

CD ROADM – Fact or Fiction

Part 2: Flexibility at a Price

While there has been substantial industry promotion of Colorless Directionless ROADMs (CD ROADMs), there has been much less discussion of the applications, benefits, limitations, and costs associated with CD ROADM technology. CD ROADMs offer an attractive architecture for carriers since they enable wavelength reassignment and re-routing without manual involvement from a technician. The real question is whether this additional flexibility is justified given the higher ROADM costs.

This paper is the second in a two-part series that provides an overview of CD ROADM architectures and their network applications, benefits, and costs. Part One examined the primary applications enabled by CD ROADM architectures, along with any limitations. Part Two examines the technologies required to implement a CD ROADM architecture and the costs compared to existing ROADM technology.

As an optical transport leader, Fujitsu is committed to supplying the industry with the highest quality products and solutions, regardless of a carrier’s architectural choices. The objective of this two-part series is to ensure carriers are making informed, fact-based decisions that support their business and optical transport networks.

ROADM Review

A ROADM consists of optical amplifiers, optical switching, multiplexer/demultiplexer, transponder, and muxponder cards to enable a complete, flexible, optical transport node. A typical ROADM implementation is shown in Figure 1.

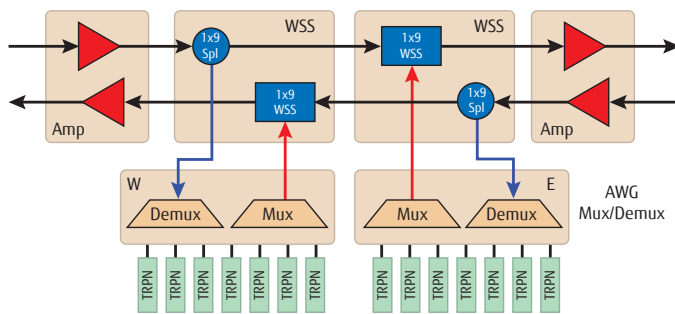


Figure 1: Typical 2D ROADM

The mux/demux provides the connection point between the composite WDM layer and the individual channels or wavelengths, which are implemented with transponder and muxponder units. With current generation ROADMs, the mux/demux is passive device implemented with Arrayed Waveguide (AWG) technology, essentially a prism that separates each wavelength into individual input and output ports. AWG technology is widely utilized, reliable, and cost competitive. However, it does require a technician to re-assign wavelengths to a new channel or to re-route them to a different WDM direction by physically unplugging the transponder from one port and re-inserting it into a different physical mux/demux port.

CD ROADMs

CD ROADMs allow wavelength reassignment without the need for manual intervention—with the tradeoff of higher complexity and higher costs. In Part One of this series, only a high-level conceptual view of a CD ROADM was provided, hiding the true complexity of this architecture. Unfortunately, this simple CD ROADM diagram is widely used throughout the industry, and has led to the misconception that the two types of ROADMs are similar in their complexity and implementation. Nothing could be further from the truth, as shown Figure 2, which is a more detailed diagram of an 88-channel, 8-degree capable CD ROADM.

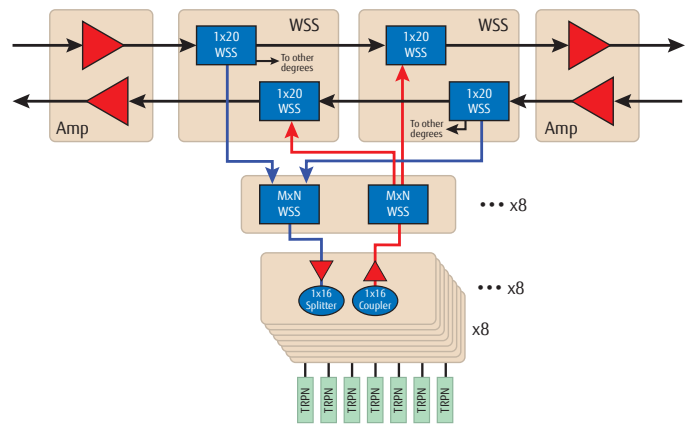


Figure 2: Colorless Directionless ROADM

While every vendor has their own detail diagram of a CD ROADM, most are based on similar approaches to Figure 2. The AWG mux/demux utilized on standard ROADMs, is replaced by a large number of optical splitters, couplers, WSS modules, and optical amplifiers to enable colorless, directionless operation. A single group of these add/drop modules supports up to 88 channels. This ROADM architecture also supports up to 8-degree optical hubbing, requiring up to eight of these add/drop groups to support full drop capacity across all degrees. At the WDM layer, 1x20 WSS modules provide optical connections to any of the eight add/drop groups, as well as connections to any of the eight degrees (8D) for pass-through traffic. The diagram shown is for a simple 2D ROADM configuration with a single add/drop group. Unfortunately, the optical loss through the additional drop side optical couplers, splitters, and WSS modules requires the use of several layers of optical amplifiers.

Colorless capability is implemented by utilizing the inherent “tuning” feature of coherent receivers. Each coherent transponder “tunes” its optical receiver to the provisioned channel, essentially blocking or filtering all other channels present at the optical port.

While outside the scope of this article, it is worth noting that the industry is also debating two somewhat related topics called Flexible Grid and “contention-less ROADM”. Existing ROADM systems support ITU-standard 50 GHz grid spacing. Next-generation ROADM systems will support flexible grid spacing, with the channel size optimized to the signal being transported (100G, 400G, 1 Tb). Contentionless ROADMs are a type of architecture that removes wavelength “contention” or blocking at nodes, but is very costly to implement. There are alternative, lower cost methods to address mesh network contention. While these are related and interesting topics, they are more appropriately addressed in separate discussions.

Flexibility at a Price

Comparing the two architectures side by side illustrates the extensive differences between a standard ROADM and CD ROADM, including the large number of optical components required to implement a CD ROADM node. While a CD ROADM does offer additional network flexibility, the additional optical components and technology carry a price premium over standard ROADMs.

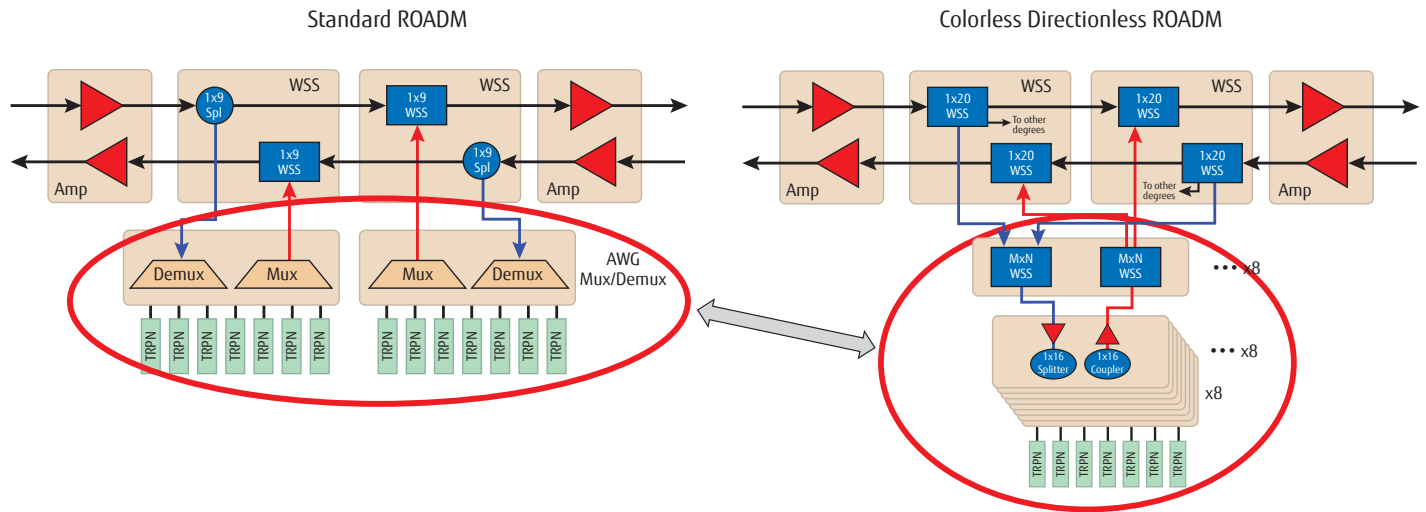


Figure 3: Standard versus CD ROADM

To get a true comparison of the architectural, component, and cost differences between the two approaches, a common model was priced based on the following configuration:

- 2D ROADM (East/West) configuration – 8-degree capable system
- 44 channel drop capacity
- No transponders

Since the transponders are common to each model, they were excluded from the comparison, allowing an analysis of just the ROADM architectural differences. Many carriers refer to this as the “first cost,” meaning the cost of the ROADM network prior to deploying any services (i.e. transponders). Figure 4 shows the primary optical component differences between a standard ROADM and CD ROADM implementations.

	Standard ROADM	CD ROADM
1x9 WSS	2	–
1x8 Splitter	2	
44-Channel mux/demux	2	–
1x20 WSS	–	4
MxN WSS	–	2
1x16 Splitter	–	3
1x16 Coupler	–	3
Amplifiers, drop side	–	6

Figure 4: Comparison of Standard ROADM versus CD ROADM

WSS modules perform vital functions in all ROADMs, including optical switching and automatic per-channel power balancing, but they remain some of the most expensive components in a ROADM platform. When additional WSS modules are added to support colorless directionless features, they have a substantial impact on the overall ROADM price. A standard ROADM architecture requires two 1x8 or 1x9 WSS modules, as shown in Figure 4. A CD ROADM requires a total of six WSS modules, all of the more expensive 1x20 WSS and MxN WSS configurations. In addition, six optical amplifiers are needed on the drop side to overcome the optical losses caused by the couplers, splitters, and WSS modules.

CD ROADM offers additional flexibility, primarily the ability to reassign and re-route channels without the need for manual technician involvement. The operational flexibility comes with higher complexity, additional optical components, and a higher price. Whether or not the additional flexibility outweighs the additional cost is an individual decision for each carrier, based on their network objectives and corporate ROI goals. Figure 5 provides a normalized price comparison of the two ROADM architectures for similarly configured ROADM nodes, based on the model configuration.

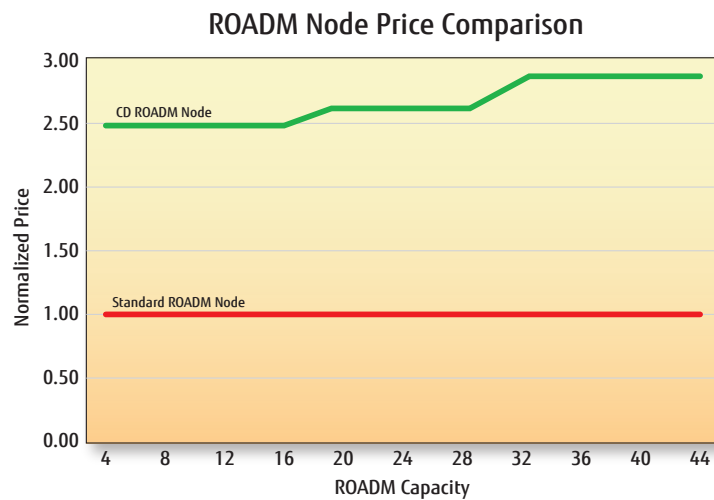


Figure 5: ROADM price comparison

The comparison highlights approximately 2.5x cost difference between similarly configured standard and CD ROADM nodes. All pricing is “normalized” with the standard ROADM configuration established as the baseline (1.00). The difference between the two ROADMs is a direct result of the additional drop-side WSS modules, amplifiers, couplers, and splitters required for a CD ROADM architecture.

In the case of the CD ROADM, there is a small increase in costs as the system capacity is increased in increments of 16 channels. Referring to Figure 2, client side optical coupler/splitter modules are configured for 16 channels per card. As node capacity grows beyond 16 channels, a second I/O module is added to support channels 17–32 and then 33–48, resulting in the slight increases shown in the graph.

Summary

CD ROADMs offer additional network flexibility by enabling wavelength reassignment and re-routing, without the need for manual involvement by a technician. However, this additional flexibility comes with increased complexity and cost. Comparing the two ROADMs resulted in approximately a 2.5x premium for a CD ROADM node. The increased cost is primarily due to the additional WSS modules, amplifiers, couplers, and splitters required to implement a CD ROADM. Given the price premium, carriers will have to evaluate their own network applications and objectives to determine whether investment in CD ROADM architectures is warranted. Whichever ROADM architecture carriers choose to implement, rest assured that Fujitsu is leading the industry with next-generation optical transport products and solutions.

Acronyms	
2D	Two-Degree ROADM
8D	Eight-Degree ROADM
AWG	Arrayed Wave Guide
CD ROADM	Colorless Directionless ROADM
DWDM	Dense Wavelength Division Multiplexing
ITU	International Telecommunication Union
Mux/Demux	Multiplexer/Demultiplexer
ROADM	Reconfigurable Optical Add Drop Multiplexer
ROI	Return on Investment
WDM	Wavelength Division Multiplexing
WSS	Wavelength Selective Switch