Advances in optical layer restoration

Creating powerful, efficient, and flexible next-generation optical networks

Strategic White Paper

This white paper describes how the combination of GMPLS optical layer restoration, along with colorless, directionless, contentionless and flexible grid (CDC-F) systems can create powerful, efficient, and flexible next-generation optical networks.

Topics addressed include: protecting mission-critical services, improving efficiency with optical layer restoration, enhancing service assurance with fast restoration, GMPLS optical layer restoration options, CDC-F wavelength routing, and fast photonic lightpath algorithms.

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Introduction

Communication providers have powerful options for protecting and restoring optical layer services. These optical layer restoration methods ensure critical services are quickly restored, with the added benefit of improved overall network capacity. Nokia has recently combined powerful optical restoration capabilities with colorless, directionless, and contentionless wavelength routing on the Nokia 1830 Photonic Service Switch, resulting in flexible and dynamic optical networking.

Carriers face the daunting task of ensuring networks operate with extremely high reliability, even in the presence of multiple failures. Optical networks routinely face construction-related fiber cuts, equipment failures, power outages, and human error. Despite these potential disasters, most networks operate with better than 99.999% availability due to multiple layers of resiliency built into modern communication networks. Using advanced protection and restoration techniques, failures can be automatically detected and services re-routed around the affected areas.

Protection and network resilience have typically been provided by Layer 1 (L1) OTN switching and Layer 3 (L3) routing nodes. Powerful, flexible, and efficient service restoration methods are easily implemented at the OTN (L1) or router (L3) electrical layers. Until recently, the protection and restoration options supported on optical networks were somewhat limited compared to more sophisticated methods used at the higher layers.

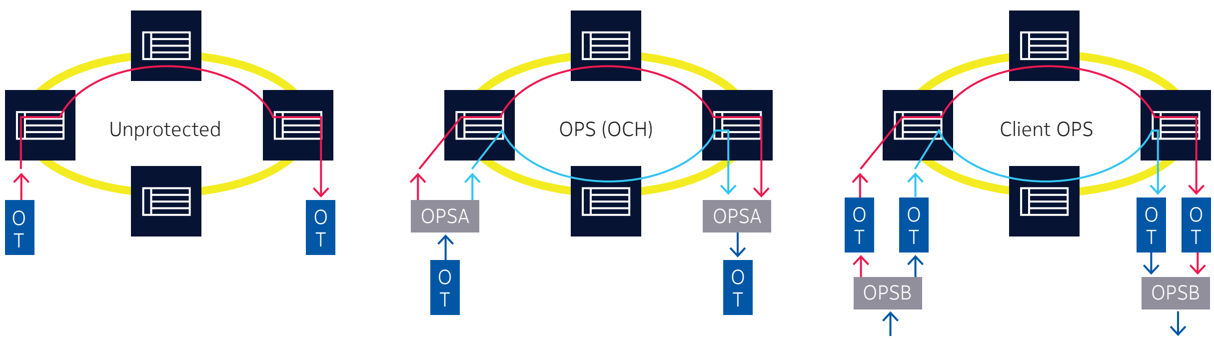
As network speeds increase so does the cost of providing advanced restoration features at L1 or L3, because all traffic must terminate at each OTN switch or router node. Using wavelength division multiplexing (WDM) to carry services between end points, bypassing intermediate OTN switching or routing nodes, significantly reduces network costs. WDM optical transport reduces the number of optical interfaces required on OTN and routing nodes, as well as reducing the switching and routing fabric sizes. Higher speed wavelengths and larger network capacities result in more traffic residing at L0, touching the OTN or router nodes only when and where absolutely necessary.

WDM systems efficiently transport large bandwidths over very long distances, but have typically relied on OTN switches and routing nodes to provide advanced service restoration. As network speeds and capacities increase, these same types of advanced restoration features are needed at the optical layer. Nokia is leading the industry with powerful optical layer protection and restoration options on the 1830 PSS optical network platform. The system has been specifically designed for high-speed wavelengths operating over flexible, dynamic CDC-F ROADM networks.

Protecting mission-critical services

Optical networks typically support two wavelength provisioning options, 1+1 fully protected wavelengths with ultra-fast 50ms switching, or unprotected wavelengths. Mission-critical services, such as banking information, financial stock transactions, and e-commerce transactions must operate regardless of network failures. Dedicated 1+1 optical protection provides high network availability by creating dual paths through a network, protecting against fiber cuts or a combination of fiber cuts and equipment failures, as shown in Figure 1. Optical Protection Switch (OPS) units perform the actual light switching, on a per-wavelength basis. The OPS units can be deployed with a single transponder to provide 1+1 protection against network fiber cuts, or deployed with dual transponders, (as shown in the far right diagram), providing protection against both fiber cuts and transponder equipment failures.

Figure 1. WDM protection options



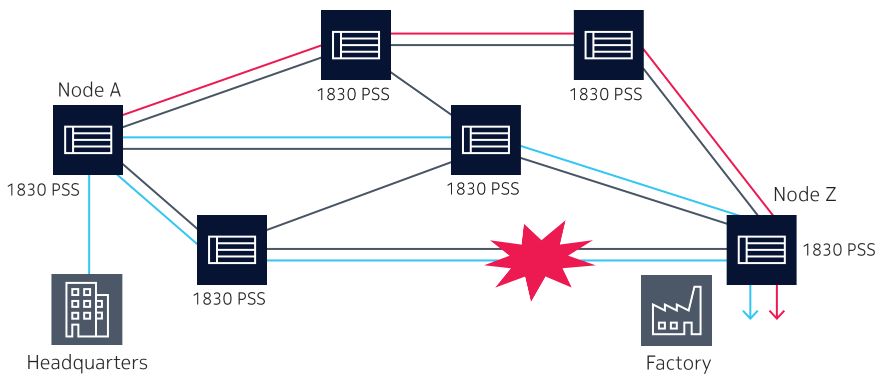
Dedicated 1+1 optical protection offers a high level of redundancy for mission-critical services with guaranteed, ultra-fast switch times (typically < 50ms). However, this guarantee comes with a steep cost of having 50% of network capacity reserved and sitting "idle". For services that are truly mission critical and must remain operational at all times, 50% idle capacity is an acceptable tradeoff to achieve the highest network and service availability. On general purpose wavelengths — those that aren't mission critical — reserving 50% of network capacity for protection is very costly and inefficient. As a result, many carriers simply deploy unprotected wavelengths at the optical layer and rely on advanced restoration methods operating at higher layers. These advanced restoration features are bandwidth efficient, while providing reasonably fast restoration times of 500ms – 30s.

Additional protection and restoration options, beyond the two simple choices of 1) unprotected wavelengths or 2) dedicated 1+1 protected wavelengths, are needed at the optical layer. With the adoption of higher speed wavelengths and larger network capacities, these additional optical layer restoration options become critical, because more and more of the network traffic remains primarily at the optical layer. Nokia has integrated advanced L0 restoration features into the industry leading 1830 PSS platform, ensuring users have a wide choice of bandwidth efficient restoration options for their optical transport networks.

Improving efficiency with optical layer restoration

A key feature of Nokia's advanced optical layer restoration is the ability to re-route and restore traffic around network faults, without the 50% network capacity penalty imposed by dedicated 1+1 protection methods. Carriers gain the benefits of automated service restoration with much higher network efficiency and capacity utilization.

Figure 2. Optical layer restoration



In the example shown in Figure 2, a single protection route provides the restoration for two "blue" working paths. When a network failure occurs, the nodes calculate a restoration path using Generalized Multiprotocol Label Switching (GMPLS) protocols, establish a new path across the network and re-route the affected wavelengths over the new restoration path. The sharing of protection path resources improves network efficiency and overall capacity. In a highly meshed real-world network, a single shared backup path can support four or five working paths, resulting in as little as 15 to 20% capacity needed to provide a robust, protected network.

Once a network failure is repaired, traffic automatically reverts back to the nominal path, ensuring an optimal network configuration. When a wavelength is initially provisioned, the nominal (default) path is optimized to the network by selecting the shortest path, or the route with fewest regens. When failures occur, the traffic switches away from this optimized configuration. Reversion to the nominal path ensures that the network returns to its original, optimal configuration.

Optical layer restoration provides another protection option in addition to traditional 1) unprotected and 2) dedicated 1+1 protected options already available. Carriers can mix and match the methods to optimize their networks, using dedicated 1+1 protection on mission-critical wavelengths, where ultra-fast switching is required, and optical layer restoration for all other wavelengths to improve efficiency and capacity utilization.

Enhancing service assurance with fast restoration

When a fiber cut occurs, it often takes 24 to 72 hours to repair the cable and restore network services. While dedicated 1+1 protected wavelengths switch in <50ms, all other unprotected wavelengths remain in outage until the physical fiber cut is repaired. For many carriers, this long outage, even on unprotected, best-effort wavelength services, is increasingly unacceptable.

A key advantage of optical layer restoration is that it can automatically detect and re-route wavelengths around fault conditions. Optical restoration takes a little longer to complete than dedicated 1+1 protection switching, but is still a vast improvement over one to three day typical repair times on physical cable cuts. Optical layer restoration enables bandwidth-efficient protection with relatively fast restoration, which is well suited for most general purpose wavelengths.

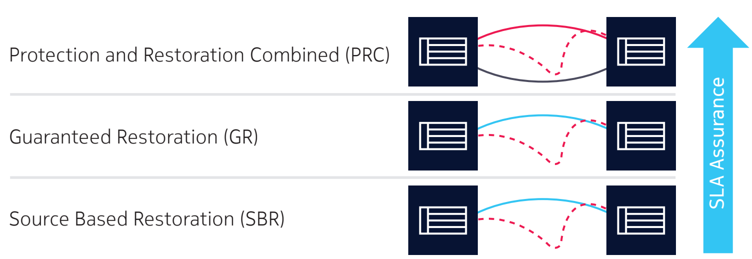
GMPLS optical layer restoration options

Nokia offers three GMPLS optical layer restoration options: Source-Based Restoration (SBR), Guaranteed Restoration (GR), and Protection Restoration Combined (PRC). The differences among the methods primarily relate to how the protection path is defined and reserved.

Source Based Restoration calculates a new restoration path over the network in real time, as the fault occurs. GMPLS calculates a new restoration path through the network, signals the nodes to establish the new path, and re-routes the wavelengths across the newly established restoration path.

Guaranteed Restoration calculates a backup path at the time that the wavelength is initially provisioned. Backup resources are signaled (i.e., pre-reserved), but not actually allocated until the fault occurs. GR assures that backup paths and capacity are available in the network at the time of wavelength provisioning. Until a failure occurs, the pre-defined backup path can be a shared protection path for other routes, or used to carry low priority, best-effort services. GR is a little faster than SBR, because the restoration route is pre-calculated and pre-reserved.

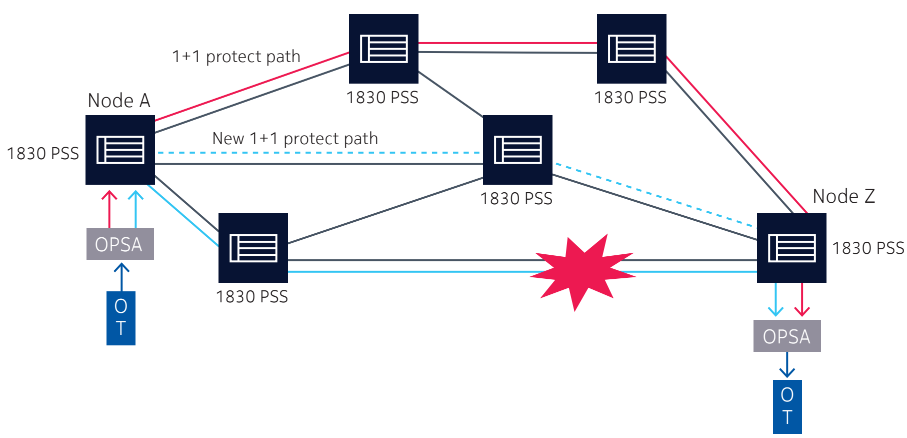
Figure 3. Optical layer restoration options



Protection and Restoration Combined offers the ultimate level of network assurance, combining dedicated 1+1 protection switching (<50ms) with optical layer restoration. Initial faults are protected by 1+1 OPS units, ensuring fast, sub-50ms protection for mission-critical services. Once the initial protection switch completes, PRC restoration establishes additional backup paths through the network to protect against any subsequent failures.

As shown in Figure 4, dedicated 1+1 protection paths (blue, red) are established over the network to support a mission-critical wavelength. A failure on the blue path causes an automatic 1+1 protection switch to the red path. Although rare, multiple faults sometimes occur in real-world networks. A subsequent failure on the red path, while the blue route is out of service and waiting for repair, would normally result in an outage, because failures exist on both 1+1 protection routes (blue, red). PRC adds additional layers of protection against second- and third-level faults by establishing additional backup paths through the network. After the initial switch, PRC automatically provisions additional backup paths, as shown by the dotted blue path in Figure 4. The new backup path provides another layer of protection should subsequent failures occur on the red path during the typical one to three one days required to repair and re-splice the damaged fiber cable on the blue route. PRC restoration repeats this same process of finding and establishing backup paths to protect against third- and fourth-level failures, as long as network resources exist. Once all PRC protection levels are exhausted, the system uses real-time SBR to protect against any further failures.

Figure 4. Ultimate network protection with PRC



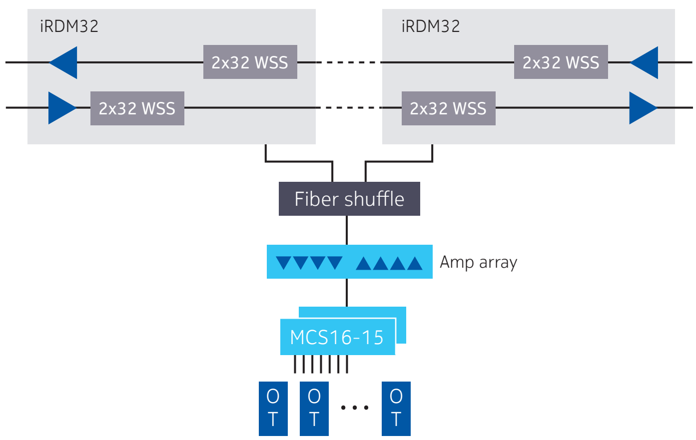
CDC-F wavelength routing

Nokia has integrated GMPLS restoration on the 1830 PSS since Rel 3.6. However, it iwas the introduction of Colorless, Directionless, Contentionless, and Flexible Grid (CDC-F) WDM systems that enabled the full benefits, flexibility, and efficiency of GMPLS optical layer restoration. CDC-F is the key, underlying technology that enables wavelength steering and re-routing under the intelligence and control of GMPLS protocols.

Key CDC-F wavelength routing benefits include:

- Simplified network planning
- Reduced operational costs through elimination of manual re-configurations
- Faster service turn-up and service velocity
- Improved reliability using hot standby optical transponders
- More advanced and efficient optical layer protection/restoration options

Figure 5. CDC-F optical networking node



Nokia Fast Photonic Lightpath setup

One issue with optical layer restoration is the speed at which wavelengths and optical paths can be re-routed and restored. Unlike protection performed at the OTN or router layers, optical layer restoration must contend with physical wavelengths, optical power levels, and real-world optical impairments — all of which must be carefully controlled to prevent adjacent channel interference and bit errors. Nokia incorporates Fast Photonic Lightpath algorithms in 1830 PSS, dramatically improving GMPLS optical restoration times. Fast Photonic Lightpath is yet another example of Nokia innovation and continuous performance improvements incorporated into each new product release.

Summary

WDM networks have traditionally relied on dedicated 1+1 optical protection for mission-critical services, resulting in 50% of network capacity remaining “idle”. As a result, most wavelengths are left unprotected, relying on OTN switches or routers to provide restoration at the higher layers. As wavelength speeds and network capacity increases, it becomes much more cost effective for the traffic to remain primarily on WDM optical layer, terminating on OTN switches or router nodes only where needed. While Nokia has supported optical layer restoration for many years, it is the combination of GMPLS and 1830 PSS CDC-F ROADM nodes that creates powerful, efficient, and flexible next-generation optical networks.

Abbreviations

CDC-F	Colorless, Directionless, Contentionless - Flexible Grid
GMPLS	Generalized Multiprotocol Label Switching
GR	Guaranteed Restoration
L1	Layer 1
L3	Layer 3
OPS	Optical Protection Switch
OTN	ITU G.709 Optical Transport Network
PRC	Protection and Restoration Combined
PSS	Photonic Service Switch
SBR	Source-Based Restoration/Routing
WDM	Wavelength Division Multiplexing

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