Nokia WaveFabric
Performance at scale for the 5G era
Transport for an agile world

In today’s digital world, new and emerging services and applications such as cloud, 5G, IoT, Industry 4.0 and smart cities are disrupting traditional business models and straining static, closed, manually operated transport networks. For you to support these new, more dynamic services, requires more network connectivity, capacity and flexibility.
Transport network transformation challenges

Transforming your transport networks for the 5G era raises many challenges.

First, you need to scale and modernize your network infrastructure. You need to grow capacity while increasing performance, resiliency and determinism.

Second, you need to reduce Opex and optimize Capex. You can achieve this by simplifying and streamlining end-to-end service operations. By making more efficient use of network resources, you reduce your cost per bit.

Lastly, and perhaps the most critical challenge, you must increase network responsiveness and automate service operations by leveraging open, programmable network components.
Transform your network with Nokia WaveFabric

Nokia WaveFabric is a world-class optical networking solution that addresses network scaling and performance needs for all optical network deployment applications. As a foundational element of the Nokia Future X architecture, it provides a high performing universal adaptive core, which dynamically supports core and converged edge clouds and massive access for personal devices, IoT sensors, moving vehicles, video monitors and industrial automation — all securely and with the highest reliability. Controlled by a software-defined, programmable network OS, it delivers a dynamic network fabric that can respond instantly to augmented cognition systems (e.g. AI, machine learning and analytics) to provide a digital value platform for everything from Industry 4.0 automation to autonomous cars and personal digital assistants.

With Nokia WaveFabric you can:

- Massively scale your transport network to stay ahead of traffic growth based on maximizing photonic scale, electro-optic scale, and switching scale
- Optimize performance and service availability per application, characterized by high levels of spectral efficiency, determinism, resiliency and security
- Automate applications for zero-touch operations using open programmability built into hardware and services
- Enhance network value creation by enabling rapid innovation in applications to optimize and monetize network infrastructure
- Ensure data integrity and high availability for service continuity through a set of technologies that address security threats cost effectively and in a manageable way.
WaveFabric is a foundational element of the Future X architecture.
WaveFabric foundational solutions and innovations

Massive scalability and high performance

Nokia has delivered coherent technology innovation to break through optical networking barriers since the first commercial deployment of a single-carrier 100G wavelength in 2010. This success was followed by the deployment of the Nokia Photonic Service Engine 2 (PSE-2) super coherent digital signal processor (DSP), which achieved additional industry-first milestones.
Photonic Service Engine-3

Our new PSE-3 continues this innovation momentum by taking coherent digital signal processing to the Shannon limit for the ultimate in wavelength performance at any distance. The first chipset to implement probabilistic constellation shaping (PCS), the PSE-3 dramatically increases capacity while lowering power and costs per bit. Probabilistic shaping, leveraging Nokia’s innovative distribution matcher algorithm, enables you to optimize capacity and spectral efficiency on every route, and it reduces operational complexity by supporting simplified spectrum planning and automatic wavelength optimization.

Constellation optimization and probabilistic shaping concepts have been known and applied for many years in the radio industry. Nokia is the first in the optical networking industry to adapt these techniques to high-speed optical wavelengths. A key Nokia innovation with the PSE-3 coherent DSP is the probabilistic shaping distribution matcher that transforms a sequence of uniform data bits into a sequence of Gaussian-shaped symbols. For optical wavelengths, the distribution matcher must operate at very high symbol rates with an efficient algorithm that can be incorporated into a digital signal processor. The distribution matcher is fundamental to generating probabilistic-shaped modulations — a Nokia patented innovation.

The Nokia PSE technology is used for interoperable building blocks across the 1830 PSS and 1830 PSI families to address specific needs for telco/mobile, data center, enterprise and industry applications. Examples include integrated functional chassis-based elements for CO applications and disaggregated functional compact modular platforms for DC applications.

PCS - Ultimate performance and flexibility

Distance

Capacity

Optimal capacity at any distance

Discrete QAM formats perform well only at specific distances

Shannon limit approaching

25% Shaping gain

PCS
**Advanced wavelength routing**

Nokia advanced wavelength routing solutions are based on new colorless, directionless, contentionless, flexible grid (CDC-F) ROADMs and their ultra-wideband options can greatly increase your network capacity. Nokia’s advanced optical layer restoration software, operating over 1830 PSS CDC-F ROADMs, automatically re-routes and restores traffic around network faults, without the 50 percent capacity penalty imposed by dedicated 1+1 protection methods.

CDC-F ROADMs also support flexible grid channel spacing, which is another key feature in enhancing network capacity. New multi-modulation transponders support a wide array of optical modulation schemes, which allow you to finely tune and optimize the capacity of wavelengths to specific optical routes. Many of these newer, higher capacity modulation options require the flexible grid spacing available on CDC-F ROADMs.

With the introduction of the Ultra-Wideband Wavelength Routing solution, Nokia doubles available network capacity on the same fiber pair. It enables use of both the traditional C-band as well as the L-band of optical frequencies, providing up to 192 channels. Carriers can deploy C-band transponders to meet their initial requirements, adding L-band capacity as needed in the future.

No changes or upgrades are required to the core reconfigurable optical add drop multiplexer (ROADM) or in-line amplifier (ILA) nodes. This reduces your operational costs and eliminates network disruptions. When additional L-band capacity is required, you simply deploy the L-band-specific drop modules and transponders where needed. The Nokia Ultra-Wideband Wavelength Routing architecture provides up to 192 channels over the C+L bands along with CDC-F ROADM functionality.

**Advanced protection and restoration**

![Advanced protection and restoration diagram](image)

**C+L ROAD M Architecture**

![C+L ROAD M Architecture diagram](image)

- **Integrated C+L Amplifier Units**
  - 2x network capacity, 192 channels

- **Wavelength Routing**
  - CDC-F enabling flexibility, lower costs

- **Transponder – Client service Interfaces**
  - Latest generation of speed & density

Nokia Advanced Wavelength Routing solutions will improve your overall network flexibility, reduce operational costs and enable new, more efficient optical restoration options.
Packet/OTN switching

The 1830 PSS-x family of packet/OTN switches mate switching and photonic scale, delivering multi-terabit packet/OTN scale by leveraging the Nokia Transport Switching Engine (TSE) and the PSE. The 1830 PSS X-series metro platforms are optimized for both metro aggregation and metro core switching applications in optical transport networks (OTNs). As enterprises move toward 10G and 100G connectivity, the 1830 PSS X-series provide the flexibility and efficiency to support an evolution to higher capacity services, thus enabling continued revenue streams by meeting customer demand for more bandwidth.

For example, the X-series metro core platform with its centralized packet/OTN fabric, delivers up to 4.8 T/b/s OTN and/or up to 9.6 T/b/s packet switching capacity per shelf. The 1830 PSS X-series backbone core platform, which is optimized for core and large metro packet/OTN switching applications — such as international, national, regional and metro core network locations — supports up to 48 T/b/s capacity per rack with terabit card slots and provides the scale and efficiency to support an evolution to 100G services.

Converged multilayer control plane

The Nokia converged L0/L1 multilayer control plane lowers overall network costs and improves service velocity by simplifying planning and services provisioning. It includes service-optimized restoration and protection methods, and improved wavelength and OTN switching utilization. The converged multilayer approach simplifies provisioning using a single step, end-to-end service provisioning method. Multiple restoration and protection options, including electrical SNCP and GMPLS-based methods, are offered to achieve optimum performance per service. The Nokia Bell Labs multilayer optimization algorithm maximizes wavelength utilization and bandwidth efficiency, while minimizing use of the OTN switching capability.

MRN Control Plane - Scale & Versatility

<table>
<thead>
<tr>
<th></th>
<th>Layer 0 switching</th>
<th>Multilayer switching</th>
<th>Layer 1 switching</th>
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<tbody>
<tr>
<td><strong>Scalability</strong></td>
<td>Optical layer scales well for high rate services</td>
<td>High scale (L0) with efficient grooming (L1)</td>
<td>Efficient up to ~ 10 T/b/selectrical switching</td>
</tr>
<tr>
<td><strong>Versatility</strong></td>
<td>Best for networks with high rate traffic</td>
<td>Optimum solution for mix of low- and high-rate traffic</td>
<td>Best for networks with mostly lower rate (10G) traffic</td>
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<tr>
<td><strong>Efficiency</strong></td>
<td>Multiplexing and grooming using transponders and muxponders</td>
<td>Fewer wavelengths and smaller OTN switches fabrics</td>
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</tr>
<tr>
<td><strong>Resiliency</strong></td>
<td>Optical layer restoration plus DWDM protection</td>
<td>Low cost optical restoration and fast electrical protection</td>
<td>Electrical switch protection and restoration</td>
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5G-ready mobile transport

Mobile broadband demand continues to drive the need for more capacity, thus fueling investments in LTE and LTE-A networks while, at the same time, driving major investments in 5G. A scalable, converged transport network can tap these investments and leverage existing infrastructures in order to cost-effectively deliver extremely scalable capacity and maximize fiber resources.

As part of the Nokia 5G Anyhaul solution, Optical Anyhaul with time-sensitive networking capability enables the deployment of a variety of distributed RAN, centralized RAN, and C-RAN architectures. It also supports high-capacity data rates, delivering minimum latency with maximum reach. These capabilities let operators optimize performance and deploy services faster — all with a fully transparent, scalable solution that supports all services.

Nokia Optical Anyhaul: supporting today's and future 5G networks

With multiple RAN architectures and RAN technologies in the mix, mobile transport networks must accommodate diverse protocols and traffic types. These must also be supported in accordance with their underlying service characteristics.

In other words, mobile transport networks must have the flexibility required to support ‘anyhaul’ (i.e., various forms of backhaul, mid-haul and fronthaul) while also meeting the strict synchronization and reliability requirements for each service. Nokia Optical Anyhaul is ideal in this role, providing you mobile transport in support of CPRI fronthaul, Ethernet fronthaul, and Ethernet backhaul applications.

Nokia Optical Anyhaul

Nokia Optical Solutions address all customers and market segments
Open programmability

Nokia offers innovative, modular open hardware and software solutions complemented by its own systems integration practice. These highly programmable, open solutions enhance network value creation by enabling you to rapidly innovate applications to optimize and monetize network infrastructure. WaveFabric solutions simplify your transformation to open optical networking with sustainable DSP, wave routing and packet-OTN innovations. They also have links to WaveSuite Service Enablement and Network Insight applications.

We build open networking into the foundation, so as to enable automation. Openness is pervasive across WaveFabric solutions with open interfaces, open applications and embedded agents, and open highly programmable platforms. This gives you maximum flexibility in deploying and upgrading best-of-breed, multi-sourced, open solutions including both integrated as well as disaggregated, compact modular platforms.

Open networking solution elements:
- Programmable, PSE/PCS-enabled muxponders, transponders and uplinks
- Advanced wavelength routing with integrated CDC-F ROADM's that enable dynamic reconfigurable networking including open line systems
- The Nokia Network Services Platform (NSP)
- Normalized open APIs and networking apps
- Mature and widely deployed GMPLS photonic control plane
- Nokia system integration practice.

Open, intuitive, focused apps for Service-automation and network optimization

Agile, multi-vendor network
Secure by design

Your business runs on data. With the increasing value of confidential data generated and transmitted across networks, confidential data has become ever more attractive to thieves and intruders. Consequently, the number of attacks and breaches continues to rise. In response, you must secure your networks to protect in-flight data and guard against network intrusions.

The Nokia Secure Optical Transport solution ensures data integrity, high availability for service continuity, and addresses security threats cost effectively and in a manageable way. Among other things, the solution implements physical layer encryption with centralized key management. This provides a first line of defense, ensuring that all transmitted data is encrypted and rendered useless if it falls into the wrong hands.

The solution employs the Nokia 1830 Security Management Server (SMS), a secure, scalable module that supports management of the cryptographic life cycle of each encrypted wavelength service — the keys generated to perform the encryption — as well as the management of encryption key expiration, rotation and destruction. The Nokia 1830 SMS enables you to offer managed infrastructure services to your customers and internal stakeholders while allowing you to keep full ownership and control of your own cryptographic keys and encryption parameters.

Combined with optical intrusion detection tools and optical time-domain reflectometer (OTDR) capability, you can localize issues and detect intrusions through variations in power levels. This improves network security while retaining the flexibility to support a wide range of applications and services, including data center interconnect, LAN interconnect, high-performance computing, wavelength services, and Carrier Ethernet services.

The Nokia Secure Optical Transport solution offers several key business benefits, including:

- Effective L1 encryption as part of an overall defense-in-depth strategy to protect business-critical data
- Lower cost, ongoing security management using centralized, unified key management
- Independently certified solution that ensures compliance with strict security standards.
The Nokia WaveFabric portfolio offers massively scalable, mission-critical solutions that cover the entire breadth of network applications from mobile transport to metro access and aggregation, from core long haul and sub-sea to private networks. And, Nokia is a leader in offering integrated packet-optical solutions based on our innovation and investment in game-changing silicon, software and optics.

**Optical is everywhere**

Nokia Optical Solutions address all customers and market segments

**Mobile**
4G/5G Anyhaul, aggregation of legacy TDM circuits and migration to packet-optical services.

**Metro Access and Aggregation**
Metro/regional networks collect and aggregate traffic to the SP core.

**Core - Long Haul and Subsea**
High data rates, massive scale, long distances, lowest cost/bit/km. Mesh core router interconnect and leased line + wholesale transport.

**Private Networks**
Enterprise, public sector, and education networks for disaster recovery and cloud connectivity.
The portfolio is comprised of two components:

**WaveFabric Core**

WaveFabric Core leverages advanced wavelength routing, packet-OTN switching and photonic service functions in integrated WDM systems, disaggregated systems, and packet-OTN systems to address metro/access aggregation, backbone and subsea applications.

- Coherent DSPs
- Packet-OTN switching
- Wavelength routing
- Security
- Multi-layer control

**WaveFabric Edge**

WaveFabric Edge provides solutions for mobile anyhaul, business services, TDM migration, cable DAA, and edge DCI. It meets new 5G-era network requirements such as multiservice, high capacity, low latency and stringent timing with WDM and Time Sensitive Networking (TSN).

- Mobile transport / TSN
- Metro / access aggregation
- Packet-optical transport
WaveFabric core

High-capacity core

Support next-generation DWDM multiservice, multilayer P-OTN transport with the Nokia 1830 Photonic Service Switch (PSS). The 1830 PSS platforms let you deploy services rapidly, reduce network TCO, and extend network lifecycles. They transform traditional DWDM into a flexible transport layer with capabilities such as 100G–600G transport wavelengths, agile wavelength routing, and scalable multilayer switching and services. The 1830 PSS portfolio helps you optimize optical networks to meet unpredictable traffic demands. The platforms provide efficient transport at any scale, from compact access to the converged Optical Transport Network (OTN)/DWDM core.

- P-OTN multiservice transport: 1830 PSS-4, -8, -16, -32
- P-OTN switching: 1830 PSS-36, -64; 1830 PSS-8x, -12x, -24x

High-capacity DCI

The Nokia 1830 Photonic Service Interconnect (PSI) product family provides industry-leading performance, scale, and simplicity for data center interconnection (DCI) applications. The massive shift to cloud-based IT services by private companies, communication service providers (CSP), and internet content providers (ICP) is dramatically lowering software application costs, while expanding computation and storage scalability. The 1830 PSI product family offers optimized optical network solutions for the cloud era.

- 1830 PSI-M modular
- 1830 PSI-L

Network management

The Nokia Network Services Platform (NSP) provides automation to deliver transport services faster, SDN control to optimize network utilization and traffic engineering, as well as dynamic assurance for operating the network with maximum performance and reliability. NSP brings more efficiency across multi-vendor IP/MPLS, Ethernet and optical networks, whether virtualized or physical – lowering operating costs and enabling services to be delivered to market faster. NSP modules for transport network resource control include the Network Resource Controller – Transport (NRC-T) and the Network Functions Manager – Transport (NFM-T).

- Nokia NSP Modules for transport network resource control: NRC-T, NFM-T
With the growing demand to connect more devices and enable new applications, you need to cost-effectively scale network capacity. The Nokia 1830 Versatile WDM Module (VWM) portfolio supports next-generation WDM multiservice transport. Provide passive or active extension of CWDM or DWDM to non-WDM-capable network elements. The Nokia 1830 VWM supports a wide range of applications and services, including mobile fronthaul.

• 1830 VWM solution elements

5G addresses a broad range of services and segments beyond traditional consumer mobile services to business-to-business-to-consumer (B2B2C) to enterprise and industrial systems control. This shift impacts network architectures and requirements. It is driving network modernization and an evolution to Cloud RAN. This evolution requires high capacity, low latency, stringent synchronization, highly reliable and deterministic transport. The new Nokia 1830 Time-sensitive Packet Switch (TPS) enables converged packet anyhaul for 3G/4G/5G networks.

• 1830 TPS

To meet demand for superior Ethernet-based cloud, mobile and video services, you need a packet-optimized metro DWDM core that provides efficient and versatile traffic aggregation. Our Integrated Packet Transport solution keeps you ahead of the demand curve. It delivers the capacity, flexibility, and packet feature richness you need to handle unrelenting traffic growth. Our solution gives you comprehensive and optimized packet transport. It lets you leverage the power and value of our Service Router Operating System (SR OS) and multiservice 1830 PSS WDM transport platforms.

• Ethernet client muxponder/OTN and uplink cards
Network demarcation and transport for Ethernet and wave services

The Nokia 1830 Photonic Service Demarcation (PSD) is a low-latency, compact and versatile Network Interface Device (NID) providing network demarcation at customer premise sites. It effectively extends the reach of the optical network in support of MEF compliant 10G Ethernet and wavelength services.

- 1830 PSD

Multi-service metro access

The Nokia Optical Network Extender (ONE) is a stackable, 1 RU multi-technology platform for disaggregated OTN, packet, and photonic functional blocks. 1830 ONE complements the 1830 PSS product family in an open, seamlessly managed edge-to-core architecture.

- 1830 ONE-hub, -aggregator, -micro-ROADM

Private optical networking

The Nokia WaveLite optical transport product family provides an enterprise purpose-built solution for DCI and corporate connectivity. Comprising a five-member set of service aggregation and transport components, WaveLite features three multiplexing transponders (muxponders) for aggregating a wide range of client services onto higher rate optical lines using commonly available pluggable optical modules.

- WaveLite Metro 20 Muxponder, Metro 200 Muxponder, Access 200 Muxponder
Extraordinary connectivity, capacity and capabilities for the 5G era

Expanding and emerging requirements for cloud connectivity, 5G applications, IoT, Industry 4.0, and smart cities requires more network connectivity, capacity, and capability. The network investment required will be significant, thus the need to create value and improve return on your investment by:

• Scaling and modernizing infrastructure to grow capacity while increasing performance and resiliency
• Reducing Opex and optimizing Capex by simplifying and streamlining end-to-end service operations, and making more efficient use of network resources
• Generating revenue by supporting innovative services and business models to create value.

Combining massive scalability, open programmability, security and high performance into application-optimized platforms, Nokia WaveFabric provides you with the best-in-class connectivity services to build your business. WaveFabric is the ideal foundation for an open, business-driven, service-ready optical network and is a foundational element for your business-driven transformation.
About Nokia

We create the technology to connect the world. Powered by the research and innovation of Nokia Bell Labs, we serve communications service providers, governments, large enterprises and consumers, with the industry’s most complete, end-to-end portfolio of products, services and licensing.

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