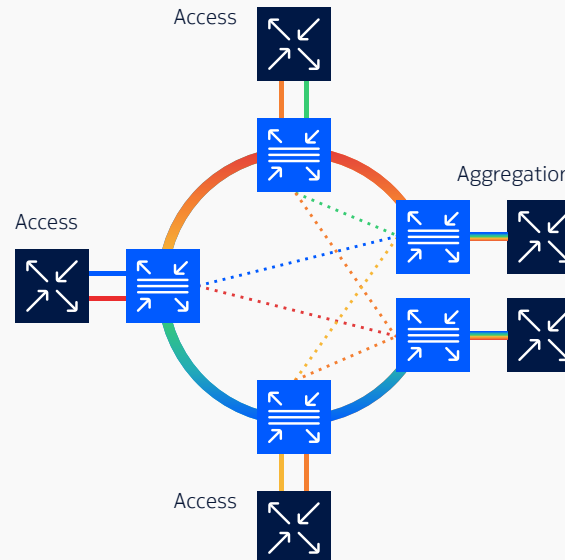
Metro access (dark fibres)



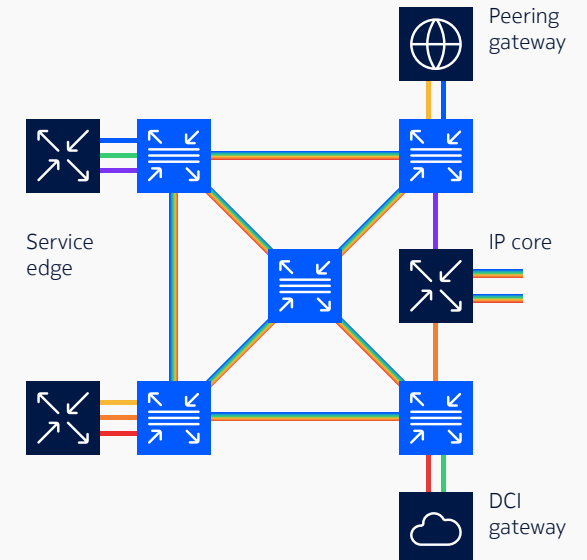
DCI (optical line systems)



Metro aggregation (ROADMs)



Metro/regional core (ROADMs)



The Nokia 1830 family of optical line systems supports these applications with a modular, function-optimized architecture that uses common platform hardware for ROADMs, amplifiers and add/drop modules across a range of chassis sizes and formats. The 1830 PSI-L provides a standalone line system solution for IP-optical integration applications that require only optical line system functions to connect 400G pluggable optics in routers. The 1830 PSS complements these capabilities by enabling the integration of both optical line system and coherent transponders for multi-service transport and IP-optical applications over long distances, or for multi-service aggregation at speeds below 400G.

Nokia 1830 optical line systems can significantly improve the capacity, reach and availability of point-to-point applications such as DCI and high-bandwidth access links by enabling:

- WDM multiplexing to combine multiple wavelengths on a single fiber
- Inline amplification (ILA) of wavelengths to significantly extend their reach
- Optical line protection of (redundant) fiber pairs to protect against fiber cuts

The QSFP-DD-LS pluggable line system is a simple and compact solution for 400ZR applications. It plugs into a 400G QSFP-DD router port and contains an 8-channel optical mux/demux with integrated Tx/Rx line amplifiers. While consuming only 3 Watts, it can interconnect up to eight 400ZR DCOs via a single fiber pair over distances of up to 120 Km.

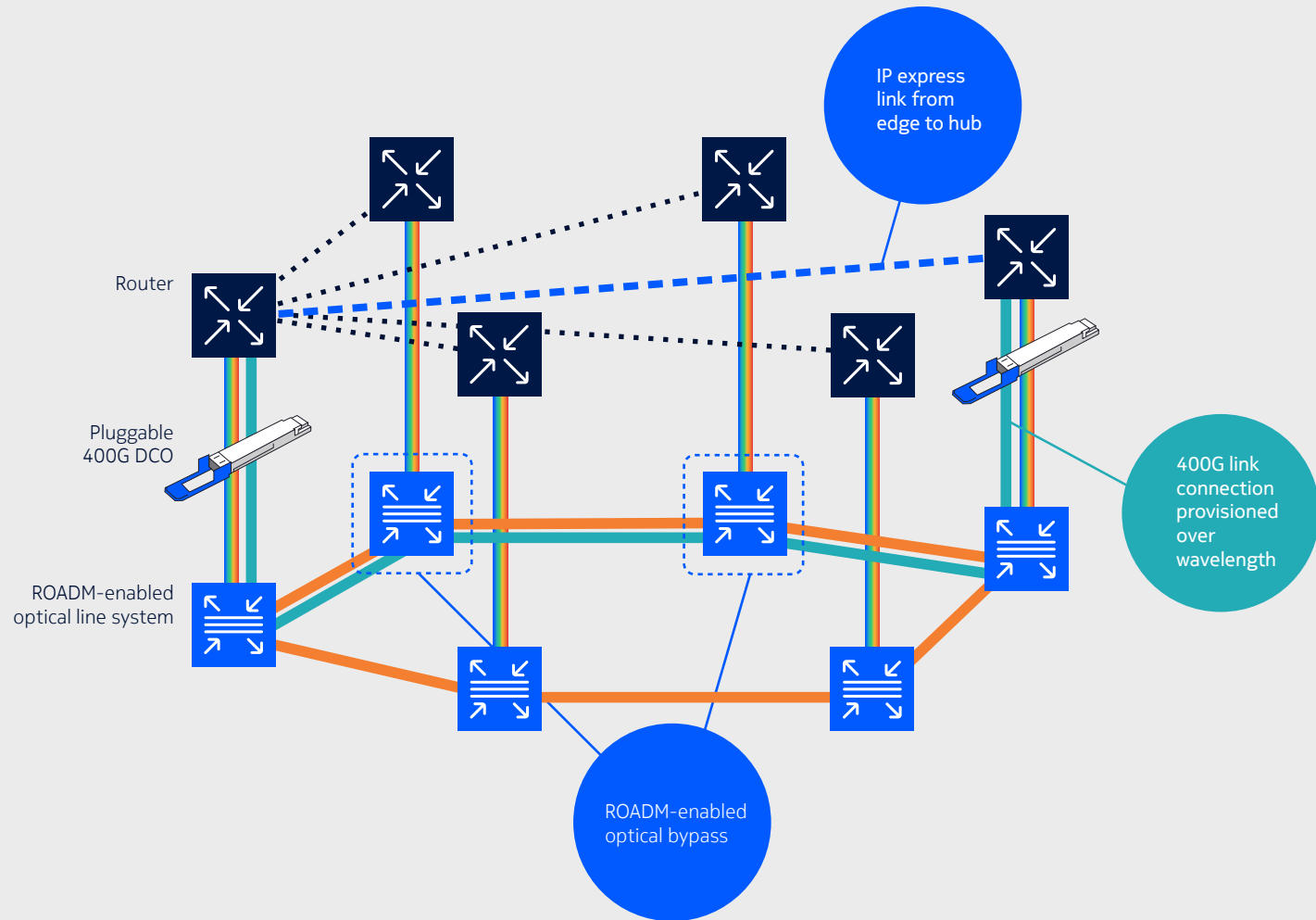
For 400ZR+ DCO network applications such as metro aggregation rings and metro, regional or long-haul core backbones, the Nokia 1830 provides a broad range of features to optimize connectivity across a wide range of deployment use cases.

Key amongst these is a ROADM-enabled flexible photonic service layer that provides dynamic wavelength routing and restoration capabilities for IP-optical networks. By logically decoupling the IP layer from the underlying physical transport network, routing engineers gain complete flexibility to optimize the IP link topology over any fiber topology. It allows them to efficiently accommodate network growth, changing demand patterns and planned or unplanned network outages. Optimizing IP-optical topologies by using ROADMs to create direct express links for end-to-end IP traffic minimizes unnecessary router transits, reduces optics use, and lowers the network cost, latency and energy consumption of end-to-end packet transport.



Enabling optimized IP topologies over ROADM-enabled optical layer

- ROADMs enable single-hop IP express links over wavelengths
- High bandwidth IP transit traffic can bypass intermediate routers
- Enables a simplified, efficient and flexible IP topology



To efficiently share multiple services and applications over a common DWDM transport network, Nokia ROADMs enable flexible wavelength switching with a full range of capabilities, including:

- Colorless operation, which enables any wavelength (or color) to be added or dropped on any ROADM port
- Directionless operation, which allows wavelengths to be switched from any direction to any ROADM port
- Contentionless operation, which eliminates wavelength blocking by allowing the same wavelength (or color) to be added or dropped in different directions
- Flexible grid operation, which allows flexible adjustment of WDM grid spacing to support a wide range of programmable DSP modulation capabilities, baud rates and wavelength spacing

Combined with Nokia's full range of router-pluggable and transponder-based coherent optics, the Nokia 1830 optical line systems deliver the following features and benefits:

- C and C+L band WDM transmission capabilities maximize network capacity.
- Flexible and customizable equalized inline amplifier (E-ILA), erbium-doped fiber amplifier (EDFA) and Raman-EDFA options maximize reach to even the longest fiber spans.
- Pluggable DCO-optimized WDM multiplexing options for 400ZR/400ZR+ support point-to-point and ROADM-switched access, metro and regional applications.

- Compact, single-card-per-degree ROADMs support 4, 9, 20 and 32 degrees to enable integrated wavelength switching across all applications.
- Support for Colorless-Flexgrid (C-F) and CDC-F provides optimal scale and topology flexibility.
- G-MPLS control plane improves the efficiency and reliability of multilayer, multi-region networks by enabling coordinated provisioning with ultra-fast protection and restoration capabilities.
- Support of alien wavelengths originating and terminating in pluggable coherent router optics.
- Use of industry-standard open APIs (NETCONF/YANG) enables open programmability and simplified management and SDN control.
- Nokia WaveSuite applications simplify optical network management, planning and assurance.

Routers optimized for coherent optics

To successfully integrate router-pluggable coherent optics, router hardware designs must be optimized to meet the additional heat dissipation requirements and support flexible deployment options for 400ZR, 400ZR+ and 400G Multihaul optics.

While 400ZR and 400ZR+ router-pluggable coherent optics can be equipped in the same QSFP-DD cages as 400GE short-reach gray optics, their power consumption and heat dissipation are much higher. The thermal design of 400G-capable line cards is a critical scaling factor because it determines a router's ability to efficiently cool interface ports with pluggable 400G coherent optics.

Nokia 7250 IXR, 7750 SR and 7950 XRS routers are designed and engineered with coherent IP-optical integration in mind. They address the challenges of integration with features such as:

- Line cards that support the full range of pluggable QSFP-DD and CFP2 DCO options
- Enhanced power and cooling capabilities that support high-powered coherent optics for 400G and 800G in future
- Integrated support of pluggable coherent DCOs in the Nokia Service Router Operating System

- Support for network management integration and automation through open, machine-programmable interfaces (e.g., OpenConfig)
- Cross-domain IP-optical management coordination with the Nokia Network Services Platform (NSP)

Nokia is a leader in high-speed routing technology with several industry firsts:

- Demonstrating the first 400 Gb/s IP routing interfaces in February 2015 based on FP3 silicon

- Shipping the first commercially available 400GE line cards in July 2018 based on FP4 silicon
- Shipping the first commercially available routers with high-density QSFP-DD 800GE ports in 2022 based on FP5 silicon
- Foresight drove innovative power and cooling designs of line cards at product inception to anticipate the introduction of high-powered router optics. This Nokia design advantage allows you to equip the full range of QSFP-DD and CFP2 pluggable 400GE DCO transceivers.

IP-optical management coordination

When DCOs are equipped in IP routers, the established network boundaries are crossed and a transparent IPoDWDM data plane emerges, allowing for closer integration of the IP routing and optical transport layers. IP-optical transport links in metro and regional networks may involve multiple fiber spans, optical line systems, ILAs and ROADMs. Optical channel selection, power balancing, grid spacing, filter settings, wavelength routes, physical diversity and restoration options must all be coordinated across IP and optical management systems.

Coordinating these tasks manually across isolated IP and optical management silos will prove to be cumbersome, error prone and time

consuming. Networks are growing in scale and complexity, and traffic demands are becoming exceedingly dynamic and unpredictable. Operators need flexible and powerful tools that can work efficiently across layers, navigating and coordinating operational activities between the IP and optical worlds. Cross-domain IP-optical management coordination is becoming increasingly important as networks scale and include multivendor solutions.

The [Nokia NSP](#) and the supporting optical management and control applications of [Nokia WaveSuite](#) provide operators with a rich application suite for coordinating and automating IP-optical networks in multivendor environments.

Multivendor IP-optical management coordination with the Nokia NSP

Topology discovery

- All layers scanned
- Cross-connections captured

Automated connection management

- Multiple domains
- Multiple vendors

Cost-effective multilayer protection

- 1 N. floating port
- Limit redundant mechanisms

Diversity analysis

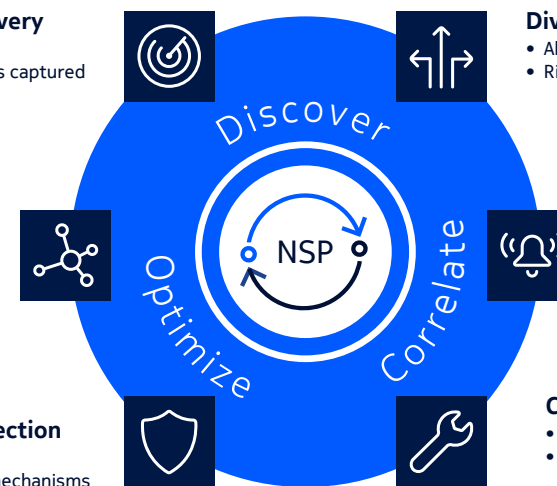
- All paths examined
- Risks flagged

Coordinated assurance

- Root causes analysis
- Cross domain navigation

Coordinated maintenance

- Proactively reroute traffic
- Minimize service impact



Partner with a global leader in IP and optics

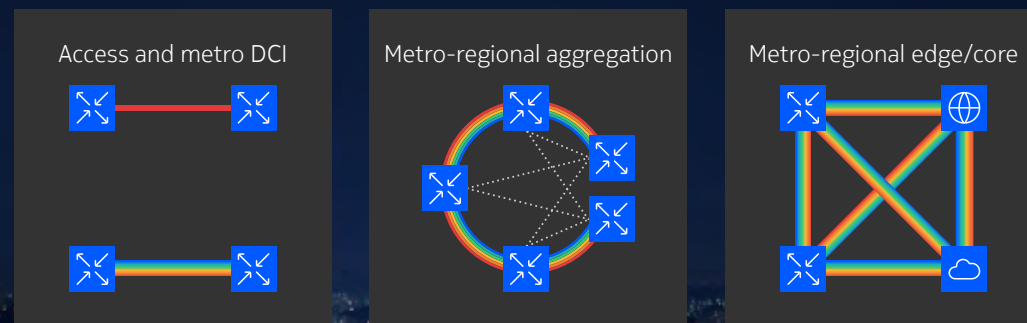
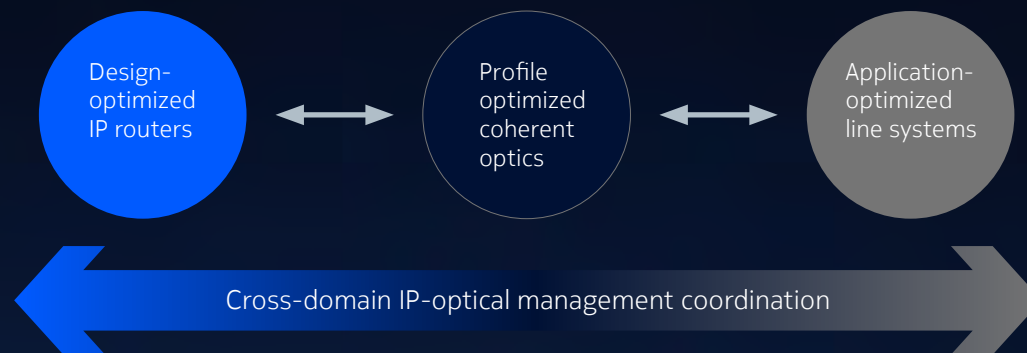
As a global leader in IP and optics, Nokia is uniquely qualified to help you remove technology barriers and transform your IP-optical network to support profitable growth:

- Unleash the power of our fifth-generation coherent optics and optical line systems to rev up your routers and light up your fiber for 400GE and beyond.
- Optimize your deployment for any application across any packet transport architecture.
- Streamline and automate your IP-optical network operations with our multivendor cross-domain management solutions.

Visit our [web page](#) to learn more about how our unique breadth and depth of expertise in the IP and optical domains can help you transition to coherent routing in the way that works best for your network and business objectives.

Resources

- [Nokia Coherent Routing eBook](#)
- [Nokia IP network solutions](#)
- [Nokia optical network solutions](#)
- [Nokia IP-optical coordination](#)



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About Nokia

At Nokia, we create technology that helps the world act together.

As a B2B technology innovation leader, we are pioneering networks that sense, think and act by leveraging our work across mobile, fixed and cloud networks. In addition, we create value with intellectual property and long-term research, led by the award-winning Nokia Bell Labs.

Service providers, enterprises and partners worldwide trust Nokia to deliver secure, reliable and sustainable networks today – and work with us to create the digital services and applications of the future.

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