Infinite Capacity Engine – Extensible (ICE-X) 400G XR CFP2

A point-to-point and point-to-multipoint intelligent coherent pluggable with rich transponder and system-level features

XR Optics Technology Overview

Since the inception of optical networking, there has been a significant misalignment between actual network traffic patterns and the technology used to transport that traffic. Network traffic patterns, particularly in metro aggregation networks, are overwhelmingly hub and spoke, with numerous endpoints consuming traffic that is aggregated by a small number of hub locations. In contrast, optical connectivity solutions have been implemented using strictly point-to-point technology, where each end of the connection is required to operate at the same speed (1G, 10G, 25G, 100G, etc.). The result is an extremely inefficient transport architecture that requires large numbers of bookended transceivers, as well as numerous intermediate aggregation devices to “up-speed” traffic flows.

XR optics is the next major inflection point in optical transceiver technologies. XR optics utilizes digital signal processing to subdivide the transmission and reception of a given wavelength spectrum into a series of smaller-frequency channels called digital subcarriers. These digital subcarriers can be independently modulated, managed, and assigned to different destinations, enabling the industry’s first scalable point-to-multipoint, direct low-speed to high-speed optical transceiver connectivity. A single 400G XR optics hub module generates 16 x 25 Gb/s digital subcarriers. One or multiple digital subcarriers can be combined and assigned to a specific destination to provide the required bandwidth. XR optics transceivers are designed to be equipped with a wide range of networking equipment, including Ethernet switches, routers, servers, wireless baseband processing systems, and passive optical network (PON) headend aggregation systems.

Nokia’s ICE-X Pluggable DCOs

Nokia’s suite of vertically integrated ICE-X pluggable DCOs leverages XR optics technology, offering network operators the performance, scale, and efficiency critical to drive down network operating costs and enhance service agility. ICE-X transceivers support industry-leading performance and a unique level of integrated intelligence and system-level functionality, simplifying deployment in a wide variety of network scenarios without sacrificing performance, visibility, or network resiliency.

Nokia’s ICE-X pluggable DCOs enhance deployment flexibility as the same coherent pluggable can be software-configured to operate in point-to-point or point-to-multipoint configurations. Nokia’s ICE-X pluggable DCOs meet most common standards for other coherent pluggable optics like 400G ZR, including physical form factor (e.g., CFP2, QSFP-DD, OSFP) and network management.

Key Benefits of ICE-X Pluggable DCOs

- A reduction in TCO of up to and in some cases more than 70%, with low first-in cost and reduced OpEx
- Transponder functions in a pluggable form factor, including rich system-level features and control within third-party hosts, providing transport network demarcation
- Multigenerational network architecture and decoupling of node upgrades from network-wide upgrades
- Network simplification through elimination of Layer 1 and Layer 2 aggregation and grooming equipment
- Flexible deployment in switches, routers, and WDM platforms and on fiber pairs, single fiber, fixed and flexible grid, ROADM network, etc.
- Dynamic capacity allocation across the network remotely, set through software by an operator or triggered by software automation tools
- Seamless introduction into existing operational model, with minimal to no disruption to existing service offering

When used for point-to-point connections, ICE-X 400G XR or 400G ZR+ pluggable DCOs lay the foundation for an architecture that can evolve to overcome ongoing challenges like increasing capacity, flexibility, and service agility. In parallel, service providers can leverage the point-to-multipoint capabilities of ICE-X 400G XR where desired, using a common set of building blocks. Moreover, when compared to conventional point-to-point coherent pluggables, ICE-X pluggable DCOs enhance deployment flexibility through the support of single fiber (bidirectional) and help network operators reduce CapEx and OpEx through leading optical performance, the elimination of intermediate sites, and the reduction of truck rolls enabled by numerous automation tools. Table 1 highlights the advantages of deploying ICE-X in point-to-point configurations.

	Conventional Coherent Pluggables (Point-to-Point)		ICE-X (Point-to-Point)	
	Near End	**Far End**	**Near End**	**Far End**
C-CMIS and CFP2 MSA	✓	✓	✓	✓
Client Service Configuration	✓	✓	✓	✓
L0 Frequency Configuration	✓	x	✓	✓
Diagnostics (Telemetry, Loopback…)	✓	x	✓	✓
Optical Performance SLA and RMON	✓	x	✓	✓
Host-independent Co-management by Transport Management System	x	x	✓	✓
Auto-Lambda	x	x	✓	✓
Optical Spectrum Analyzer	x	x	✓	✓
Single-fiber Operations	x	x	✓	✓

Table 1: Conventional coherent pluggables vs. ICE-X for point-to-point applications

Whether deployed in point-to-point or point-to-multipoint applications, ICE-X pluggable DCOs are more than just a set of pluggables, they are a system in a pluggable form factor. An ICE-X pluggable DCO has several card- and system-level features, such as in- and out-of-band communication channels and topology awareness, allowing automated turn-up and remote management of XR optics deployed at remote sites/devices (leafs) directly from the hub, while ensuring clear demarcation points. Moreover, ICE-X pluggable DCOs support Layer 1 wire-speed AES-256 encryption, point-to-multipoint aggregation for Layer 1 and Layer 2 traffic, topology awareness, control plane features, constellation power management, optical spectrum analyzer (OSA), and much more. With ICE-X pluggable DCOs, network operators will be positioned to dramatically reduce the number of transceivers in the network, eliminate the need for costly intermediate aggregation devices, and more efficiently optimize optical transport infrastructure around end-user traffic flows at any given point in time, resulting in TCO savings of 70% or more.

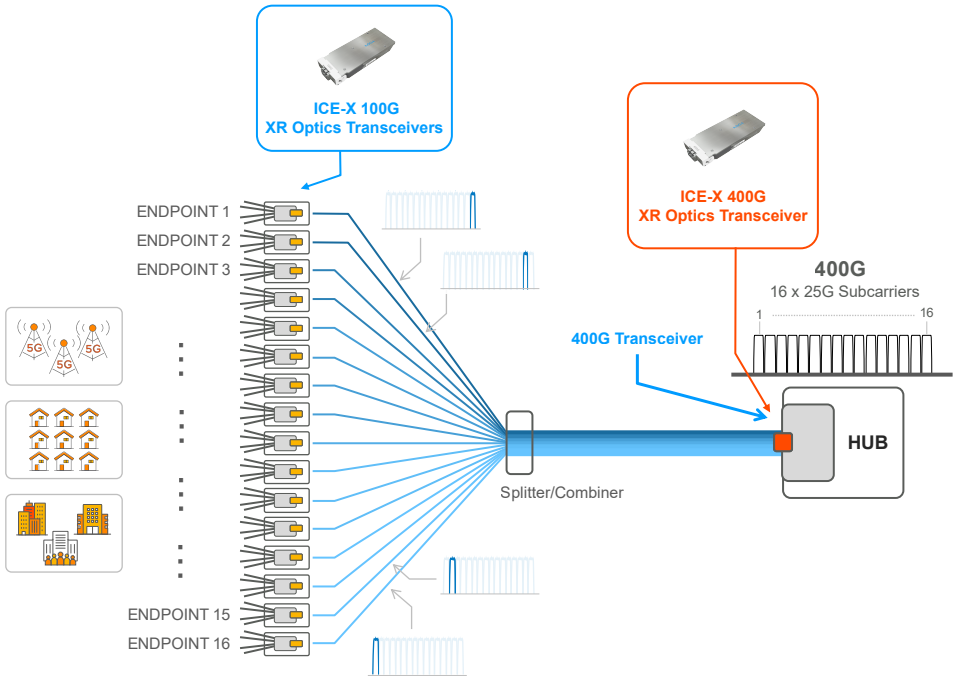

Figure 1: ICE-X 100G/400G XR point-to-multipoint connectivity

ICE-X Pluggable DCO Applications

ICE-X pluggable DCOs can be used for traditional point-to-point optical transport applications like any other ZR+-type pluggable transceiver. Differentiating features in this application are high output power and unique management capabilities that allow the co-management of the pluggable transceiver hosted in a third-party platform, providing visibility and optional management from the transport management and control system. This greatly simplifies management of an IPoDWDM network and provides similar operational conditions to a transponder-based network. ICE-X pluggable DCOs can also be used for point-to-multipoint transport, which is ideal for traffic aggregation where low-speed to high-speed optical interconnectivity is required (also known as hub and spoke), such as metro access and aggregation, cable fiber deep, wireless xHaul, DSL/PON backhaul, business services, and many other applications. For example, ICE-X pluggable DCOs can be deployed to connect aggregation routers in an operator's central offices to hub routers at the operator's core sites. This is a generic application that can be applied to any operator's network and backhaul traffic, be it residential backhaul, OLTE aggregation, mobile backhaul, or connectivity for business services.

ICE-X pluggable DCOs are also designed for point-to-point applications where the underlying traffic is being aggregated and redistributed. In addition to providing scalable and highly flexible connectivity, ICE-X pluggable DCOs offer numerous features, as depicted in Figure 2.

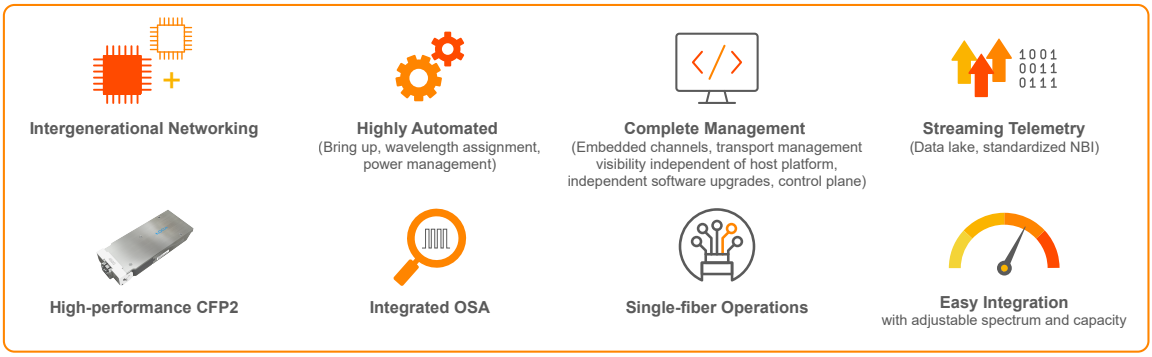

Figure 2: Features of ICE-X pluggable DCOs

Other examples are 5G fronthaul, where multiple radio units (RUs) connect to a distributed unit (DU); 5G mid-haul, where multiple DUs connect to a centralized unit (CU); and 5G backhaul, where the CU or converged cell site (DU/CU) is backhauled to the mobile core (NGC). Cable MSO examples include distributed access architecture (DAA), where many Remote PHY devices (RPDs) connect to a virtual Converged Cable Access Platform (vCCAP) or many Remote MAC-PHY devices connect to a router. XR optics' ability to be deployed over single fibers makes it a very compelling solution for backhaul, next-generation passive optical technologies such as XGS-PON and NG-PON2, and high-speed business services.

Deploying ICE-X pluggable DCOs has major implications across access, aggregation, and metro optical networks. Benefits include a significant reduction in total cost of ownership of up to and in some cases more than 70%, dramatic network simplification, and an unprecedented level of network flexibility.

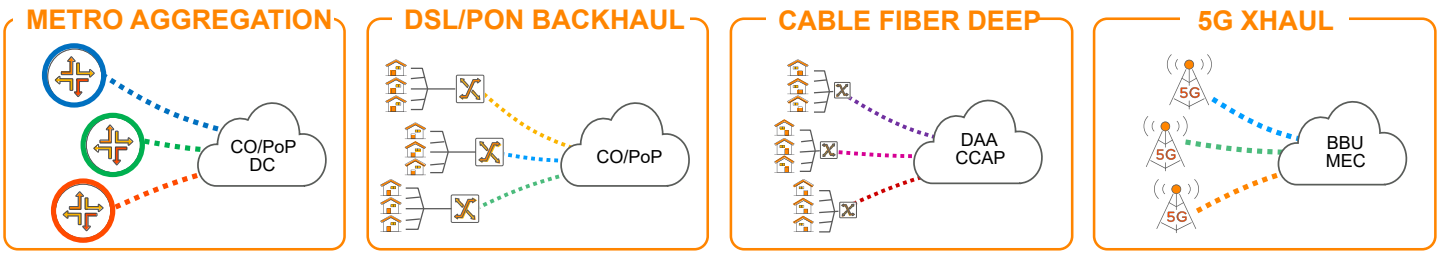

Figure 3: Target applications

Key Specifications

- CFP2-compliant module
  - 400G total capacity with 16 x 25G subcarriers
  - Compatible with any XR optics module
  - 25 GbE, 50 GbE, 100 GbE, 200 GbE, 400 GbE, OTU4 client support
  - Point-to-point and point-to-multipoint deployments
  - Low-speed to high-speed interconnection (100G to 200G to 400G)
- Dual management
  - MDIO/CFP2MSA-compliant host interface
  - Management through host device or via optical layer XR gateway
  - Remote in-band management
  - In-band communication to remote XR modules
  - Automated power management
  - Nodal upgrades versus the need for system-wide upgrades

- System features
  - Layer 1 wire-speed AES-256 encryption
  - Demarcation
  - Topology awareness and auto-discovery of remote XR modules
  - Point-to-multipoint aggregation for Layer 1 and Layer 2
  - Flexible packet bandwidth mapping to subcarrier bandwidth using port or virtual transport interfaces defined by VLAN or other packet parameters
  - Compatible to brownfield ROADM transport networks and colorless add-drop architectures

Technical Specifications (Preliminary)

Environmental Specifications				**400G CFP2-DCO**			
Parameter	**Conditions**		**Symbol**	**Min**	**Typ**	**Max**	**Unit**
Storage temperature			T_S	-40		85	°C
Case operating temperature	Central office applications	Long term	T_{OP}	0		70	°C
		Short term <96h		-5		75	
	Outdoor applications (under consideration)	Long term	T_{OP}	-40		85	°C
Relative humidity	Non-condensing	Long term	RH	5		85	%

DC Electrical Characteristics							
Power supply voltage			V_{CC}	3.2	3.3	3.4	V
Power supply current	Low-power mode		I_{CC}			0.7	A
	Steady-state current, C-temp, all operating modes					8.1	
Power dissipation	Low-power mode		P_{diss}			2	W
	Steady state, C-temp, all operating modes				22	26	

Interface Specification
Client Interface (Supported Protocol)
25 GbE (25GAUI-1), 50 GbE (50GAUI-1), 100 GbE (100GAUI-2, CAUI-4), 200 GbE (200GAUI-4), 400 GbE (400GAUI-8), and OTU4 (OTL-4.4, OTL-4.2)

General Optical Characteristics						
Parameter	**Conditions**	**Symbol**	**Min**	**Typ**	**Max**	**Unit**
Symbol rate		R_{baud}	4		64	Gbaud
Modulation formats		QPSK, 8QAM, 16QAM				
Channel frequency range	Default	v_C	191.3		196.100	THz
Channel spacing	Flexible grid (6.25 GHz) compliant	Δv_C	75	100		GHz
Frequency fine tuning (FTF)			-6.25		+6.25	GHz
Frequency accuracy (EOL)			-1.5		+1.5	GHz
Laser linewidth				120		KHz

Tx Electro-Optical Characteristics						
Tx output power	QPSK and 16QAM with subcarrier At 0 dB attenuation	P_{out}	-1			dBm
Tx in-/out-of-band OSNR	~0-6 dB Tx VOA attenuation			42		dB/0.1 nm

Rx Electro-Optical Characteristics						
Maximum reach	400G, 16QAM	L		1,500		km
Rx signal input power range	400G, 16QAM	P_{in}	-12		0	dBm
Rx OSNR tolerance at minimum Rx input power range	400G, 16QAM, using 3SD Turbo FEC, with subcarrier gain sharing		23.5			dB
Rx signal power sensitivity	400G, 16QAM OSNR > 35 dB/0.1 nm		-22			dBm
DGD tolerance	0.1 dB OSNR penalty, 16QAM, 4 GHz subcarriers		100			psec
CD tolerance	200G, QPSK			80		nsec/nm
	400G, 16QAM			37		nsec/nm

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.

With truly open architectures that seamlessly integrate into any ecosystem, our high-performance networks create new opportunities for monetization and scale. 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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