Nokia end-to-end optical transport network (OTN)

Building OTN solutions from access / edge to core

NOKIA

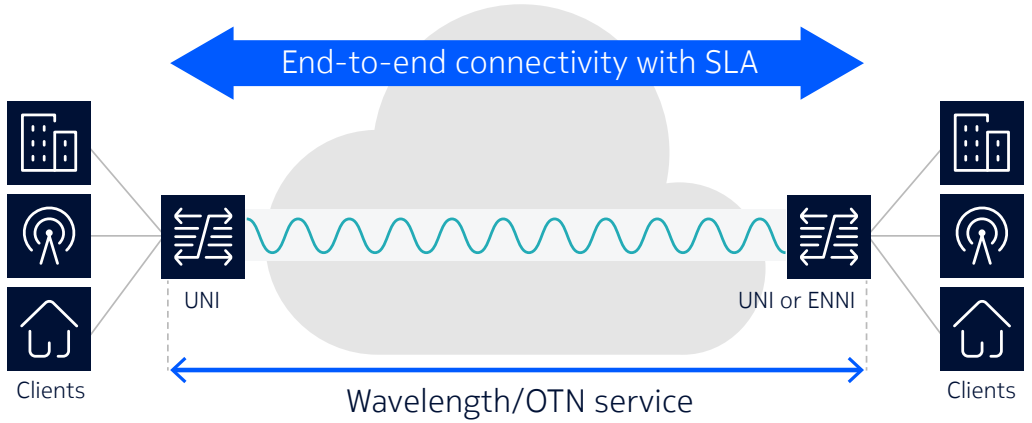
Modern OTN network architectures are driven by the SLA-optimized requirements of today's business and wholesale services. OTN services deliver deterministic performance, bandwidth efficiency, low latency, hard isolation, and fast service activation. Nokia delivers complete end-to-end OTN solutions from access / edge to core, using multiservice platforms designed for versatility and scalability, and comprehensive end-to-end management and operations.

Modern OTN networking

Modern network architectures are driven by service requirements for end-to-end connectivity with enhanced Service-Level Agreements (SLA) requirements. The ITU-T G.709 Optical Transport Network (OTN) standards are ideally suited to provide an end-to-end solution for the stringent service requirements that demand security, scalability, low latency, and high availability. OTN improves network efficiency and utilization and can carry any traffic type including legacy services. Layer 1 (L1) OTN networks are composed of transport, multiplexing, and switching applications and include products like transponders, muxponders, and OTN switches. Multilayer optimization is achieved by using an optimal mix of electrical grooming and photonic Wavelength Division Multiplexing (WDM) transport for increased scalability and flexibility.

Today's OTN network architectures require capacity and scaling in the core, combined with flexibility and fit on the edge of the network. In the core, OTN networks incorporate the latest coherent WDM electro-optics to optimize reach and capacity over large metro, regional and long-haul networks. At the network edge, OTN solutions need to be compact, versatile and extend services all the way to customer premise sites in-order to provide carrier-grade service demarcation with end-to-end service assurance. Modern OTN networks are managed by state-of-the-art network management and automation tools and can offer advanced control plane features for carrier-grade restoration and protection options. Nokia provides a comprehensive, fully-featured end-to-end solution for OTN transport, multiplexing and switching from access / edge to metro and core of the network.

Figure 1. OTN end-to-end services



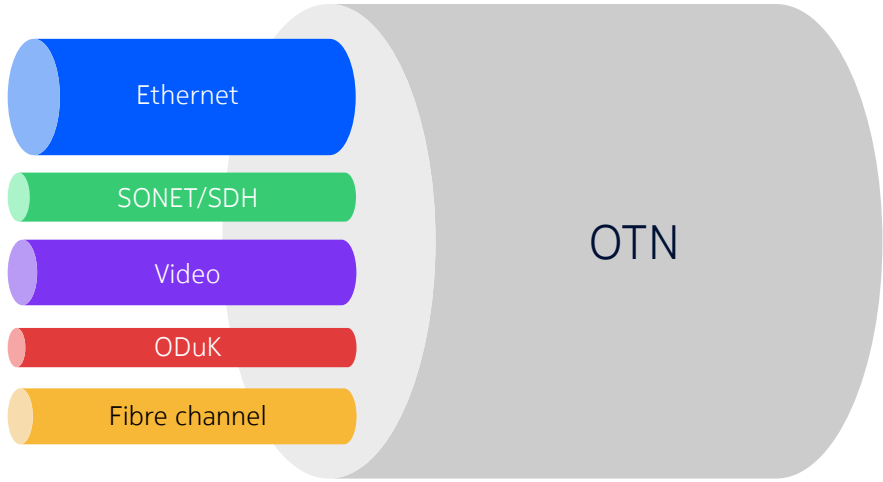
OTN overview

OTN is defined by the ITU as a method to efficiently encapsulate, transport, multiplex, and switch a wide range data and legacy services over optical wavelengths. OTN is often referred to as a digital wrapper in that it can function as a generic, transparent container for services that include SONET/SDH, Ethernet, Fibre Channel, video, etc. Over time OTN's role has continued to evolve from simply a digital wrapper for WDM wavelengths, to a protocol agnostic container for efficient multiplexing and multi-degree switching. OTN technology continues to gain momentum in transport networks due to its efficient aggregation and wavelength utilization, scaling capability, protocol agnostic and deterministic transport, hard service isolation, and end-to-end OAM that includes overhead for performance monitoring and protection switching.

OTN is well suited for mission-critical traffic due to its inherent security characteristics including hard isolation and protocol-agnostic wire-speed Layer 1 network encryption options. Hard isolation is a method to isolate traffic on an interface or a link using a circuit-switched connection. OTN provides standardized mappings of OTN clients like SONET/SDH and Ethernet into dedicated ODUk/ODUflex timeslots. OTN hard isolation ensures low latency, high level of security using dedicated connections, and deterministic Quality of Service (QoS).

Due to its flexible and efficient nature, OTN has been broadly deployed across the globe for a wide range of applications, and used in edge, metro, and core networks - including submarine networks. As OTN has evolved over time it has incorporated higher client and line rates and now supports line speeds of beyond 100G with a flexible OTUCn line structure, and Ethernet clients that go to 400GE and beyond. OTN continues to drive next-generation network evolution and supports complete end-to-end network applications with deterministic performance and enhanced Service-Level Agreements (SLA) assurance.

Figure 2. OTN - protocol agnostic container for transport / multiplexing / switching

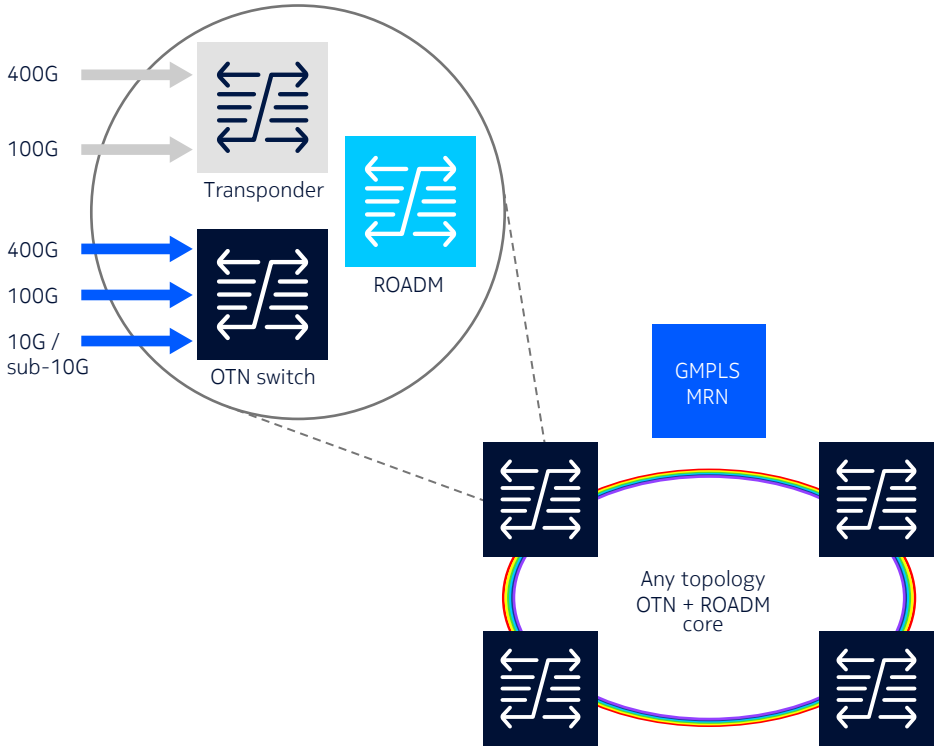


Multilayer optical networking

Modern OTN networks are deployed using multilayer capabilities that combine superior scalability and flexibility. OTN multiplexing and switching are combined with integrated WDM transport to optimize traffic rates and to minimize network costs. Electrical grooming of OTN-encapsulated services at Layer 1 is used to efficiently fill wavelengths, which reduces the number of WDM interfaces needed, and therefore lowers network cost and power. This is combined with savings at the optical layer, where reconfigurable optical add/drop multiplexers (ROADMs) enable photonic bypass and restoration, and can be used to further reduce the scale of required OTN switches.

Using OTN with Carrier Ethernet and MPLS-TP allows further aggregation benefits using statistical multiplexing, comprehensive end-to-end OAMP, and an optimized solution using a Packet OTN (P-OTN) architecture. In addition, multilayer control planes like Generalized Multiprotocol Label Switching (GMPLS) can be used for distributed intelligence that includes path computation, signaling and routing, and for carrier-grade service restoration and protection. Optimized multilayer networking improves overall network efficiency and lowers Total Cost of Ownership (TCO).

Figure 3. Multilayer optical networking



OTN technologies

OTN technology is used in a variety of ways in optical networks starting with straight-forward OTN transport using a protocol-independent wrapper of client data with a powerful Forward Error Correction (FEC). This can then be extended to OTN multiplexing where multiple clients are combined into a single container to increase network efficiency – muxponder-based solutions are often used for this purpose.

OTN switching takes this a step further and allows a common electrical switch fabric to cross-connect many wavelengths and clients. This can be performed at ODUk/ODUflex granularity, therefore enabling efficient fill of OTN wavelengths. OTN switching allows the multiplexing, routing, protection, and restoration of traffic using a flexible network architecture. This allows any-to-any site connectivity with optimal and efficient connection granularity, while being able to address changing bandwidth demands and traffic patterns and simplifying network planning and provisioning. It also offers client traffic segregation through inherent hard isolation of various sub-rate services within the OTN payload.

Multiple deployment options are possible when using OTN switching. Blade-based and distributed switching can be used to extend OTN switching capabilities to the access / edge of the network using smaller footprint and cost efficiency. Centralized switching increases switching capacity using a centralized OTN fabric that scales the traffic flows that can be cross-connected and then groomed at a particular node. Centralized switching is ideal for network deployments in large metro, regional and core node applications. Nokia provides solutions for all three types of OTN switching applications and allows for the best fit based on footprint, power, and optimal scalability.

Table 1. OTN switching – multiple deployment options

	Blade switching	**Distributed switching**	**Centralized switching**
Typical application	Access / edge	Small node aggregation	Larger metro, core
Node switching	Card switching, card-pairing options	Backplane, mix and match of client and uplink interfaces	Centralized OTN switch fabric, any-to-any connections
Characteristics	Lowest cost, least scalable	Hybrid configurations, photonic and OTN switching	Higher I/O density, large switching capacity

Scaling OTN in the core

Regional and metro networks require high-scalability and high-density platforms in the core that are agile across multiple layers for photonic reach, OTN switching and transport, as well as packet switching. For core OTN switching and transport Nokia provides both the 1830 PSS-x and 1830 PSS scalable, multiservice platforms:

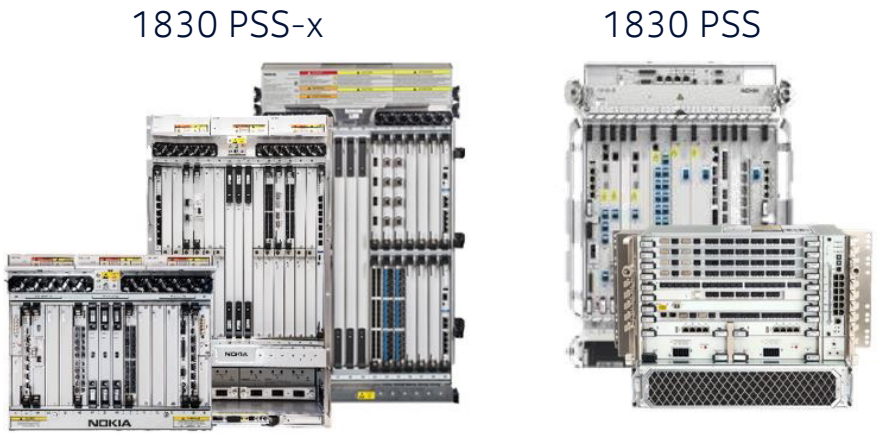
- **1830 PSS-x:** a highly scalable, multiservice platform optimized for centralized OTN switching and transport. It features high-density client and line interfaces, integrated coherent Wavelength Division Multiplexing (WDM) transport optics, and carrier-grade GMPLS restoration and protection.
- **1830 PSS**: a unified multiservice platform that provides optical transport and line system including ROADM and C+L line system for maximum fiber capacity, distributed OTN switching capability, and integrated packet transport interface cards.

Centralized OTN switching

Centralized switching provides high scalability and density in compact design using a centralized OTN switch fabric. Centralized OTN switching decouples clients from wavelengths transport interfaces allowing any client to be individually routed to any line or client port. This ensures high fill of wavelengths and efficient use of network resources while allowing increased flexibility of service provisioning and ease of deployment. Latency optimized, with WDM interface integration, centralized OTN switching offers flexible and unrestricted any service point-to-point connectivity. Scaling of OTN in metro and core networks is achieved using beyond 100G applications, including extension of client interfaces to 400GE and beyond. Robust protection and restoration functions are key components of centralized OTN switching and to allow guaranteed performance for end-to-end services.

The 1830 PSS-x family consists of platforms optimized for optical transport network (OTN) switching applications. The 1830 PSS-x family includes the 1830 PSS-8x, PSS-12x and PSS-24x multiservice platforms that scale from 1.6 Tb/s to up to 48 Tb/s and provide the flexibility and efficiency operators need to deliver today's optimized, high-capacity services.

Figure 4. Nokia core and backbone optical network solutions



Distributed OTN switching

Distributed switching enables small node aggregation using the backplane. Mix and match of client and uplink interfaces can be used for a cost effective OTN switching solution for access aggregation applications. Photonic and packet capabilities are integrated within the same shelf to allow full multilayer capabilities. Nokia 1830 PSS-4II, PSS-8, PSS-16II, and PSS-32 multiservice platforms provide distributed OTN and packet switching capabilities using interconnected full mesh backplane connections. An example of this type of configuration is a S13X100 card on the PSS-8 and PSS-16 which can be cross-connected across the backplane to form an Add / Drop Multiplexer (ADM) OTN switch. In many cases, distributed OTN switching in this method can provide 100 Gb/s capacity towards the network edge at or better than 10 Gb/s cost.

Figure 5. Centralized OTN switching with Nokia 1830 PSS-8x, PSS-12x, PSS-24x

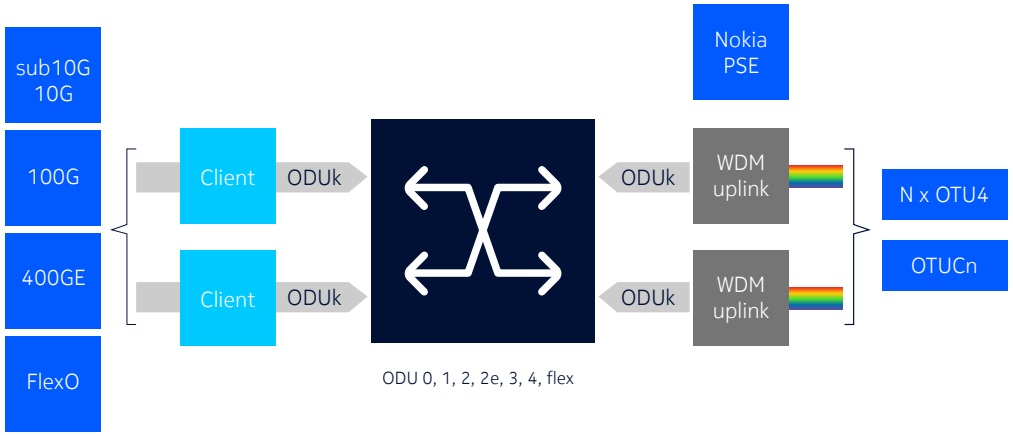
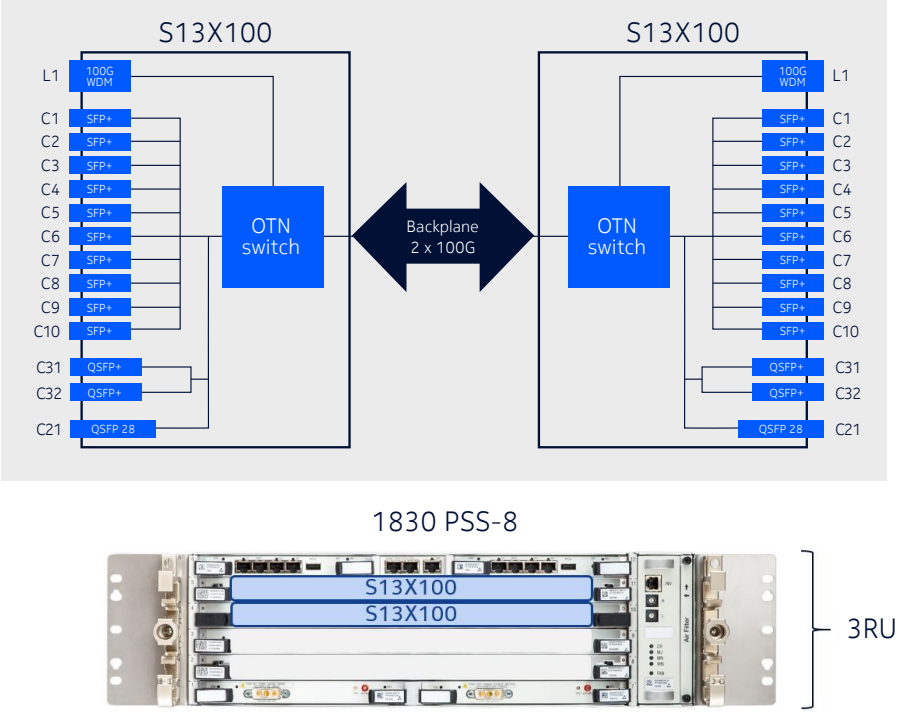


Figure 6. Distributed OTN switching with 1830 PSS-8 and S13X100



OTN in access, edge, and enterprise

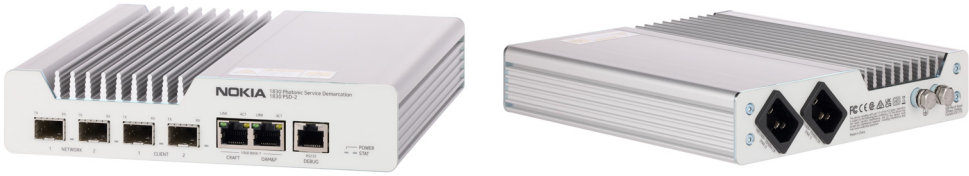
OTN functionality and services can be extended to the network edge using flexible platforms optimized for a variety of service interfaces, footprint, and power consumption. Compact, but scalable these WDM solutions are tailored to network access and extend OTN networking all the way to customer premise sites.

Nokia 1830 Photonic Service Demarcation (PSD), Nokia 1830 PSS-4II and Nokia 1830 Optical Network Extender (ONE) are application-optimized, compact, and power-efficient optical networking products that extend OTN functionality and services to the network edge. Working together with 1830 PSS and 1830 PSS-x platforms using common management and operations, they provide end-to-end OTN solutions for business services, multiservice transport applications and enterprise private networks.

OTN service demarcation – 1830 PSD

Nokia 1830 PSD is a compact, low-power, and low-latency demarcation device that extends the reach of optical networks at customer premise sites. It supports MEF compliant OTN and Carrier Ethernet service for a wide range of applications for access, service extensions, and network interconnection. The 1830 PSD provides both AC and DC power options (including dual AC or DC power on the 1830 PSD-2) and is rapidly deployable with easy installation and minimal configuration. It offers carrier-grade features including OTN and Ethernet OAM for end-to-end service assurance and robustness features for optional line and service protection.

Figure 7. Nokia 1830 PSD-2



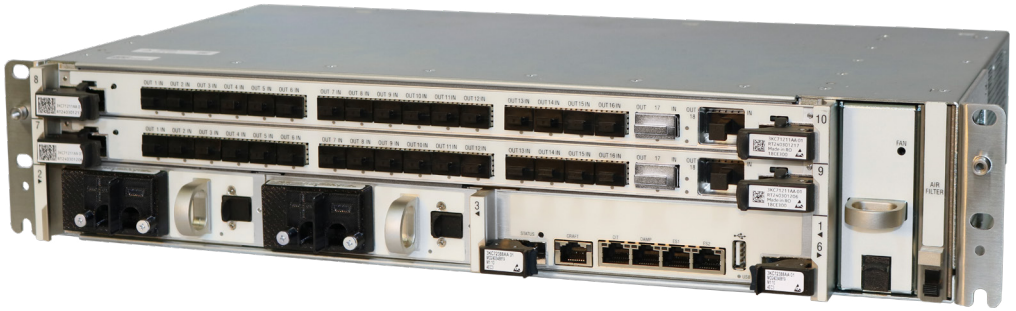
- Space and power efficiency
- Service demarcation
- Simple commissioning and service activation

The 1830 PSD can be connected through a OTN / WDM network or can be simply book-ended with multiple client types including Ethernet, SDH/SONET, and OTN. Traffic segregation is achieved using hard isolation between services and this provides guarantees for service bandwidth, packet loss and latency. 1830 PSD supports ODUflex for adjusting rates in 1.25 Gb/s tributary slots, using bandwidth more efficiently and maximizing ODU use. The 1830 PSD is tightly integrated with the 1830 PSS platforms using common management and operations for a complete end-to-end solution.

Access and edge - Nokia 1830 PSS-4II

Nokia offers a flexible and multiservice solution for access / edge applications. The Nokia 1830 PSS-4II is a compact multiservice transport and WDM line system supporting a wide range of applications scaling to 400G and beyond. It enables cost-effective, efficient aggregation and optical transport for Ethernet, optical transport network (OTN), time division multiplexing (TDM), and wavelength services. With its compact size, flexible AC or DC power supply options, and support for extended temperature range environments the solution flexibly accommodates diverse customer premise environments. Capable of highly precise sync distribution, including Class C and Class D T-BC, it supports mobile backhaul applications and business services. Leveraging the same operations and cards across the 1830 PSS portfolio, it serves a wide range of client traffic (Ethernet, OTN, Fiber Channel) and increases traffic efficiency through muxponding, Add Drop Multiplexing (ADM), Layer 2 ADM, and edge optimized ROADM configurations. This includes service aggregation onto 400G uplinks for transport using 400G DCO pluggables enabling extended reach in the network.

Figure 8. Nokia 1830 PSS-4II



Scalability
Service aggregation of 10G to 400G clients

Easy
Simple to build
Easy to manage

Secure
Quantum safe encryption and trusted platform

Resilient
Dual power
Fiber-cut protection

Access OTN – 1830 ONE

1830 ONE enhances 1830 PSS portfolio in metro access with high-density, compact platforms that support OTN, packet and photonic solutions. The 1830 ONE features modular and versatile platform architecture for maximum scalability and configuration flexibility. It supports applications that include business OTN and P-OTN access, access WDM, and TDM transformation.

In the 1830 ONE family, OTN and packet functionality is supported on the 1830 ONE Hub (1830 ONE-h) shelf. 1830 ONE-h is a 1 RU, modular shelf that supports two electrical slots, and fully redundant, field replaceable power supply. The 1830 ONE-h functions include OTN switching, muxponder, transponder, packet switching, and TDM renewal.

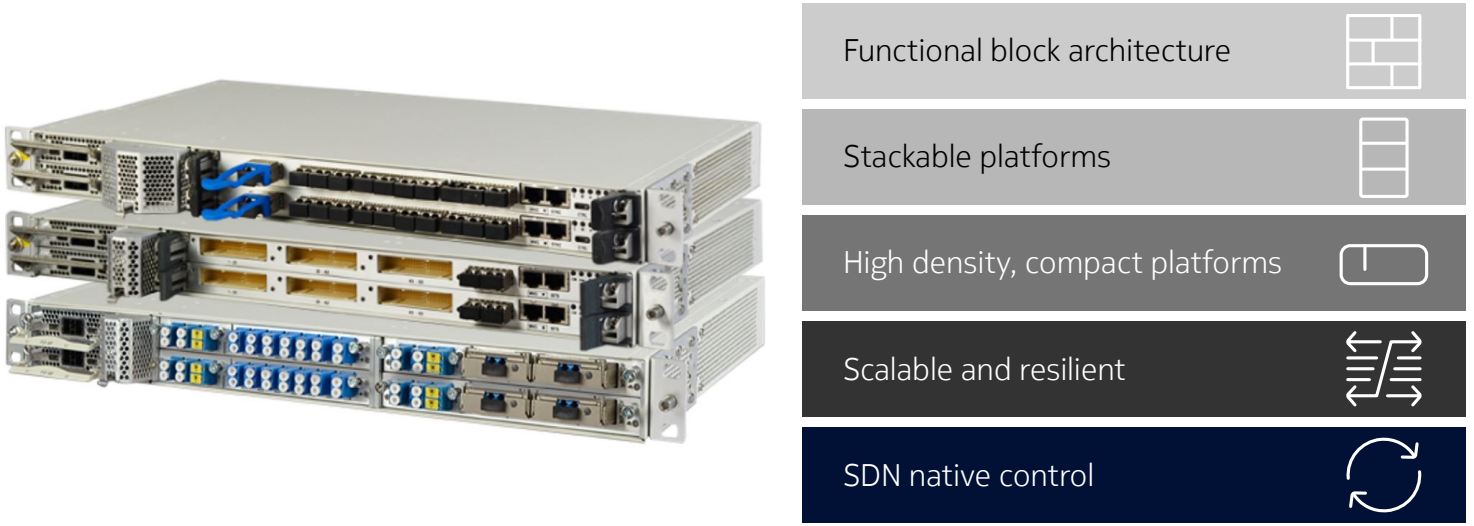
1830 ONE-h features several OTN switches to extend OTN networking into metro access. This includes a 10G OTN switching card that can be paired for 280G full-duplex OTN switching capacity with ODU0 granularity. It also supports a 100G OTN switching cards that can be paired for 400G full-duplex OTN switching capacity with ODU0 granularity. The 100G OTN switching cards support both B&W (QSFP28) and coherent (CFP2 DCO) interface options. To improve flexibility, the ports on the OTN switching cards can be provisioned as client or line interfaces depending on the configuration needed.

For legacy access and transformation, the 1830 ONE features a TDM renewal solution. This allows legacy TDM to be directly mapped into OTN and to leverage the core P-OTN transport infrastructure for legacy transport.

For example, the 1830 ONE supports direct mapping of E1, E3, and VC4 into sub-1G OTN containers based on ITU-T supplement agreement. The 1830 ONE TDM transformation solution supports high-density cards with E1 terminations plus SDH clients to regain space and fiber and to reduce power and maintenance. The 1830 ONE allows the selective migration of PDH/SDH traffic to the OTN/WDM network and to modernize the networks in steps as needed.

The 1830 ONE is integrated with 1830 PSS using common operations and network management for a complete access / edge to core solution.

Figure 9. Nokia 1830 ONE



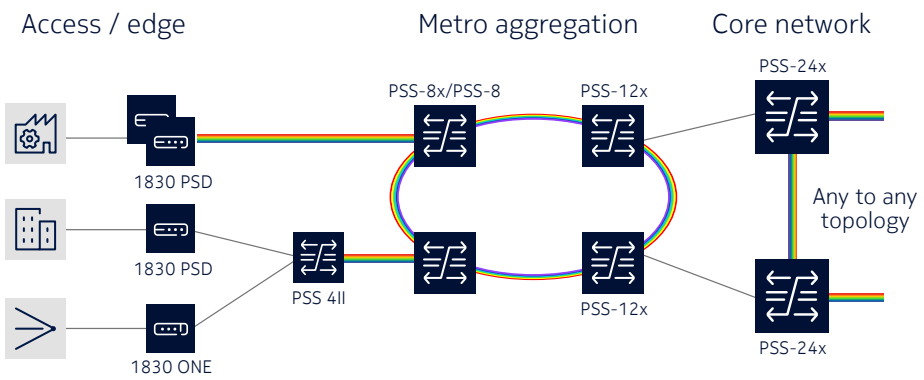
OTN business services

OTN provides a high-value, SLA-aware solution for premium wholesale and business services with service efficiency, flexibility, security, and guaranteed performance. The business services can span from network edge to metro aggregation and core for end-to-end connectivity. OTN delivers efficient aggregation and multiplexing of services that avoids cascading and complexity, while supporting any topology mesh with fast service rollout. OTN services are flexible with client interface and protocol versatility, using any-to-any service connectivity, and SLA-aware provisioning. OTN services are also reliable with multi-failure restoration, secure through hard isolation, guaranteed latency, and deterministic bandwidth.

At the standards level, Metro Ethernet Forum (MEF) has published a set of Layer 1 (L1) service definitions. These are services characterized by highly available point-to-point private line offering where end customers have dedicated full-rate bandwidth over Layer 1 WDM or OTN networks. The motivation for defining Layer 1 services in MEF is to standardize the use of terminology and to define service attribute definitions, similar to those for the MEF definition work of Carrier Ethernet and IP services:

- Standard MEF 63 defines the subscriber L1 service attributes of UNI-to-UNI retail services for Ethernet, Fibre Channel, and SONET/SDH.
- Standard MEF 64 defines the operator L1 service attributes of ENNI-to-UNI/ENNI wholesale services for access and transit.

Figure 10. Nokia OTN business services example blueprint



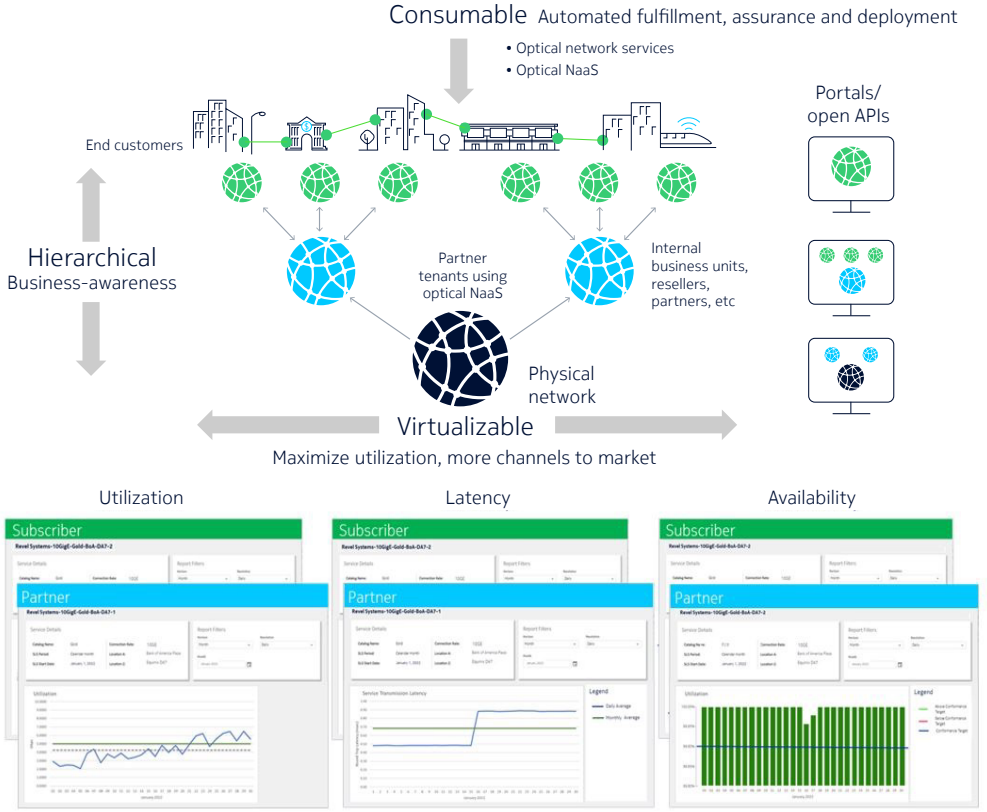
The MEF definitions allow subscribers to identify consistent offerings for comparison and for operators to enable simplified and faster interconnect. Nokia is at the forefront of the publishing activities for MEF 63 and MEF 64 standards that allow service providers to define and provide common reference for high-performance and standardized offerings for optical transport services.

OTN control, management, and automation

The OTN data plane can be augmented with a control plane for intelligent, multilayer control and restoration. Nokia Generalized Multiprotocol Label Switching (GMPLS) control plane, powered by Bell Labs network optimization algorithms, adds distributed intelligence (path computation, signaling, routing), resilience to multiple failures, and planning capabilities to enhance the service layer and to reduce overall TCO.

A management plane further enhances the data and control planes by providing centralized management functions. Nokia provides a complete OTN solution with open and transformative software to manage the end-to-end solution. This includes a comprehensive suite of network automation and management tools under Nokia's WaveSuite family including the WaveSuite Network Operations Center (formerly NFM-T) and applications like WaveSuite Service Enablement, WaveSuite Health and Analytics, and WaveSuite Planner.

Figure 11. Nokia WaveSuite Service Enablement



Conclusion

ITU-T G.709 OTN is a flexible and reliable protocol that is used to provide transport, multiplexing, and switching across optical networks. OTN combines protocol agnostic services onto a common network to deliver deterministic performance and efficient operation with enhanced SLA. OTN networking is combined with multilayer optimization for better fiber utilization and optimal mix of traffic flows across photonic, OTN, and packet layers. Nokia provides a complete OTN networking portfolio from customer premise to core, including common end-to-end management and operations.

In the core, Nokia enhances switching capacity with the 1830 PSS-x family that delivers multi-terabit switching scale along with integrated WDM transport optics. This is complemented by the unified multilayer 1830 PSS platform that supports OTN distributed switching, multiplexing, and transport, along with full photonic layer and packet layer capabilities. At the access and edge, Nokia provides high-density, compact platforms – including 1830 PSD for service demarcation, and 1830 ONE for first aggregation and transport. These platforms extend the network reach and increases the agility and efficiency of the end-to-end solution.

To learn more about Nokia end-to-end OTN solutions for network operators, visit nokia.com/optical

Abbreviations

B&W	Black and White optics
ENNI	External Network-to-Network Interface
FEC	Forward Error Correction
GMPLS	Generalized Multiprotocol Label Switching
ITU-T	International Telecommunication Union - Telecommunication Standardization Sector
MEF	Metro Ethernet Forum
MPLS-TP	Multiprotocol Label Switching – Transport Profile
MRN	Multi-Region Networks
OAM	Operations, Administration, and Maintenance
ODU	Optical Data Unit
ODUflex	Optical Data Unit-flexible
OTN	Optical Transport Network
OTU	Optical Transport Unit
PDH	Plesiochronous Digital Hierarchy
PCE	Path Computation Engine
P-OTN	Packet-Optical Transport Network
QoS	Quality of Service
ROADM	Reconfigurable Optical Add Drop Multiplexer
RU	Rack Unit
SDH	Synchronous Digital Hierarchy
SLA	Service-Level Agreements
SONET	Synchronous Optical Network
TCO	Total Cost of Ownership
TDM	Time-Division Multiplexing
UNI	User-Network Interface
WDM	Wavelength-Division Multiplexing

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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.