IP-optical networks for research and education networks

Providing high-performance, scalable and secure networks

White paper

Research and education networks (RENs) are the lead users of networking technology, often years ahead of commercial service providers. Innovations in photonic transport and switching, combined with IP routing and open software control and security, enable RENs to better serve their collaborative communities with a powerful communications infrastructure that will further education, scientific and industrial research as well as commerce and will improve overall quality of life. This white paper explores the goals and challenges of RENs and the technologies that can provide high-performance, scalable and secure IP-optical networks to serve them.

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Introduction

Research & Education (R&E) networks (RENs) facilitate massive collaboration as they connect universities and laboratories to one another and to cloud services. They require unusual bandwidth capacity and flexibility without the constraints placed on them by commercial service providers.

Over the years, various states, nations and groups of nations formed collaborative networks to serve the unique needs of the R&E community. National research and education networks (NRENs) were established to connect R&E computing communities that are state-of-art in their research. The result is that RENs are the lead users of networking technology, often years ahead of commercial service providers.

Technological innovations in photonic transport and switching, combined with IP routing and open software control and security, enable RENs to better serve their national communities with a powerful communications infrastructure that will further education, scientific and industrial research as well as commerce and will improve overall quality of life. Using these advanced networking tools, RENs can provide services to their constituents that match their specific needs through a high-bandwidth, highly agile, secure and scalable network. In turn, RENs make the best use of their network resources while fostering collaboration among R&E institutions.

Purpose and goals of RENs

The purpose of RENs, first and foremost, is to advance the research to improve our lives and solve basic problems faced by humanity. High-performance computer networks are needed to foster the co-operation and communication among the R&E institutions and to bring the ideas and brilliant minds together.

Foster global, national or regional innovations

The scientific discoveries that improve our lives come from scientific research, inventions and discoveries. Sharing of the knowledge and information expedites the innovations.

Provide terabit network and multi-cloud connectivity

Long a proving ground for networking technology, RENs continue to push the envelope when it comes to the latest and most advanced technology advancements. To share the voluminous research data in real time requires terabit interconnectivity among various universities, research institutions and government departments and their networks.

Security: Protect user identity and provide data protection

Given the sensitive nature of the confidential information (data), RENs need to assure security: both data integrity and identity protection.

Sample IP services offered by RENs

RENs need to provide a variety of IP services, including internet transit, Layer2/Layer 3 (L2/L3) VPNs and security.

Internet transit

Transit allows traffic from an ISP or customer network to cross or “transit” the transit provider network to connect to the rest of the internet.

Internet transit is also referred to as internet or IP transit.

RENs provide reliable, high-performance and secure IP transit service to their customers—the R&E institutions.

L2/L3 VPN

The VPN service can be used for connectivity between clusters, grids, clouds and high-performance computing centers (HPCs), allowing them to share distributed resources.

VPNs are used in a variety of ways, from a long-term infrastructure with a high demand for intensive network usage to quick point-to-point connections for a conference demonstration.

L3 VPNs are offered for many-to-many or one-to-many environments and data isolation across the REN for assured performance (10G to 100G) and security.

Security

RENs carry data from many users. Some of this traffic is government-related research; other traffic is industry-sponsored research. All of this has implicit value to someone and is a potential target.

The REN team needs to secure the logical and physical infrastructure of the REN and all data crossing the network, responding to network security incidents and mitigating breaches, weaknesses and risks.

Essentially, this security relates to the prevention, detection, reporting and mitigation of incidents targeting the REN infrastructure.

REN networking and security challenges

The higher-education landscape is exceptionally complex. Research institutions and universities—some with tens of thousands of students, researchers, faculty and staff—need to support robust communications and collaboration. The network is the foundation for almost everything that happens at these institutions and for collaborative research among scientists and students within and across various universities and research organizations. Legacy networking infrastructure may not be up to the task.

With the proliferation of complex networks comes the increased risks of cyber attack. With sensitive research in advanced fields such as genomics, medicine and high-tech in the higher-education institutions, the data that is shared, the devices and users are subject to cyber attack and IP theft. The RENs, because they are also a provider of the internet exchange, can be at the center of distributed denial of service (DDoS) and ransomware attacks.

Due to their large footprint, RENs also pose challenges of network management—specifically to monitor and configure the vast number of devices, often from multiple vendors. Network automation with artificial intelligence/machine learning (AI/ML) tools are needed for agile configuration and compliance management.

The challenges include complexity, scalability, automation and security.

Network complexity

The large number of researchers and scientists belonging to different organizations and their interconnectivity (WAN, data center, cloud) pose significant network complexity challenges.

Scalability

NRENs span states, countries and continents, and they connect thousands of components and millions of users. The networks need to be highly scalable in a sustainable manner.

Automation

The complexity and size of the networks can result in management and provisioning challenges. Network automation tools can help alleviate these challenges. Intent-based network management and automation are critically important to the network and security administrators at the network operations center (NOC) of a REN. The lack of resources and expense of staffing is a gating factor in R&E institutions, and most of them are funded by non-profit organizations.

Security

Given the complexity and size of the RENs, the security perimeter is extremely vast. The nature of the data is sensitive and confidential. The reliability of RENs can be tested by DDoS threats and various types of attacks.

Technologies pertinent to RENs

In this section we discuss a few of the technologies that are most relevant to RENs. These include IP networking solutions such as Ethernet VPN (EVPN) and segment routing, security solutions such as DDoS protection, advanced optics via 800G coherent routing, and management techniques such as IP-optical coordination.

EVPN

There is inherent complexity in today's networking environment. There are a wide range of services, each using different protocols to deliver each service: L2 VPN, L3 VPN, data center interconnect (DCI) and software-defined wide area network (SD-WAN). This leads to management complexity and increased service delivery costs for new services.

In addition, services cross multiple WAN domains, multiple cloud domains, multiple branches and multiple exchanges. Finally, there is the added challenge of automation to deliver on-demand services with cloud-speed interconnect.

EVPN unifies service delivery with network and operational simplification. EVPN has a single control plane, the flexibility for any data plane plus extensive interworking functions. In addition, EVPN is common to the data center and WAN; this ensures seamless service delivery across WAN and data center boundaries.

Finally, agile and dynamic services require end-to-end orchestration across all services. Cloud-friendly EVPN enables end-to-end orchestration to simplify operations support system management and provisioning with a single VPN technology that unifies service delivery through service automation and rapid service enablement.

Segment routing

Segment routing is a source routing tunneling mechanism in which the paths are encoded as sequences called segments, which are advertised by link-state routing protocols: Intermediate System-to-Intermediate System (IS-IS) and Open Shortest Path First (OSPF).

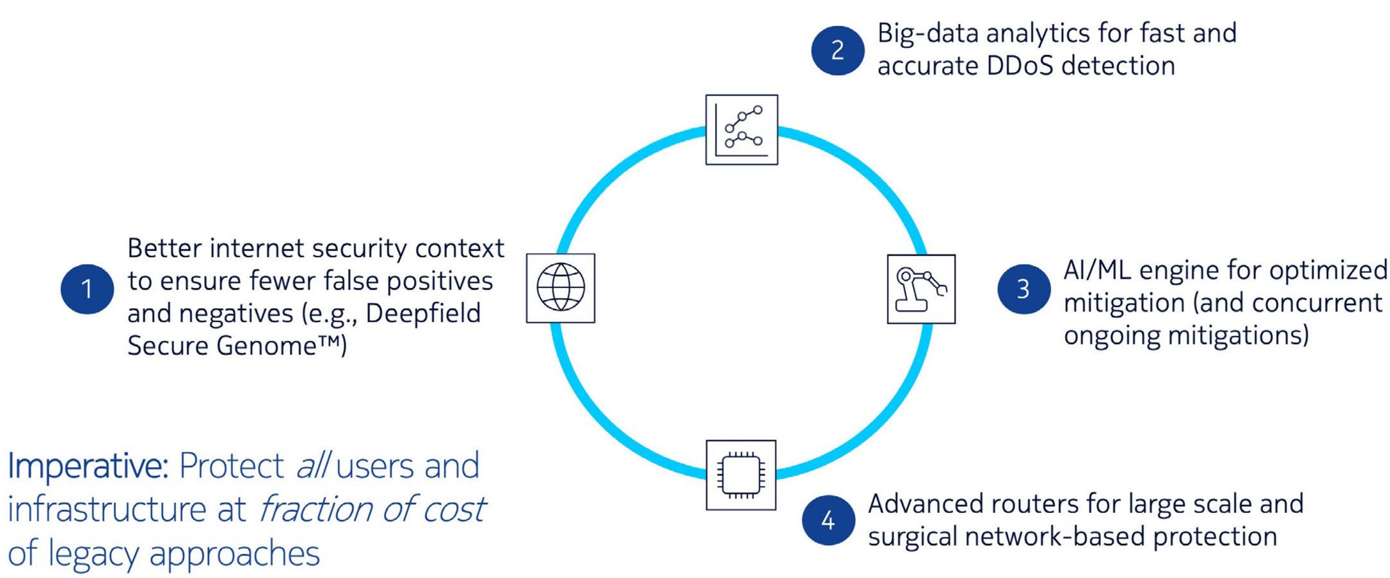
Segment routing is becoming the unified transport layer of choice because it is simple to understand, provides the path control and protection you need, and is very scalable and stateless.

The biggest advantage of segment routing is that it removes all the protocol complexity. The Nokia Service Router Operating System (SR-OS) implements segment routing.

Advanced DDoS protection

RENs require next-generation DDoS protection that leverages big data analytics, AI/ML and advanced routing technology (see Figure 1).

Figure 1. Next-generation DDoS protection

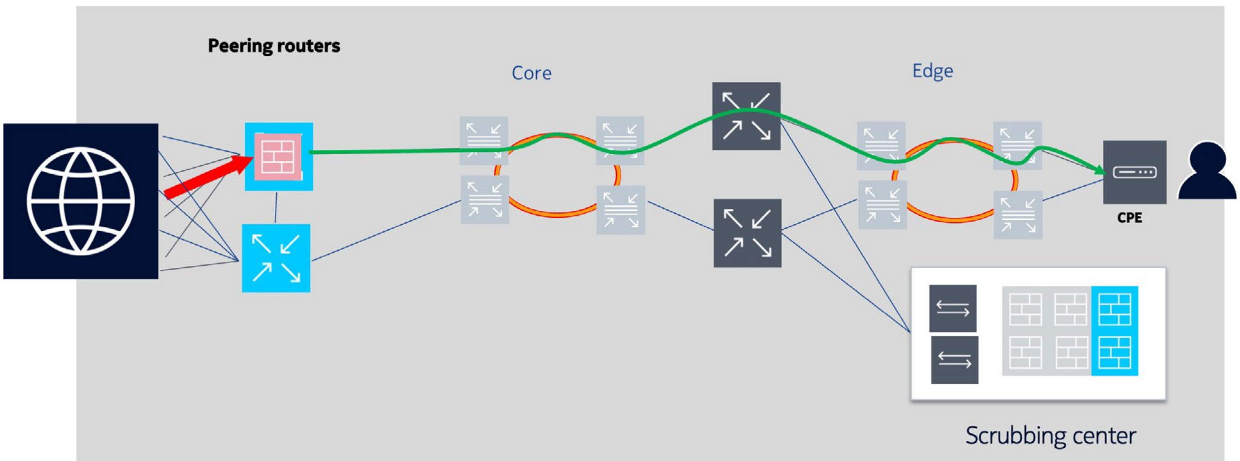


As shown in Figure 2, advanced routers can also be part of the DDoS defense by:

- Leveraging the latest network processing for in-line, terabit-scale, deep filtering
- Stopping attacks at the network edge
- Building a surgical filter list for each attack.

Advanced routers do all of these things without any service performance degradation.

Figure 2. Advanced routers for network-based DDoS mitigation

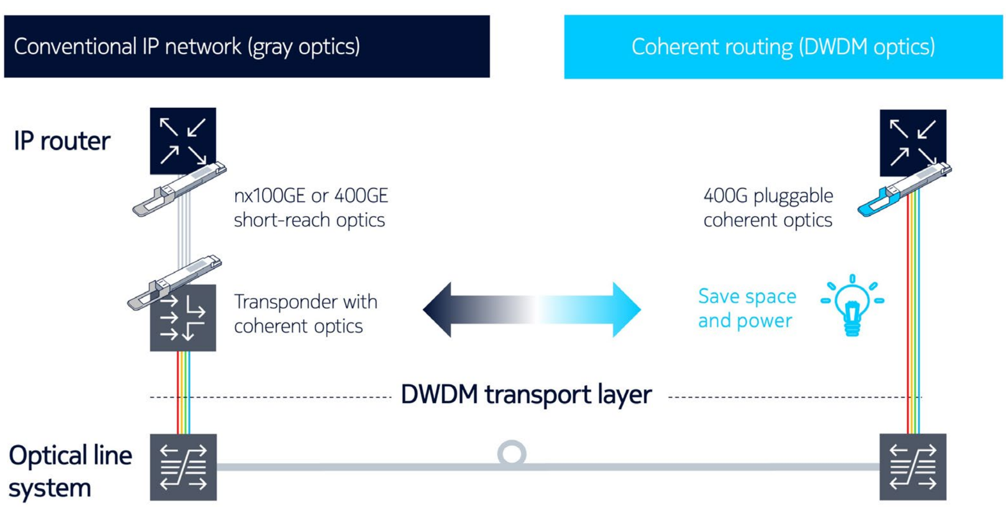


400G/800G coherent routing

Conventional IP networks deploy short-reach gray optics to connect to a transponder with dense wave division multiplexing (DWDM) optics. The DWDM optics emit tunable wavelengths with coherent detection that can be carried across the optical transport network over any distance.

Coherent routing (see Figure 3) leverages profile-optimized 400GE/800GE digital coherent optics (in QSFP56-DD and CFP2 line cards) to interconnect IP routers directly and efficiently over coherent DWDM wavelengths that can span distances of hundreds of kilometers.

Figure 3. Coherent routing using DWDM optics



This approach saves on cost, space and power by eliminating the additional optical-electrical-optical conversion in external DWDM transponders while achieving similar port densities to conventional IP-optical interfacing methods using 400/800G gray optics.

Coherent routing can be deployed over a DWDM optical layer as well as over dedicated fiber spans.

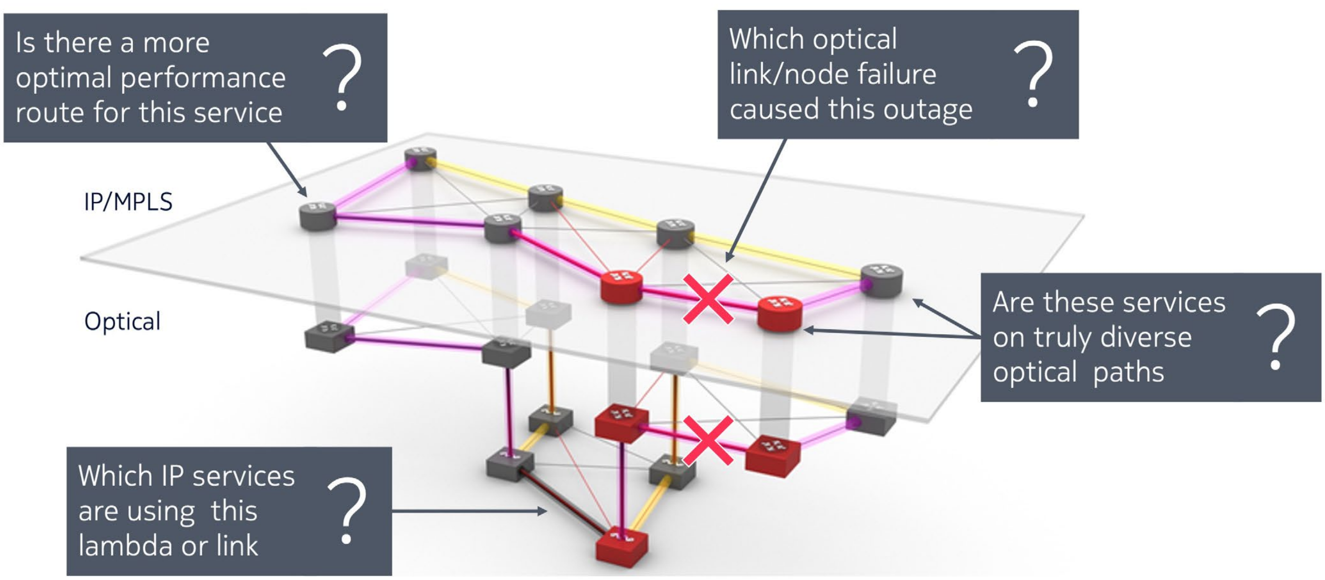
IP-optical coordination

In recent years IP routing and optical transport have gone through a significant technology evolution to address the connectivity and capacity needs of the digital era.

However, IP routing and optical transport are in many cases still deployed and operated as separate domains; this makes it difficult to coordinate and automate cross-domain service provisioning and assurance processes. The separate domains also duplicate functions and costs.

Figure 4 shows the multi-layer management and coordination challenges caused by separate IP and optical layers in a network.

Figure 4. Interdependencies and cross-impacts of separate IP and optical layers

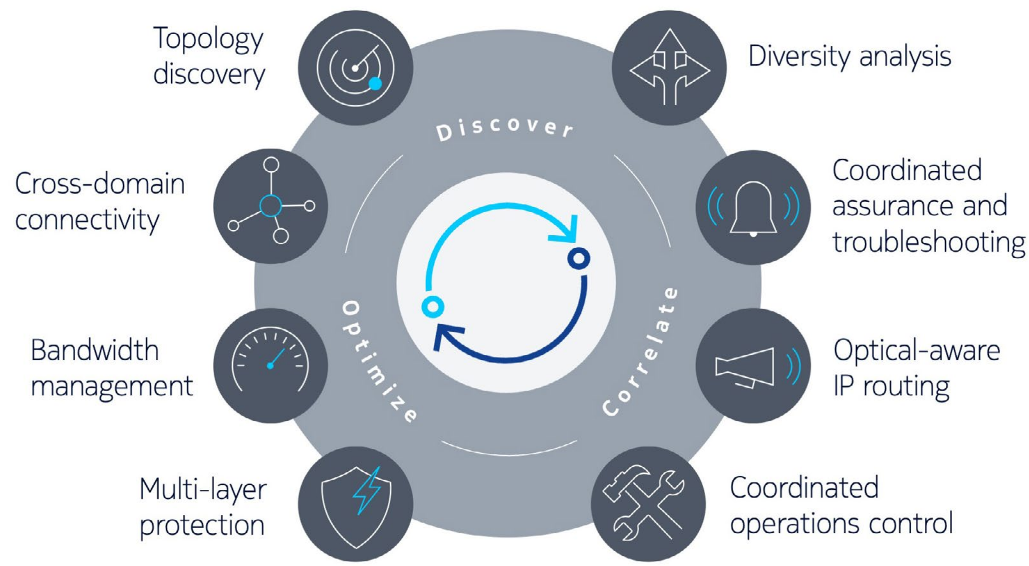


The advent of pluggable coherent optics delivered via Nokia Coherent Routing helps network operators build faster and more efficient IP transport solutions for 400 Gb/s and up. Coherent routing also scales and simplifies network operations by managing and coordinating IP routing and optical transport domains through automation.

The IP-optical coordination and automation shown in Figure 5 delivers the following operational benefits:

- Streamlined operations, for OPEX savings
- Better network utilization, for CAPEX savings
- Higher quality and reliability, for improved customer satisfaction
- Faster service provisioning, for faster time to revenue.

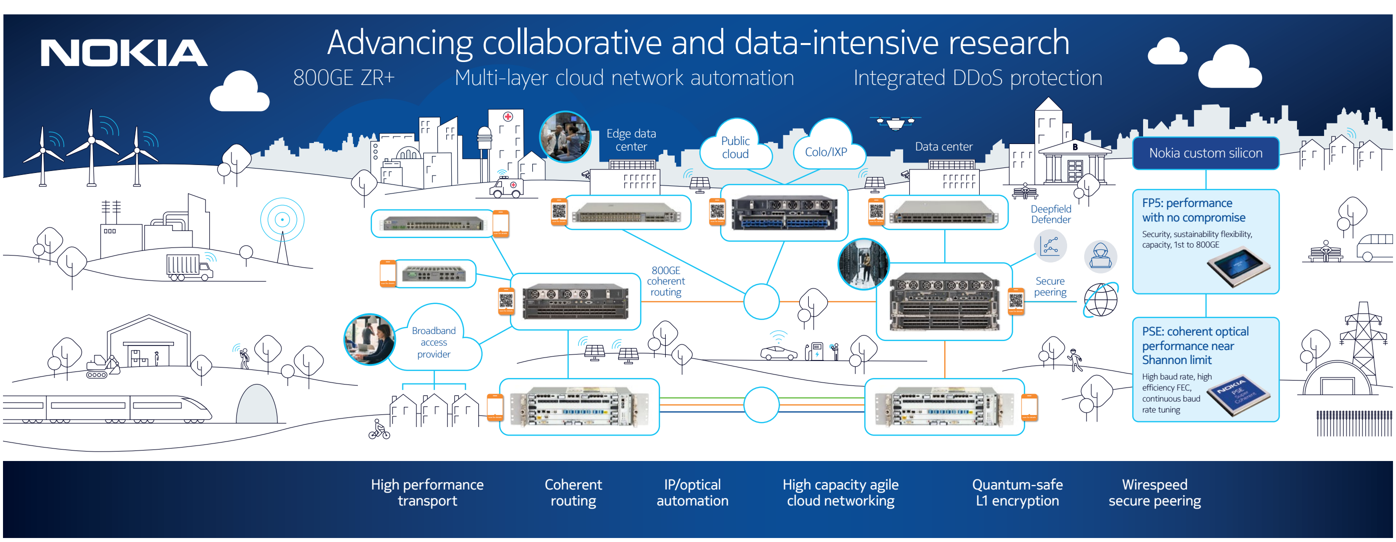
Figure 5. IP-optical coordination and automation



Putting this all together with Nokia

As shown in Figure 6, the Nokia REN solution leverages all the technologies discussed in the previous section.

Figure 6. Nokia REN solution



High-performance optical transport with IP routing

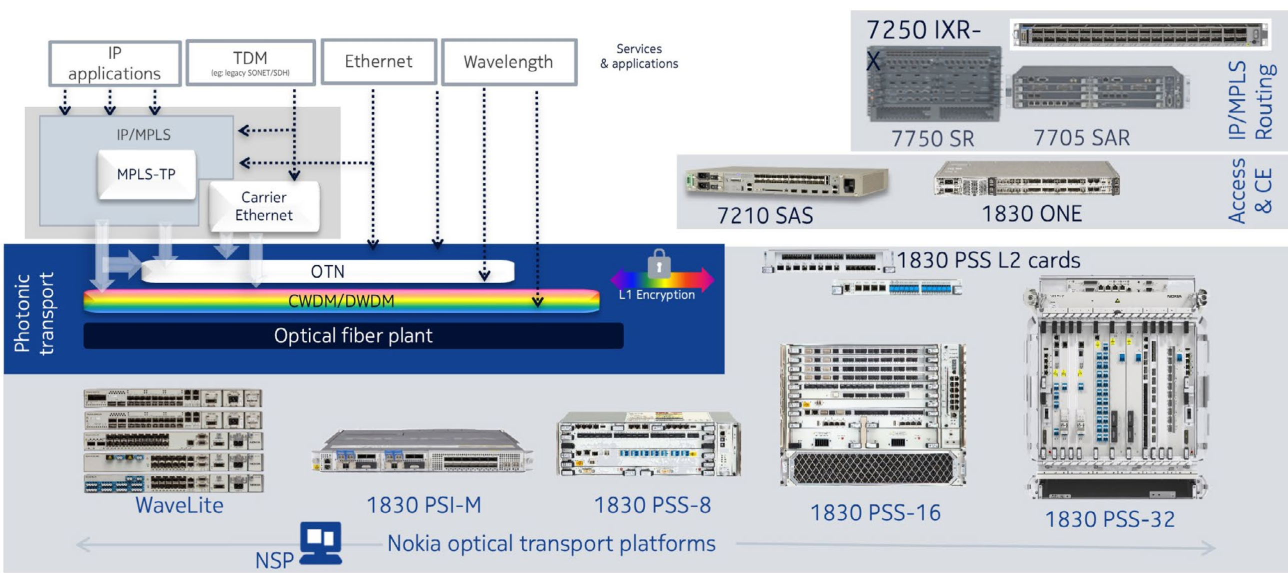
By integrating IP routing capabilities into a packet optical transport backbone, the NREN becomes equipped to deliver any premium service, from L1 optical wavelengths to MEF Carrier Ethernet or L3 VPNs. Whether the communication is point-to-point or multipoint, Ethernet, IPv4 or IPv6, any service can be easily provisioned and delivered on demand with high security, integrity and reliability.

At the optical layer, traffic is secured thorough AES-256 optical encryption that meets FIPS-140-2 and CC certification standards for key strength through centralized key management.

With an integrated IP and optical transport structure, the REN can easily reach any institution in its photonic nation, connect the institution with a high-capacity optical line matched to its needs, and service those needs with a high degree of reliability and service customization.

Nokia's portfolio of products for RENs (see Figure 7) is uniquely designed to offer this high degree of control through its IP routing and optical transport products controlled by a single, unified network management platform.

Figure 7. Nokia portfolio of NREN products



Nokia 1830 Photonic Service Switch

The 1830 Photonic Service Switch (PSS) is a multi-reach photonic platform utilizing coherent detection and Nokia's industry leading PSE coherent signal processors. Building on the zero-touch photonics approach, which enables easier operations for reduced costs and faster wavelength services deployment, the 1830 PSS exceeds requirements for NREN networks.

Nokia 1830 Photonic Services Interconnect - Modular

The Nokia 1830 Photonic Services Interconnect – Modular (PSI-M) platform provides industry-leading performance, scalability and simplicity for DCI applications. The massive shift to cloud-based IT services by enterprises, communications service providers and internet content providers is dramatically lowering software application costs while expanding computation and storage scalability. The 1830 PSI-M offers optimized optical network solutions for the cloud era.

Nokia 7210 Service Access Switch

The Nokia 7210 Service Access Switch (SAS) product family provides the deployment flexibility, service richness and reliability you need to extend segment routing, IP/MPLS and Carrier Ethernet to the access points of your network. With a wide variety of platforms, it is used for business VPN, residential broadband, demarcation and mobile backhaul, and is also widely used in industry, public-sector and enterprise applications.

Nokia 7250 IXR-X Series Routers

Nokia 7250 Interconnect Router-X series (IXR-X) routers are high-speed, high-density 1RU platforms. They are ideal as leaf nodes in data centers and multi-access edge computing nodes and are valuable for access and aggregation as well as 5G interconnectivity.

Nokia 7705 Service Aggregation Router

The Nokia 7705 Service Aggregation Router (SAR) delivers legacy TDM and advanced IP/MPLS services, making it ideal for industries, enterprises and NRENs. The 7705 SAR provides an easy migration path from TDM networks. With depth in routing protocols, service scaling, security and timing, it meets the rigorous demands of mission-critical networks. It is available in multiple compact platforms that reduce equipment footprint and energy costs. These platforms deliver highly available services over a wide variety of network topologies. Strong quality of service (QoS) capabilities deliver customer satisfaction and the ability to differentiate service levels.

Nokia 7750 Service Router

The 7750 Service Router (SR) is a high-performance, multiservice edge router designed for the concurrent delivery of advanced residential, business and mobile services on a common IP edge platform. Leveraging the Nokia in-house 400 Gb/s FP3 silicon technology, the 7750 SR delivers exceptional performance and scalability to a wide range of IP services, with service intelligence to further drive operational efficiency.

Nokia 7950 Extensible Routing System

The 7950 Extensible Routing System (XRS) portfolio is a suite of powerful core routing platforms that deliver leading scalability, efficiency and versatility without compromising flexibility. The portfolio revolutionizes the economics of delivering the internet by offering up to five times the density of existing alternatives while consuming only one-third the electricity. With support for up to 80 100GE and/or 800 10GE ports in a single 19-inch rack, the 7950 XRS shatters current density norms and paves the way for scaling the service provider cloud infrastructure.

Nokia WaveLite

Nokia WaveLite is a compact, modular optical transport family that provides a means to build an enterprise purpose-built DCI solution. Included are multiplexing transponders (muxponders) that aggregate a wide range of client services, such as Fibre Channel, Ethernet, OTN, SDH/SONET and SDI video, onto higher-rate optical lines through the use of commonly available pluggable optical modules.

IP-optical automation

The IP-optical automation and coordination in NRENs is provided by the Nokia Network Services Platform (NSP).

The Nokia NSP unifies service automation with network optimization, enabling IP/optical network operators to deliver on-demand network services cost effectively and with scalability. The NSP provides operators with an efficient way to define, provision and activate network services across networks that can span multiple layers (L0 to L3), services and physical/virtual infrastructure as well as equipment from multiple vendors. The NSP allows operators to keep service quality and network efficiency high by intelligently adapting networks to real-time changes in demand and traffic patterns.

Wire-speed security

RENs can now ensure the confidentiality and integrity of all data flowing through their networks with ANYsec universal network encryption. ANYsec leverages Nokia FP5 silicon to extend the low latency and simplicity of Media Access Control security (MACsec) encryption to tunnels, flows and slices engineered using MPLS, segment routing and IP. With FP5 silicon, network encryption becomes a universal function of the network itself.

DDoS protection

Nokia Deepfield Defender stops DDoS traffic before it impacts you. Nokia Deepfield uses big-data IP analytics, combining network data (telemetry, DNS, BGP, etc.) with Nokia's patented Deepfield Secure Genome™.

Secure Genome is a cloud-based, up-to-date data feed that tracks the security context of the internet. With detailed visibility into over 5 billion IPv4 and IPv6 addresses, Secure Genome tracks internet traffic over 30 categories and deploys more than 100 ML rules for automatic classification and precise allocation of applications and flows into security-related traffic types and categories. As a result, Secure Genome "knows" intricate security details of the internet, such as details about prior attacks, insecure servers and compromised Internet of Things devices that can be used for DDoS attacks.

Conclusion

Long a proving ground for networking technology, RENs continue to push the envelope when it comes to the latest and most advanced technology advancements. Many RENs were first to trial technologies such as IPv6, 100G core routing, coherent optics as well as Wi-Fi 6 and private wireless 5G access well before mainstream communications service providers. More often than not, Nokia's optical or IP routing equipment, or both, were part of those trials.

The deployment of a ubiquitous, national IP and optical REN provides the community with an essential backbone to connect educational institutions, enable research collaboration and foster economic development.

Nokia offers the industry's most powerful IP and optical routing and transport solutions, delivering the most critical network capabilities—scalability, automation and network-level applications—to form the REN. Nokia solutions are based on the latest, most advanced transport and routing technologies. As a complete solution, an IP-optical network allows the NREN to offer high-capacity services dynamically.

For more information about Nokia integrated IP-optical solutions, please visit:
www.nokia.com/networks/ip-networks/

Abbreviations

AI	artificial intelligence
BGP	Border Gateway Protocol
CAPEX	capital expenditures
CE	customer equipment
CPE	customer premises equipment
CWDM	coarse wave division multiplexing
DCI	data center interconnect
DDoS	distributed denial of service
DWDM	dense wave division multiplexing
EVPN	Ethernet VPN
IP	Internet Protocol
ISP	internet service provider
IXR-X	Nokia 7250 Interconnect Router – X Series
MEF	Metro Ethernet Forum
ML	machine learning
MPLS	Multiprotocol Label Switching
MPLS-TP	MPLS – Transport Protocol
NSP	Nokia Network Services Platform
ONE	Nokia 1830 Optical Network Extender
OPEX	operating expenditures
OTN	optical transport network
PSI-M	Nokia 1830 Photonic Services Interconnect - Modular
PSS	Nokia 1830 Photonic Service Switch
SAR	Nokia 7705 Service Aggregation Router
SAS	Nokia 7210 Service Access Switch
SDH	Synchronous Digital Hierarchy
SDI	serial digital interface
SONET	Synchronous Optical Networking
SR	Nokia 7750 Service Router
TDM	Time Division Multiplexing
VPN	virtual private network
WAN	wide area network

About Nokia

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

As a B2B technology innovation leader, we are pioneering the future where networks meet cloud to realize the full potential of digital in every industry.

Through networks that sense, think and act, we work with our customers and partners to create the digital services and applications of the future.

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