Optical transport networks for power utilities

Network modernization with the Nokia 1830 Optical transport portfolio

Application note

Abstract

Utility communications networks face new challenges as capacity demands increase, new IP/packet-based grid applications are introduced and embedded technologies age. The continued evolution of smart grid systems is combining with increased requirements for facility surveillance, AI-cloud data center interconnect (DCI) and other corporate IT functions while continuing to support existing operational technologies, such as SCADA and teleprotection. These factors and the pressure to ensure service reliability while controlling costs are forcing utilities to invest in the modernization of communications networks. Many technology choices are available to evolve the communications transport network toward a highly agile, easily scalable and efficient asset that the utility can depend on for the next few decades.

This paper focuses on the optical transport technologies and solutions of the Nokia 1830 Optical transport portfolio.

Contents

Modernizing power utility communications

The power utility grid in most countries was constructed in the early to mid-20th century. Power generation was centrally located and powered by coal or oil. Power was transmitted over high-tension lines to substations that reduced voltage for distribution to energy consumers. In many places, decades passed with few upgrades to transmission or distribution facilities. Yet in the last 25 years, advances in power line transmission, communications, monitoring and control technologies have offered utilities the possibility of reducing wasted energy while improving service reliability, customer satisfaction and safety. The advent of broadband communications services, and the need for connectivity among private data centers, presents many utilities with the opportunity to utilize their unique right-of-way position to realize new revenues.

Communications infrastructure must help the utility deliver energy to its customers with greater efficiency and reliability. In doing so, utilities improve customer satisfaction and operational performance. The communications network needed in a modern utility is quite different from that of a few years ago. Most power utilities have adopted smart grid technologies to efficiently and remotely monitor, control and automate service delivery. Many utilities are converging corporate operations and IT networks into shared WAN infrastructures. Each utility has a strategy to modernize its communications network, which requires an architecture that can support existing operations, ensure consistent service delivery and adopt new technologies. Taking the first step requires careful consideration of projected needs, embedded investment and available resources.

Requirements: Moving toward a packet optical network

The landscape of communications networks is rapidly changing as utilities deploy advanced grid control devices to improve energy efficiency and customer service while also reducing operational costs. These devices utilize different data protocols to communicate, yet need to operate across a common infrastructure. Modernization does not occur in a single step; older systems are replaced over time. The network must be capable of gradual upgrade, with ongoing support for older systems. At the same time, the network must be highly reliable and secure because it is the common foundation for the operation of the entire utility. The network is truly mission-critical.

A utility communications network must meet several requirements to deliver the promise of modernization. Specifically, it must offer:

- **Flexibility and scalability**: Application-specific networks are no longer viable in an environment where needs rapidly change, and resources are limited. For example, a utility network may need to support surveillance video as well as teleprotection, SCADA, advanced metering infrastructure and voice traffic. As utilities undertake grid modernization, networks need to scale in capacity while being flexible enough to support any type of data protocol, including Ethernet, IP, TDM, video, Fibre Channel and others.
- **Reliability**: For any utility application, the network must be highly resilient. Networks must be built using equipment designed for high availability, utilizing redundant systems and automatic protection mechanisms. The network also should utilize diverse connectivity paths and a rich set of diagnostics to predict and prevent outages before they occur.
- **Security**: As essential infrastructure to a region's stability, power utilities must protect their networks from an intrusion that could lead to service outages and protect consumer information from theft. In a world of rapidly increasing threats from bad-state actors, networks must be secured against highly sophisticated quantum computer attacks.

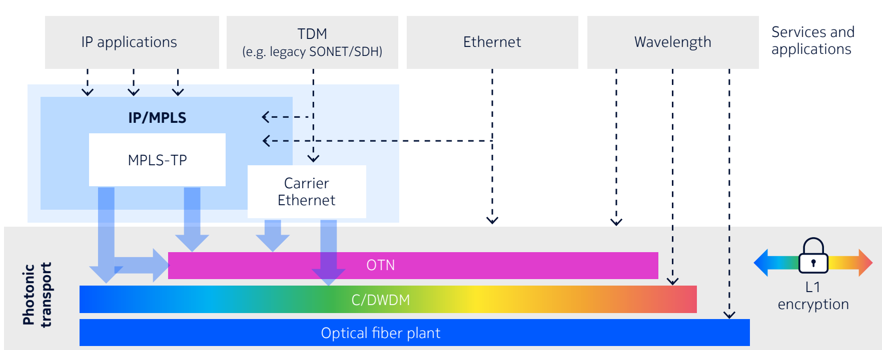
- **Deterministic performance**: The network should assign priority to critical applications to ensure availability during peak traffic periods. For example, teleprotection and surveillance video traffic should be assigned a higher priority than data center backup traffic, such that if total demand exceeds available bandwidth, only the lower priority data center backup traffic is temporarily impacted.
- **Ease of use**: The network must be easy to provision, operate and maintain. Software control should extend across network elements, reducing the need for physical hardware changes and allowing remote provisioning.
- **Long asset life**: Organizations require that capital assets be depreciated over relatively long time periods. A modernized network must support technologies from at least 15 years ago and for 10 years in the future. This implies use of a modular and extensible architecture, allowing older technologies to be easily maintained or phased out while new technologies such as software-defined networking (SDN) are gradually introduced.
- **Cost benefit**: All these requirements must be met with a high degree of economy, balancing initial capital expense with ongoing operational expense. Use of common platforms for multiple applications and a high degree of software control are desirable as are modular equipment architectures and common software control.

Utilities are increasingly moving toward applications needing IP or Ethernet connectivity. As a result, the need for packet transport is also increasing.

Optical transport in the modernized utility network

Meeting the requirements outlined above demands a network that makes use of modern technologies. Packet optical transport combines the efficiency and flexibility of packet services with the scalability, reliability and determinism of optical transport. Packet optical transport usually includes technologies such as WDM, SDH/SONET, G.709 OTN, MEF 2.0 Carrier Ethernet and MPLS-TP. The exact choice depends on specific applications and operator objectives. It is helpful to consider the major functions of each technology when making network design choices. Optical transport technologies are discussed below; packet technologies, such as Carrier Ethernet and MPLS-TP are outlined in other papers.

Figure 1. Optical transport ecosystem



Together, optical layer transport, switching and routing technologies provide connectivity for applications and services that accomplish a given task. Figure 1 depicts these technologies positioned roughly within the Open Systems Interconnection (OSI) reference model and shows their chief interdependencies.

Optical layer

At the optical layer, fiber is commonly used to build the physical network that connects utility offices, data centers and field operations. In a utility communications network, this may be accomplished through a privately owned outside fiber plant, and sometimes complemented with leased dark fiber, terminated by utility-owned equipment. Capacity can be scaled easily using coarse or dense wavelength division multiplexing (C/DWDM) systems. In optical WDM systems, each fiber can carry at least 96 wavelengths, each delivering traffic at speeds exceeding 1.2Tb/s or greater. Individual wavelengths can be dropped or added around the network and reconfigured as needed. In some applications, individual wavelengths provide logical separation between user groups carried along the same fiber. In addition to pure capacity, optical WDM can transport data over a wide range of distances, from very short spans within a data center to undersea cables connecting continents.

SDH/SONET and OTN

Optical wavelength capacity is usually shared among applications and users through various multiplex and switching technologies. SDH/SONET is a TDM method that was widely used to share capacity, deliver circuit-based services and ensure high reliability. As utilities upgrade their networks, they need the ability to efficiently carry both circuit-based TDM services and packet-based services.

SDH/SONET was developed in the 1980s to transport increasing volumes of voice traffic over fiber, based on fixed increments of voice channels. By the early 2000's, the ITU-T had defined an Optical Transport Network (OTN) in which optical networks reduced the complexity associated with scaling capacity and service diversity. In OTN, any client protocol, including packet or TDM, is placed into a flexible container as a payload for transmission over an optical channel. As the entire client signal is carried as payload, OTN is transparent to the end application.

Migration from an SDH/SONET network toward an OTN transport network is not done solely for reasons of increasing capacity. OTN offers scale plus the ability to transport any protocol including packet-based services such as IP, multiprotocol label switching (MPLS) or Ethernet. Virtually any application can be encapsulated into an OTN payload container for transport. These capabilities enable the utility to cleanly manage and maintain separation among internal applications, such as corporate IT and operational functions.

Security and encryption

Ensuring data integrity is essential to communications supporting vital transportation infrastructure such as railways, roadways or airports; networks must be safe from data theft and intrusion. Increasingly, operators should be concerned about the risk from attack by quantum computers, capable of breaking traditional cryptography. Data must be protected while at rest in a data center, contained with storage media or in-flight across a network. Protecting data in-flight requires layers of cryptography working together using a "defense in depth" approach. Operators should consider adopting Quantum-Safe Network approaches- at more than one network layer. Security measures should include:

- **Encryption**: Utilization of AES-256 GCM across optical links.
- **Centralized key management**: A symmetric key management authority that ensures 256-bit key strength while controlling key rotation, expiration and destruction.
- **Optical intrusion detection**: Methods to monitor minute changes in received optical power levels, which could indicate tampering along a fiber span.
- **User authentication and network element control**: Multiple levels of user classes with robust password protection.
- **Independent certification**: Solutions should be certified by independent entities for compliance with relevant standards, such as NIST FIPS 140, common criteria (CC) and others.

Nokia optical networking transport solution

A modernized optical transport network provides a foundation for any application or service needed for utility operations and corporate IT support. It includes a scalable packet optical transport network that can support any traffic type, including IP/MPLS, Ethernet or legacy TDM. This foundation utilizes OTN encapsulation and switching and has native support of packet transport methods such as MPLS-TP or Carrier Ethernet and TDM. The network should also be safe from theft or intrusion through certified Layer 1 encryption with centralized, symmetric key management.

The Nokia 1830 PSS offers capabilities exceeding the requirements of a modernized utility transport network. This includes a chassis sized to match network capacity needs, flexible modules for optical transponder, amplification and add-drop functions, packet switching and transport and Layer 1 encryption. The 1830 PSS supports Layer 2 packet switching through integrated switching cards supporting MPLS-TP and Carrier Ethernet or through other Nokia IP routing products. Legacy TDM services are supported by 1830 PSS interfaces on Layer 2 cards.

Meeting the requirements for an agile and scalable transport network for utility communications requires a range of technologies spanning optical transmission, Carrier Ethernet, and IP/MPLS. Nokia offers solutions based on decades of experience delivering advanced communications networks to utilities, service providers and enterprises. Leveraging Nokia Bell Labs as its innovation engine, Nokia solutions build dependable, scalable, yet flexible network infrastructure that brings together IP routing, optical transport and automation software.

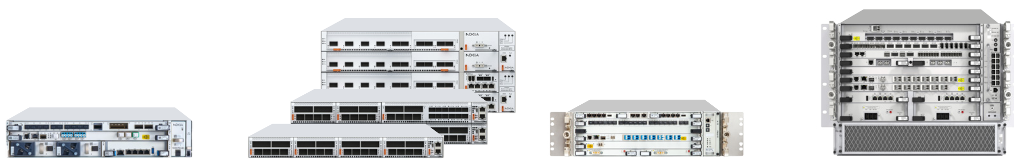
Figure 2. Nokia Optical Networking Portfolio

Select platforms

Scalable
- Transport from 10G to 2.4T per card; pay as you grow
- Multi-band, multi-fiber line systems
- Multi-layer switching: wavelength, OTN, Ethernet

Simple
- Automation: AI automation software and solutions
- Open: Line systems and management interfaces
- Architecture: Application-optimized

Secure
- Quantum-safe transport
- Multi-failure resiliency
- Powerful intrusion detection and isolation



Features	1830 PSS-4II	1830 GX	1830 PSS-8	1830 PSS-16
Application and key benefits	• Enterprise and WAN access • PtP DCI • LO-2 aggregation and transport; ADM and ROADM	• Application-optimized DCI • Open APIs, data models and telemetry • Family of compact, modular chassis in 600 mm or 300 mm depth for DC and ILA	• Scalable access/ aggregation • Data center or field node	• Backbone node • Multi-shelf scaling • Core or data center
Chassis	2RU, 2 modular slots	1, 2 and 4RU variants	3RU, 4 full height slots	8RU, 8 full height slots
Capacity	400G	Up to 2.4 Tb	800G	1.6Tb

Nokia 1830 PSS product family highlights

The Nokia 1830 PSS optical transport portfolio forms a flexible transport layer through its agile optical, multi-layer switching capabilities and network intelligence. It enables high scalability, easier operations, accelerated provisioning and reduced cost. The 1830 PSS employs optional distributed OTN switching and a range of interface cards that can be used across different chassis types with few limitations.

Highlights of the 1830 PSS portfolio include:

- Chassis sized to match application needs, including data center interconnect (DCI), optical access/aggregation and an optical WAN backbone with capacities ranging to beyond 2.4 Tb/s per line card.
- Coherent silicon and indium phosphide (InP) technology provides the basis for software-controlled interface cards capable of optimizing span reach and data rate through adaptive modulation, variable baud rates, advanced soft-decision FEC and optical super channels.
- Advanced P-OT interfaces, providing MEF 2.0 Carrier Ethernet and MPLS-TP capabilities, seamlessly operating with Nokia IP routing platforms .
- TDM migration options through Layer 2 packet interfaces, providing a flexible means to evolve toward packet services
- Quantum-Safe Network capabilities, including AES-256 encryption per wavelength and centralized, symmetric key management with key strength exceeding NIST and NSA recommendations, certified to FIPS, CC EAL and ANSSI standards.

As utility communications evolve, secure high-speed optical technology will be essential for corporate IT and operational functions. DCI, interoffice field connectivity, smart grid and teleprotection are all best served through a single, agile optical backbone, built with the capability of keeping these applications distinct and separated.

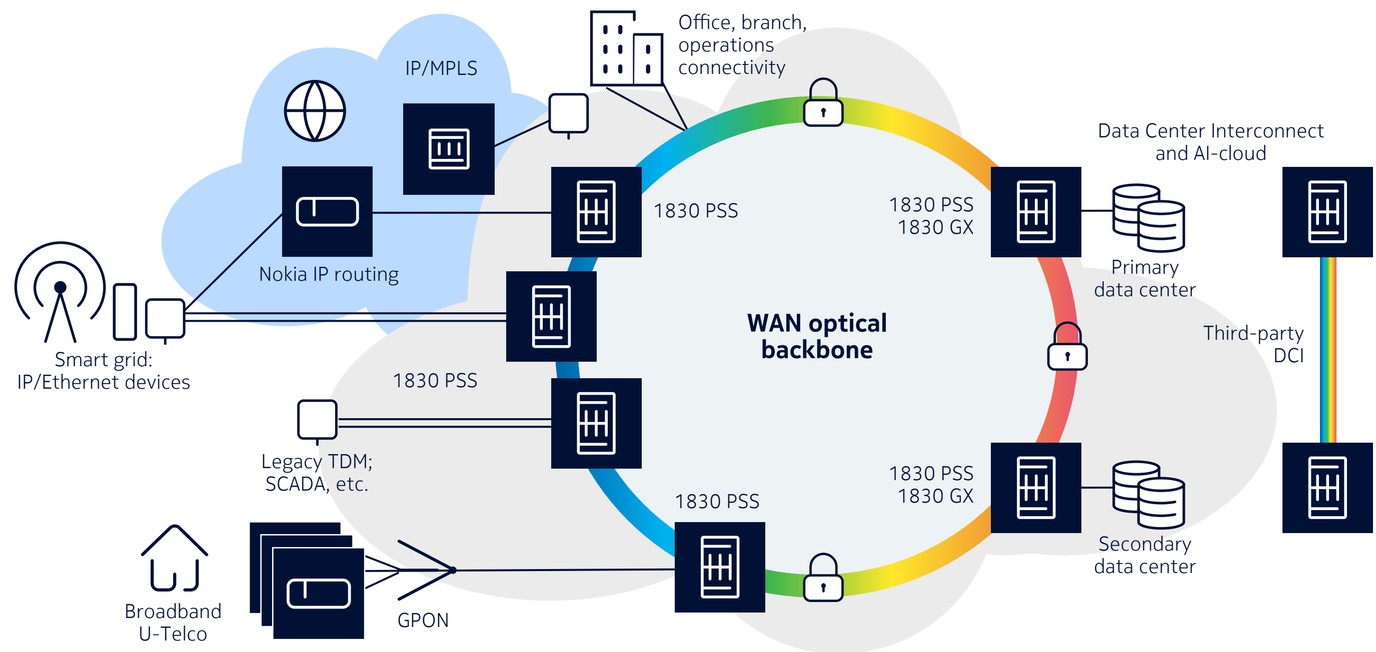
Summary

Utility communications networks face increasing demands from across the organization. Faced with integration of operational technology and IT functions, utilities need communications networks that are agile to meet constantly changing service requirements, scalable to carry increasing capacity demand, and highly secure to protect vital infrastructure. Figure 3 illustrates how this network could be built as a corporate mission-critical WAN, with the Nokia 1830 PSS forming an optical backbone that transports traffic from various applications.

This paper has provided context for several of these choices and the Nokia solutions that support them, specifically:

- Capacity scaling and continued capabilities for embedded traffic such as TDM services
- Migration toward a packet transport core supporting Ethernet and IP traffic
- Protocol-agnostic optical transport utilizing OTN
- Flexible Layer 2 architecture, capable of supporting multiple technologies such as carrier Ethernet
- Quantum-Safe Networks through Layer 1 encryption as part of a defense-in-depth strategy

Figure 3. Utility mission-critical WAN with Nokia 1830 PSS



The Nokia product portfolio offers the industry's most complete set of options to meet modern utility communications requirements. The Nokia 1830 PSS offers the most powerful optical transport solution to meet these needs.

Abbreviations

AES	Advanced Encryption Standard
CC	common criteria (security standards)
CC EAL	common criteria evaluation assurance level
CE	Carrier Ethernet
CWDM	coarse wavelength division multiplexing
DCI	data center interconnect
DWDM	dense wavelength division multiplexing
FEC	forward error correction
FIPS	Federal Information Processing Standard
IPsec	IP security
IT	information technology
ITU-T	International Telecommunication Union – Telecommunication Standardization sector

L1	Layer 1
L2	Layer 2
MACsec	media access control security
MEF	Metro Ethernet Forum
MPLS	Multiprotocol Label Switching
MPLS-TP	MPLS - Transport Profile
NIST	National Institute of Standards and Technology
NMS	network management system
NSA	National Security Agency
NSP	Network Services Platform
OAM	operations, administration, and maintenance
OAMP	operations, administration, maintenance and provisioning
OSI	Open Systems Interconnection
OTN	optical transport network
PCS	probabalistic constellation shaping
PSS	Optical Service Switch
SAR	Service Aggregation Router
SCADA	Supervisory Control and Data Acquisition
SDH	synchronous digital hierarchy
SONET	synchronous optical network
SR	Service Router
SR OS	Service Router Operating System
TDM	time division multiplexing
TE	traffic engineering
WDM	wavelength division multiplexing

About Nokia

Nokia is a global leader in connectivity for the AI era. With expertise across fixed, mobile, and transport networks, powered by the innovation of Nokia Bell Labs, we're advancing connectivity to secure a brighter world.

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