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Benefits of CDC-F ROADMs

Enhanced flexibility, efficiency, and capacity for next-generation optical networks

White paper

The introduction of Colorless, Directionless, Contentionless, Flexible Grid (CDC-F) Reconfigurable Optical Add Drop Multiplexers (ROADMs) enables enhanced efficiency, flexibility, capacity, and operational simplicity for next-generation optical networks. Carriers can deploy flexible, dynamic optical networks that automatically detect and restore around network faults, adjust and optimize to network changes, and automate many operational tasks that currently require costly manual intervention.

This optical layer flexibility and support for additional capacity lowers overall optical network costs. At the same time, a whole host of new applications and automations can be supported, leading to additional operational savings.

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Introduction

Reconfigurable optical add drop multiplexers (ROADMs) have been deployed since 2004, providing significant efficiency, utilization, and operational benefits when compared to the previous generations of banded, fixed-filter WDM systems that were popular up until that time. Today, approximately 90 percent of all WDM systems deployed on metro, regional, and long haul (LH) optical networks are based on ROADM architectures and technologies.

ROADMs allow any wavelength to be added or dropped at any node, through simple software provisioning. This additional flexibility and capacity simplifies network operations and offers the scalability needed to meet the ever-increasing demand for bandwidth. One limitation of classic ROADM systems is that their wavelengths, once initially provisioned, require manual changes to implement any network modifications. As a result, re-routing or re-configuration of wavelengths are rarely performed, as they require significant time, cost, and disruption.

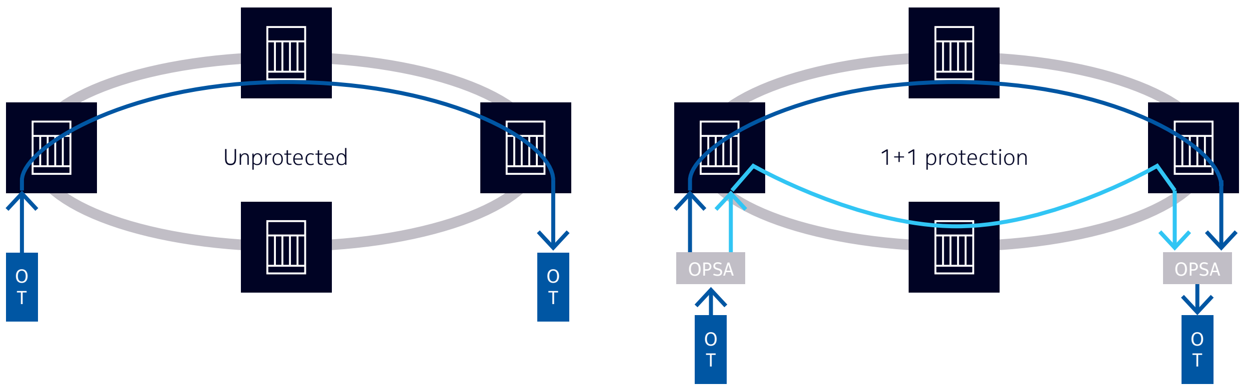
Fortunately, a new generation of Colorless, Directionless, Contentionless, Flexible Grid (CDC-F) ROADMs are now available with the ability to move, steer, and re-route wavelengths automatically, without the need for costly manual changes. These new CDC-F ROADM architectures dramatically improve network utilization, efficiency, and capacity, resulting in significantly lower optical network costs. New optical layer applications utilize this new ROADM flexibility to automatically re-route wavelengths around network faults, optimize network traffic patterns, and maximize wavelength capacity. Deployments of CDC-F ROADMs began in 2016. Over the next 10 years, the industry will see a dramatic shift to new, powerful, flexible, optical networks, based on CDC-F ROADMs.

New technology delivers significant advances

In simple terms, CDC-F ROADMs allow more capacity to be transported over networks than comparable classic ROADM architectures, resulting in lower optical network costs, on a per Gigabit (Gb) basis. In addition, the flexibility of CDC-F networks enables the automation of many operational tasks that previously required costly, manual changes.

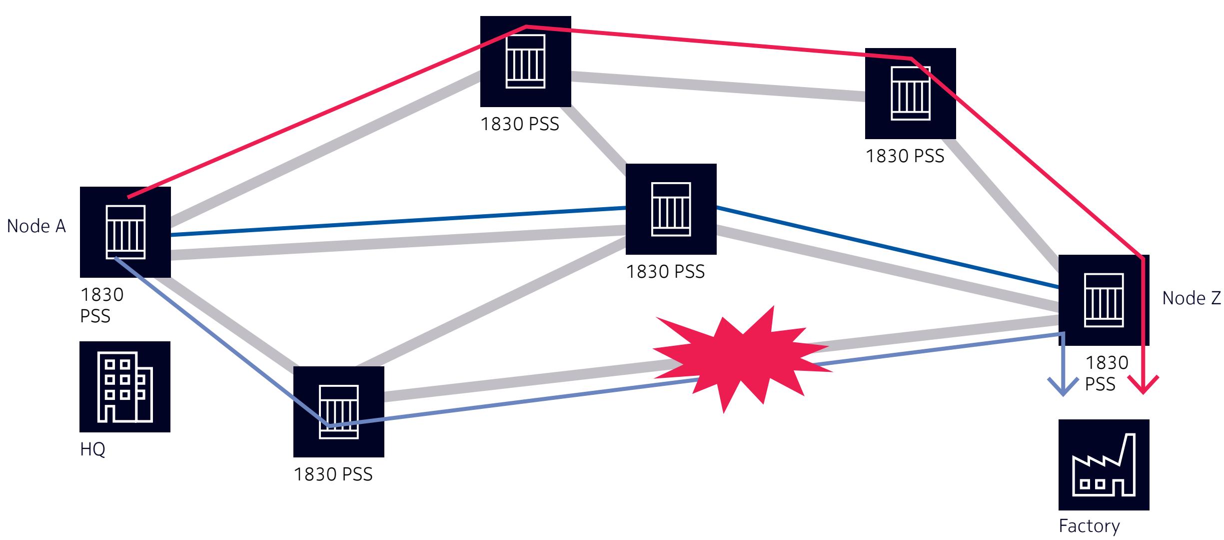
Until recently, optical networks transported services in one of two ways: "unprotected" or 1+1 protected wavelengths (Figure 1). Dedicated, 1+1 optical protection offers a high level of redundancy for mission-critical services with guaranteed, ultra-fast switch times (typically < 50ms). However, this guarantee comes with a steep cost of having 50% of network capacity reserved and sitting idle.

Figure 1. Optical protection



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% capacity penalty imposed by dedicated 1+1 protection methods. Carriers gain the benefits of automatic restoration and increased network efficiency and capacity. It's the underlying flexibility of CD and CDC-F ROADM networks that enable the wavelength steering, resulting in more efficient restoration methods.

Figure 2. Optical layer restoration via CDC-F network flexibility



CDC-F ROADMs also support flexible grid channel spacing, which is another key feature in enhancing network capacity. Classic ROADMs are based on 88 channels, with 50 GHz channel spacing for each wavelength. While 50 GHz is the standard channel spacing for 100G QPSK wavelengths, it doesn't offer the flexibility to support newer higher capacity modulations or more spectrally efficient superchannels.

New multi-modulation transponders support a wide array of optical modulation schemes, which allow the capacity of wavelengths to be finely tuned and optimized to specific optical routes. Many of these newer, higher capacity modulation options, such as 200G 8QAM using 62.5 GHz channels, require flexible grid spacing available on CDC-F ROADMs.

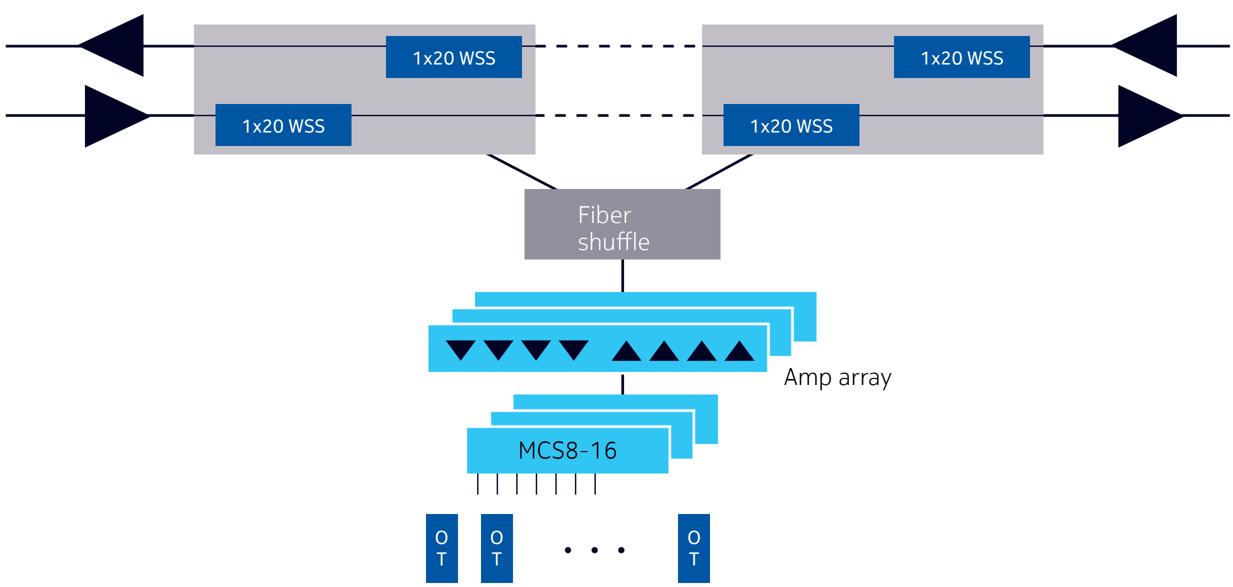
Superchannels are another key feature in enhancing network capacity. Superchannels are a grouping of two to four carriers, with slightly closer spacing between each of the wavelengths. Superchannels provide an additional 15 – 20% capacity on an optical network by utilizing flexible grid spacing.

The additional capacity enabled by optical layer restoration, flexible grid spacing, and superchannels, results in lower per Gb optical network costs.

Key CDC-F ROADM benefits include:

- More advanced and efficient optical layer protection / restoration options
- Support for new higher capacity modulations
- Support for more spectrally efficient superchannels
- Lower effective cost/Gb of optical transport
- Reduced operational costs through elimination of manual operations
- Faster service turn-up and service velocity
- Simplified network planning

Figure 3. CDC-F ROADM node



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Value—Changing industry perception

One industry misperception is that CDC-F ROADMs are significantly more expensive than classic ROADMS, which is simply not true. Due to the additional flexibility and capacity, CDC-F ROADMs actually lower the cost per Gb ($/Gb) in most network applications.

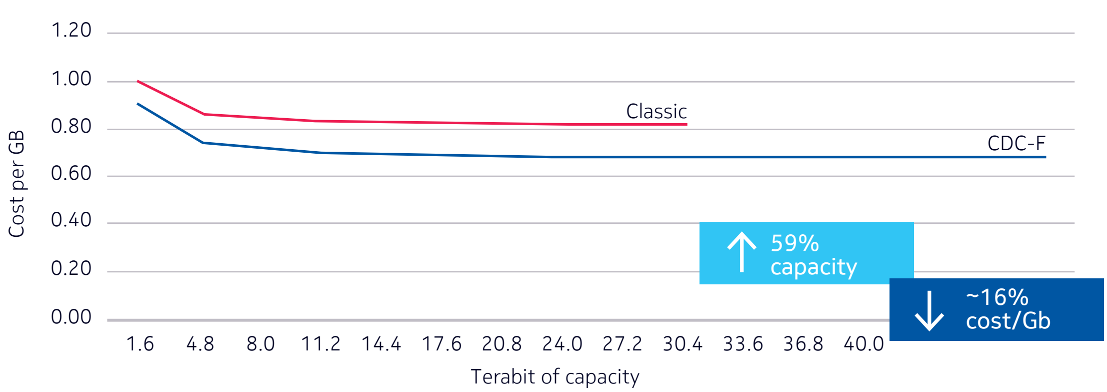
The optical networking industry debated very similar cost arguments in 2004, when ROADMs were first introduced and began to replace legacy 32-channel banded, fixed filter WDM systems popular at that time. While the absolute price of ROADMs in 2004 were slightly higher than banded, fixed filter WDM systems, they offered significant improvements in scalability, capacity, flexibility and operational simplicity, all of which effectively lowered the overall cost per Gb on optical networks. Today, over 90% of all WDM systems deployed are based on ROADM architectures.

CDC-F ROADMs offer the same benefits of improved scalability, capacity, flexibility, and operational simplicity over classic ROADMs, mirroring the exact same arguments the industry debated in 2004 during the transition to classic ROADMs.

The additional features and benefits associated with CDC-F ROADMs—including additional capacity, more efficient restoration/protection options, support for advanced modulation types, and operation simplicity—effectively lower the cost per Gb below that of existing classic ROADMs.

The diagram below shows a comparison between a 4-degree node based on a classic ROADM and a CDC-F ROADM. In addition to lowering the cost per Gb on optical networks, the additional capacity extends the life of the network before a costly, disruptive overbuild is needed. In Figure 4, the classic ROADM is limited to 31.2 Tb of total capacity across four degrees, while the CDC-F ROADM option supports up to 49.6 Tb. Actual results will vary by application, including network configuration, size, traffic patterns, wavelength rates, and protection methods, but 30% – 70% capacity improvement is typical for CDC-R ROADM networks compared to mux/demux based classic ROADM networks.

Figure 4. Myth busted, CDC-F vs classic ROADM costs



Enabling an array of new applications

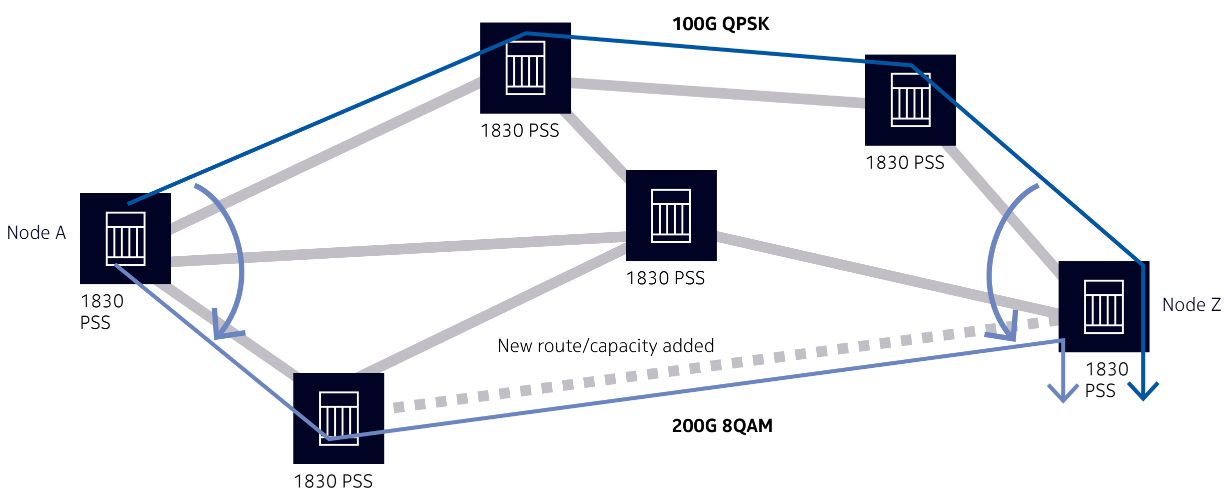
In addition to lowering the cost/Gb for optical networks, the flexibility to move, steer, and re-arrange wavelengths enables a whole array of new applications over CDC-F ROADM networks, including:

- Optical layer restoration
- Dynamic network optimization
- Bandwidth pre-positioning
- Hot standby sparing

Optical layer restoration, as shown in Figure 1 and discussed previously, allows wavelengths to automatically be re-routed around network faults. It's a much more powerful and efficient restoration method than 1+1 protected wavelengths, since it protects against multiple fiber cuts, while eliminating the 50% idle bandwidth penalty imposed by 1+1 protection methods.

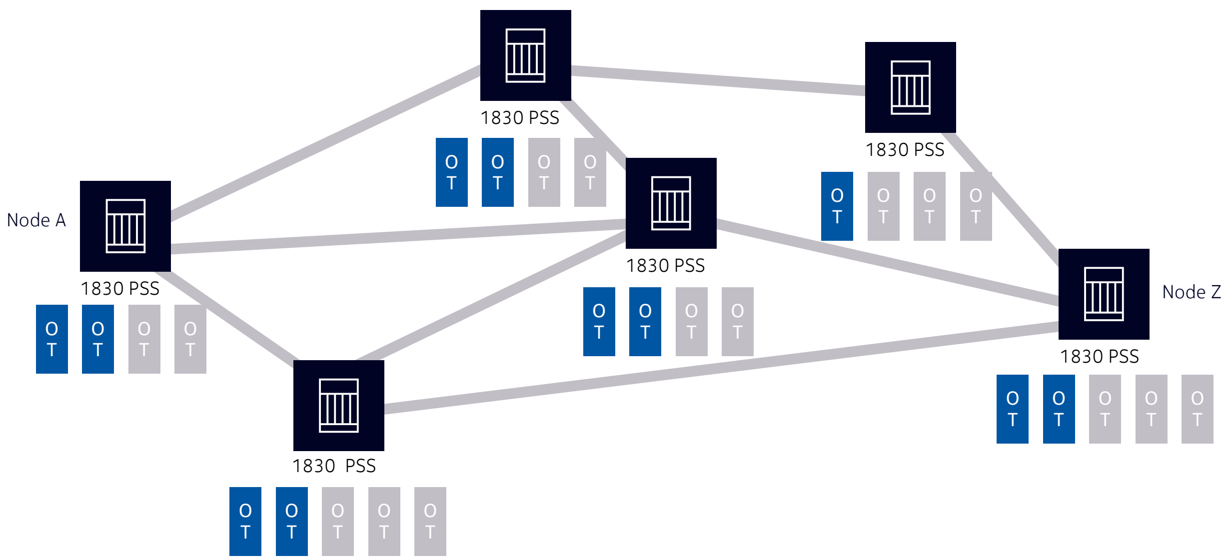
As optical networks evolve over time, through the addition of new routes and capacity, existing wavelengths aren't always optimized to these new network changes. Network re-optimization ensures wavelengths, and how they are mapped over a network, use the most cost efficient routes available. In Figure 5, the dark blue wavelength is routed around a long path requiring a large number of network resources (spans, nodes, regens). As additional capacity becomes available on the shorter, more direct route (as shown by the dotted gray line), network re-optimization can automatically identify and move wavelengths to this shorter, lower cost, more efficient path. In some cases, moving the wavelength to a shorter, more efficient route also allows the wavelength to carry additional capacity, such as 200G shown in this example.

Figure 5. Network re-optimization



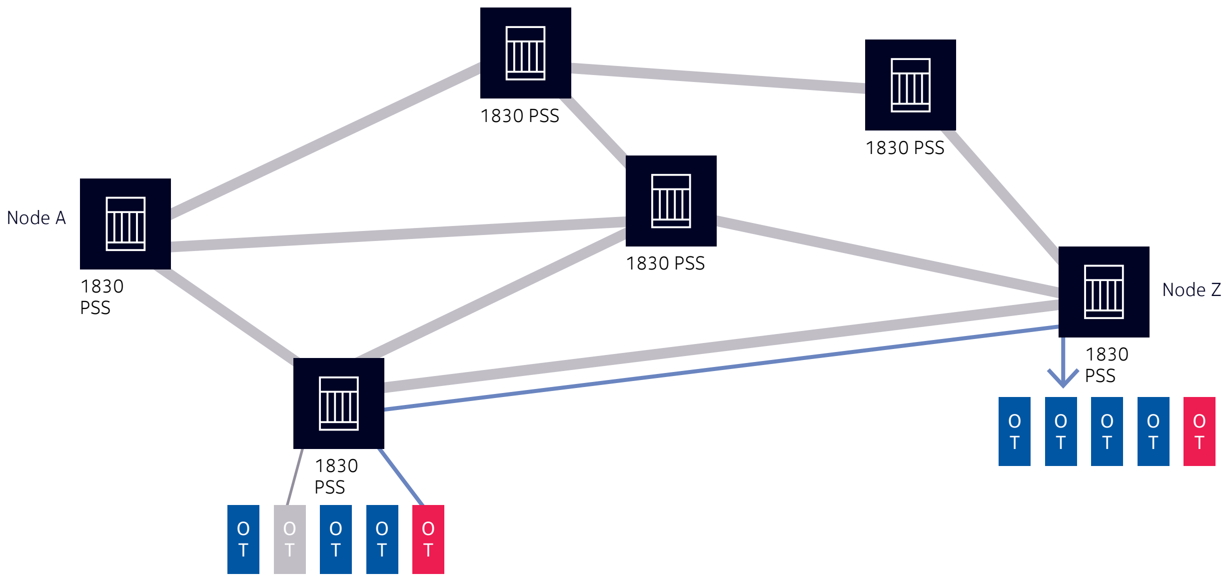
Bandwidth pre-positioning allows carriers to dramatically improve service velocity, establishing new services in minutes as opposed to weeks or months. Traditionally, when a new service is ordered or additional capacity required, a network engineer determines where to deploy the new transponders (A – Z nodes), decides the type of transponders needed, places an equipment order for the units, and schedules work orders for installation and provisioning of the new equipment when it arrives. These steps can require weeks or months before a new wavelength becomes fully operational and "ready for service". With CDC-F ROADM networks, transponders can be pre-positioned at each node, using the network's ability to dynamically assign and connect the wavelengths to any port (colorless) and to any other network node (directionless), as needed. New services can be remotely provisioned in minutes instead of months, improving service velocity and carrier competitiveness.

Figure 6. Bandwidth pre-positioning



Hot standby sparing also utilizes CDC-F networks' ability to steer wavelengths, along with their colorless and directionless ports. A single standby transponder can be used to provide 1:n equipment protection for working transponders, as shown in Figure 7. When a transponder failure occurs, as shown by the light grey optical transponder (OT), the CDC-F node detects the failure, provisions the hot standby transponder to become "active", tunes it to the same wavelength or channel, and moves the connection over to the hot standby card.

Figure 7. Hot standby sparing



Summary

The Nokia 1830 PSS product family supports a new generation CDC-F ROADM architecture, providing enhanced capacity, flexibility, efficiency, and operational simplicity. The additional capacity, along with powerful optical layer applications, reduce optical networks costs ($/Gb). In addition, the optical layer flexibility allows automation of many operations tasks that previously required costly, disruptive, manual changes.

Nokia is the industry leader in the development of flexible, dynamic optical networks. Nokia was the first vendor to introduce Colorless - Directionless (CD) ROADMs with optical layer restoration in 2012. Building upon years of control plane experience and thousands of ROADM deployments, Nokia introduced the 1830 PSS CDC-F ROADM in 2015 – part of Nokia's advanced optical SuperWave architecture.

Acronyms

CD	Colorless, Directionless
CDC-F	Colorless, Directionless, Contentionless, Flexible grid
Gb	Gigabit
GHz	Giga-Hertz
GMPLS	Generalized Multiprotocol Label Switching
L0	Layer 0
LH	Long Haul
ms	Millisecond
OPSA	Optical Protection Switch
OT	Optical Transponder
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
ROADM	Reconfigurable Optical Add Drop Multiplexers
WDM	Wavelength Division Multiplexing

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