NORTEL

White Paper

Evolution to enhanced Reconfigurable Optical Add/Drop Multiplexers (eROADM)

Introduction

The fast adoption of business and residential broadband services is certainly igniting service providers' and cable operators' momentum. However, their deployment requires the implementation of emerging technologies (such as broadband access networks, Resilient Packet Ring, etc.) and the use of multiple network topologies to meet subscribers' (residential or business) expectations to access 'on demand' content at any time and from anywhere. Many of these new services, such as video on demand (VoD), voice over IP (VoIP), content sharing, etc. are difficult to forecast in terms of bandwidth demand, traffic routing patterns and requirements in addition to their stringent requirement for a high level of quality of service.

As a result, traffic patterns are becoming diversified and unpredictable, thus creating a new operational challenge for service providers and cable operators to effectively forecast bandwidth requirements at the numerous sites spread across the network. Alternatively, providing high bandwidth connectivity (e.g. a wavelength) to every single site requires a major capital investment and results in a significant increase in network complexity.

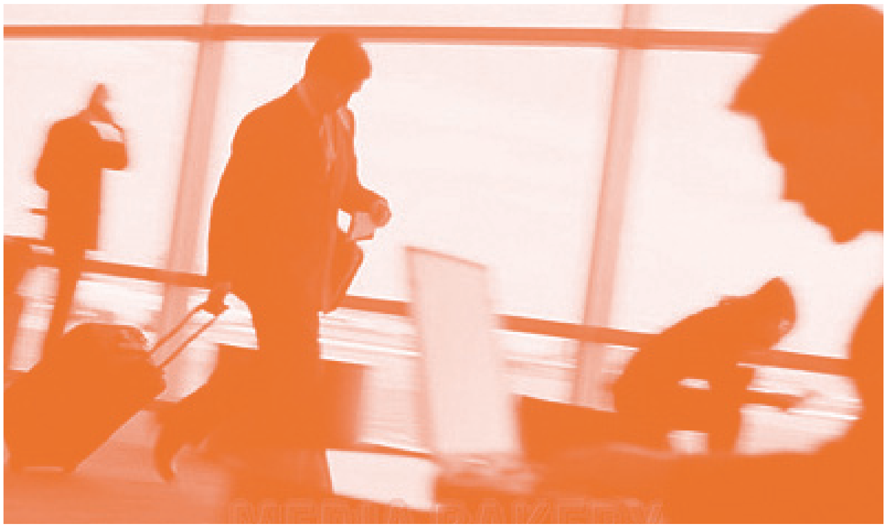
Therefore, service providers and cable operators are looking for a flexible and cost-effective solution to dynamically provide 'on the fly' high bandwidth connectivity to any network site without interrupting the existing services or re-engineering the network.

Through the fast pace of technology evolution in photonics, many equipment vendors have developed Reconfigurable Optical Add/Drop Multiplexers (ROADMs) that allow service providers and cable operators to terminate or insert a specific wavelength at a certain site.

First and second generation ROADM architectures

Most available ROADMs today are based on one of the two following architectures — Wavelength Blockers (WB) or Planar Lightwave Circuit (PLC).

ROADMs based on Wavelength Blockers are considered to be the first generation of these network elements, where all wavelengths are sent "broadcasted" to the site at which some wavelengths need to be terminated.



The WB, in conjunction with a set of optical filters, blocks the selected wavelengths from passing through the site and directs them to filters for extraction as depicted in Figure 1. Similarly, wavelengths can be inserted past the WB using optical combiners, and added to the line.

The WB-based architecture provides many advantages such as cost-effectiveness, remote configurability, 100 percent add/drop capacity (access to all wavelengths) and good optical performance. However, adding a new optical path to the site (branching) is a very costly and complex task, as service providers need to re-engineer the site and in some cases interrupt the existing service. This limitation translates into a significant reduction in network flexibility and as a result reduces dramatically service providers' ability to dynamically meet traffic demands and service expansion into new territories in a cost-effective and timely manner. In addition, WB-based ROADMs require the use of an extensive set of components (filters, splitters, etc.), hence increasing the site's cabling complexity and reducing its reliability.

The second generation of ROADMs is based on PLC where service providers can remotely insert/terminate (add/drop) or route any particular wavelength through wavelength directors. This approach provides a reduced networking cost over WB-based ROADMs; however, optical performance (affected by PDL issues) and the limitation to 100-GHz spaced wavelengths are less attractive than WB-based ROADMs. In both architectures, optical branching remains a complex task.

Figure 1. Wavelength Blocker-based ROADM — first generation ROADMs

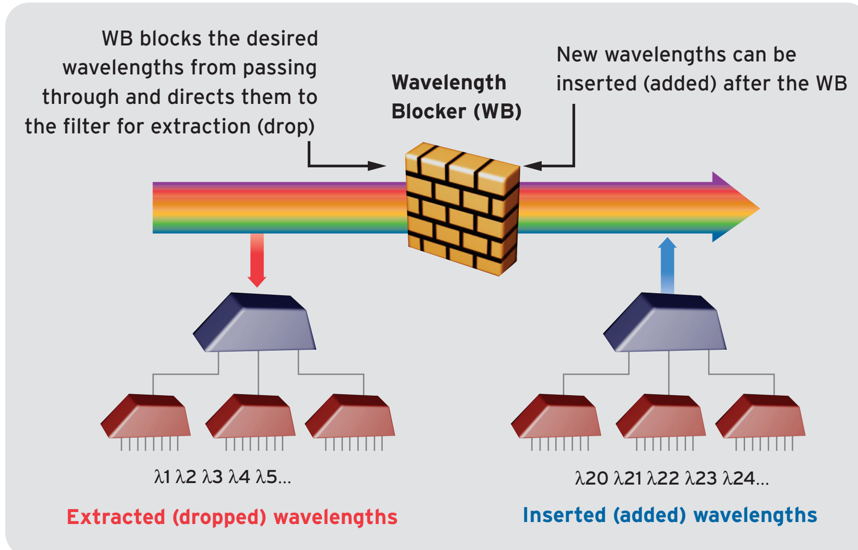
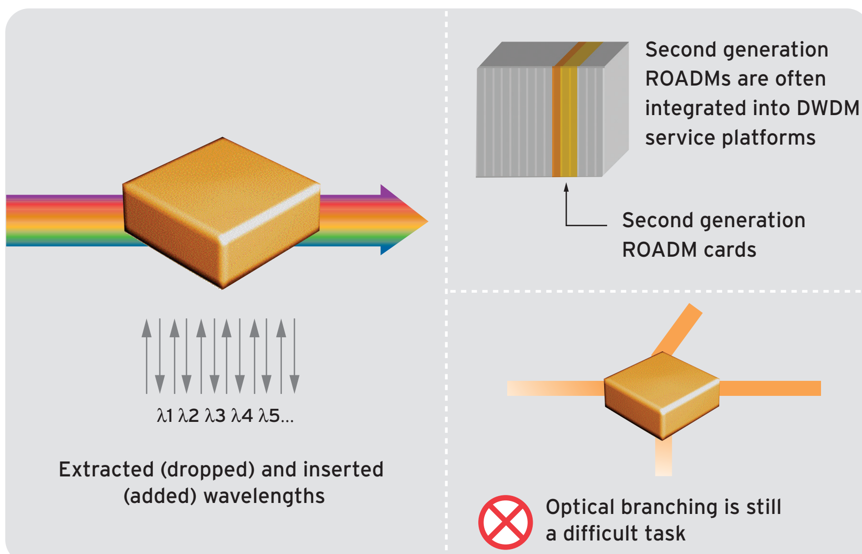


Figure 2. PLC-based ROADM — second generation ROADMs



Many vendors have packaged second generation ROADM capabilities and wavelength multiplexers/demultiplexers into their existing DWDM platforms in the form of a circuit pack, allowing service providers to leverage their installed base to benefit with these ROADM capabilities. However, equipping a DWDM platform with all the circuit packs required for the ROADM functionality (e.g., with the ROADM module requiring two slots, the demultiplexer module requiring one slot and the necessary fiber breakout panel due to the number of connectors required to terminate, etc.) drives towards a quick exhaust of the platform's real-estate (slots) and hence the deployment of additional platforms that house the service interfaces.

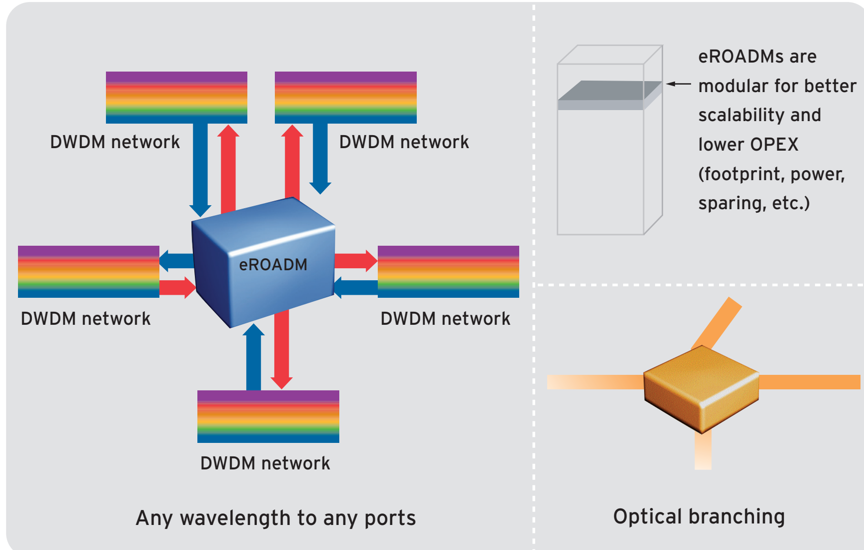
Furthermore, the ports on PLC-based ROADMs have predetermined wavelength values (hardwired to a specific frequency). As a result, service providers, regardless of whether tunable lasers are used or not, cannot remotely configure wavelength connectivity and must send technicians to perform the reconfiguration manually.

Evolution to enhanced ROADM (eROADM) architecture

As described in the previous section, second generation ROADMs allow service providers to have slightly better control over adding/dropping or routing any wavelength at a specific site; however, it still doesn't offer cost-effective and simple optical branching, a key aspect in VoD deployment. Moreover, second generation ROADMs integrated in existing DWDM platforms drive service providers towards a heavy investment in hardware covering the entire wavelength spectrum at the initial deployment in order to meet future bandwidth growth (high initial first cost).

A new disruptive ROADM architecture has been recently introduced to the market, called enhanced ROADM (eROADM). It leverages the simplicity, the fine precision and the unmatched flexibility of Micro Electro-Mechanical Systems (MEMS) technology to allow unrestricted add/drop and redirection of any wavelength at any port, thus enabling service providers to remotely perform 'on the fly' wavelength insertion, termination or switching at any site or adding a new optical path (branch) without re-engineering the network or interrupting the existing services (Figure 3).

Figure 3. enhanced ROADMs (eROADMs)

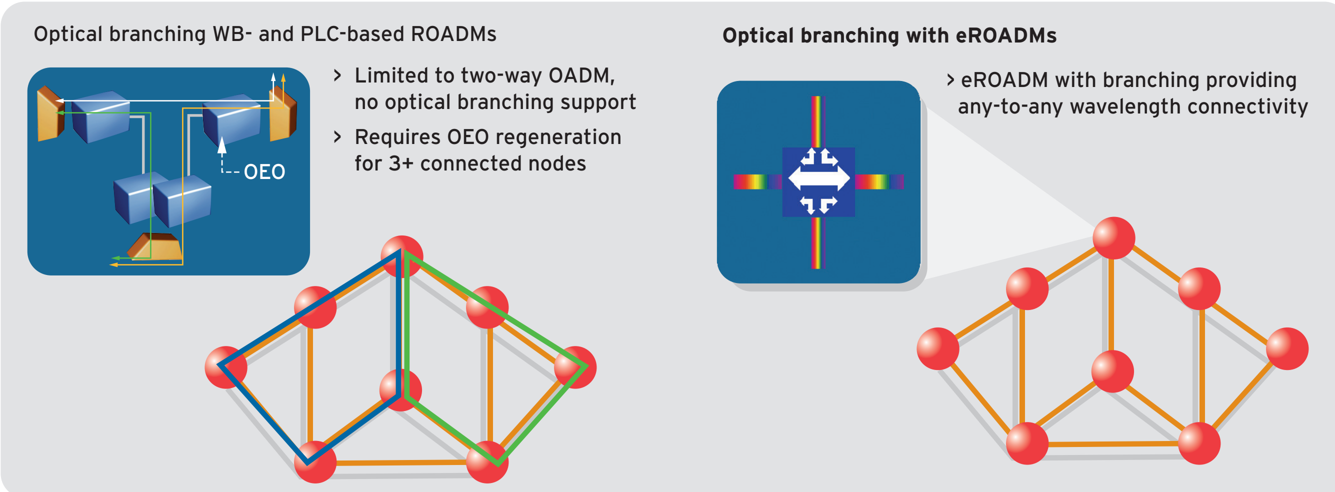


Unlike second generation ROADMs which are only offered as integrated circuit packs, the DWDM line platforms (i.e. chassis-based) eROADMs are offered in both forms — integrated circuit packs as well as stand-alone modules (i.e. chassis-less).

The advantages of eROADMs are summarized in the following bullets:

- **Low initial first cost —** As service providers can dynamically and cost-effectively add eROADM modules to meet traffic requirements and service growth — 'add-as-you-grow'.
- **Significant reduction in capital expenditures —** As eROADM eliminates the need to deploy O-E-O platforms when optical branching is required (Figure 4).
- **Significant reduction in operational expenditures —** As eROADM modules have significantly less cabling, footprint and power consumption than ROADMs integrated on DWDM transport platforms. For example, an eROADM consumes 200 Watts, equivalent to two 100 Watt light bulbs, while offering any-wavelength to any of the five ports.
- **Successful multi-product interoperability —** eROADMs can be deployed as a point of flexibility connecting DWDM terminals, MSPPs, OXCs, routers, etc. from different vendors, where chassis-based ROADMs are 'hard-wired' to the shelf's optical interfaces.
- **Future-proof and seamless services evolution —** As the modular design of eROADMs separates the service layer from the photonic layer, network operators can keep up with the latest developments on service evolution without the need to re-deploy new hardware on the photonic layer. Moreover, the support of 40-Gbps line rates and a significant number of wavelengths (e.g. 72) provides scalability to meet future growth and maximizes wavelength connectivity in optical branching applications.

Figure 4. Optical branching with first, second generation ROADM and eROADM



Another key attribute of eROADMs is the ability to provide complete remote re-configurability without truck rolls through 'colorless' ports. Unlike previous generations of ROADMs where each port is assigned to a particular frequency (wavelength), eROADM ports are not assigned to a wavelength in particular (i.e. colorless), thus enabling service providers to perform remote and unrestricted wavelength rerouting for true network agility.

Table 1 summarizes the differences between first and second generation and enhanced ROADMs.

Nortel's implementation of eROADM on the Common Photonic Layer (CPL)

Nortel offers the eROADM functionality on its Common Photonic Layer (CPL) that delivers any wavelength, anywhere, anytime, without impact to the existing traffic. The implementation of eROADM is modular (two Rack Units), enabling dynamic 'on the fly' optical branching to up to five different optical paths in addition to facilitating basic add/drop of individual wavelengths. Unlike previous generations of ROADMs with colored ports, Nortel's eROADMs are 'colorless', which means any wavelength (color) can be added/dropped on any port without truck rolls, thus increasing network agility while reducing operational

Table 1. A comparison between the various generations of ROADMs

ROADM technology	ROADM technology (WB-based)	Second generation (PLC-based)	eROADMs (MEMS-based)
Availability	2002 to 2004	Late 2004	Late 2005
Pay-as-you-grow	Must install all wavelengths from day 1	Must install all wavelengths from day 1	Modular add-as-you-grow
Optical branching	No	Complex	Yes
Colorless ports	No	No	Yes
Number of wavelengths	Up to 72	Up to 36	Up to 72
Spectral efficiency	100 GHz	100 GHz	50 GHz and 100 GHz
Patch cord count	Moderate	High	Low to moderate
Packaging	Good	Integrated in DWDM platforms 3 services slots	Good — modular or integrated

expenditures. Nortel's eROADM also supports both 50 GHz and 100 GHz wavelength spacing for increased spectral efficiency.

Figure 5. Nortel's eROADM

Service providers and cable operators can redirect wavelengths to any span and create new optical branches at strategic fiber junctions without requiring conversion back to electrical signals. Nortel's Domain Optical Controller (DOC) control plane provides continual network optimization during reconfigurations and network expansions for a fully-automated process.

Wavelengths on Nortel's eROADM are managed optically and on a per-channel basis, thus avoiding stranded bandwidth and limiting the need for fiber interconnections, while reducing the risk of outage due to incorrect manipulation of equipment. In short, per-wavelength management maximizes network utilization and efficiency while increasing reliability.

Application example

The scenario

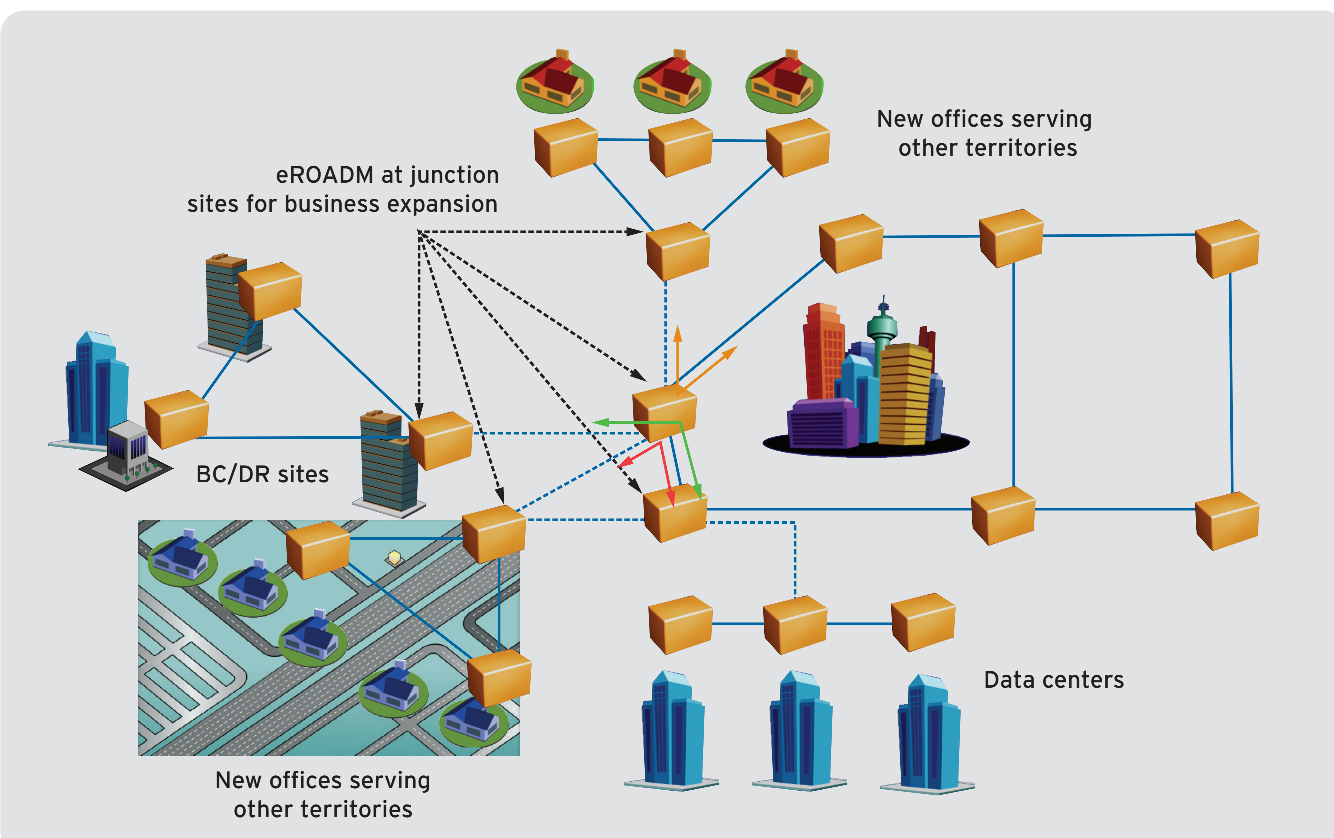
A service provider is planning to start offering new broadband and triple play services. The deployment plan consists of offering these services initially (Phase 1) to highly populated areas with a high expected take rate. In Phase 2, the service provider will extend the service offering to new territories (served by competitors) as depicted in Figure 6.

The challenge

To extend the offer of broadband and triple play services while addressing the following business and operational requirements:

- Ensure a minimum capital expenditure for faster return on investment (ROI)
- Maintain the service integrity as triple play services (e.g. IPTV, VoIP) have stringent quality requirements (low jitter and latency, etc.)
- Avoid at any cost increasing network complexity
- Extend the services in Phase 2 to new territories without interrupting the network and at minimal costs
- Ensure seamless network and service scalability

Figure 6. Deploying eROADMs at junction sites for business expansion



The solution

Given the limited and cumbersome implementation of optical branching with first and second generation ROADMs, the service provider had no other option than to deploy numerous OEO platforms and extensive cabling in junction sites to meet the service expansion in Phase 2. This will require an extensive capital investment and significant increase in network complexity and operational expenditures which might result in invalidating the service provider's business case for growth.

Nortel's eROADM was designed to address the dynamic changes in the network 'on the fly' — a key capability in the broadband and triple play deployments which are often characterized to have unpredictable traffic patterns.

The service provider can deploy Nortel's eROADM at junction sites (Figure 5) providing unrestricted any-wavelength-to-any-port connectivity between all five ports in addition to quick and simple setup of new optical branches to serve new territories when the service expansion plan is put to action (Phase 2).

The colorless ports on Nortel's eROADM eliminate truck rolls while providing true network agility that gives the service provider a leading edge over its competitors.

The benefits

The added value of Nortel's eROADM lies in its ability to address traffic changes and network expansion and reconfiguration 'on the fly' and at minimal cost. The benefits can be summarized in the bullets below:

- Enables wavelength agility throughout the network to dynamically address network demands without re-engineering or service interruption
- Extends the service offering to new territories quickly and without truck rolls with optical branching (up to five branches per eROADM)
- Reduces overall network latency and increases the network robustness through the elimination of numerous OEOs at junction sites
- Ensures seamless interoperability with other standards-compliant vendors through the support of foreign wavelengths
- Provides scalability from 1 to 72 wavelengths supporting both 50 GHz and 100 GHz spacing
- Ensures a future-proof network by supporting 40 Gbps wavelengths

Conclusion

While the first and the second generation ROADMs enabled service providers to remotely insert, terminate and redirect wavelengths across the network, they fell short in terms of providing a simple and flexible solution for optical branching, a key capability for service providers offering triple play services. Enhanced ROADMs (eROADMs) fully fill this requirement with a higher level of flexibility and efficiency while providing low initial first cost, significant reduction in operational expenditures, successful interoperability and seamless service evolution. Enhanced ROADMs were designed and built around broadband service network requirements and they are a key factor in the successful deployment and growth of these services.

NN115940-041906

In the United States:
Nortel
35 Davis Drive
Research Triangle Park, NC 27709 USA

In Canada:
Nortel
8200 Dixie Road, Suite 100
Brampton, Ontario L6T 5P6 Canada

In Caribbean and Latin America:
Nortel
1500 Concorde Terrace
Sunrise, FL 33323 USA

In Europe:
Nortel
Maidenhead Office Park, Westacott Way
Maidenhead Berkshire SL6 3QH UK
Phone: 00800 8008 9009 or +44 (0) 870-907-9009

In Asia Pacific:
Nortel
Nortel Networks Centre
1 Innovation Drive
Macquarie University Research Park Macquarie Park, NSW 2109
Australia
Tel +61 2 8870 5000

In Greater China:
Nortel
Sun Dong An Plaza, 138 Wang Fu Jing Street Beijing
100006, China
Phone: (86) 10 6510 8000