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Flexible, Intelligent CDCF Networking

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As bandwidth continues its exponential growth, service providers must adapt their networks to accommodate the ever-increasing throughput demand. As data moves closer and closer toward the end user, multiple 100G circuits to edge data centers are the new norm, while 400GbE services will become available to more and more content delivery network operators over the next couple of years.

To keep pace with the ever-growing complexity, incorporating colorless, directionless, and contentionless functionality in flex-grid deployments (CDCF) is essential to effectively manage and operate super-high bandwidth networks. CDCF provides design flexibility for network architects and capacity growth for network planners. Pragmatically, incorporating CDCF in an economic manner while also interoperating with legacy systems is key.

The core building blocks with all fiber networks are optical add-drop multiplexors which, as the name implies, enable a wavelength to be added (inserted), dropped (accessed), or passed through (bypassed) at the network node. Initial generations of optical add-drop multiplexors were hard-wired with every change requiring manual intervention, resulting in more touches and limited routing options. Today's reconfigurable optical add-drop multiplexers (ROADMs) provide software-enabled control and configuration changes, yielding more efficiencies and flexibility.

ROADMs are used to steer specific wavelengths from one fiber route to another fiber route. Where previous generations required the use of expensive optical-to-electrical-to-optical (OEO) regeneration (or, back-to-back transponder regeneration), this switching can now be done in an optical-only domain. The optical-only paths of these transparent networks, commonly referred as express routes, eliminate OEO regeneration, which equates to fewer equipment elements and lower overall costs.

Further expanding on these attributes, the newer generation of optical transport technology introduces colorless, directionless, contentionless, flex-grid (CDCF) add-drop functionality. CDCF greatly adds to the capacity, design flexibility, and operational efficiency of the network. To help understand these CDCF benefits, here are some simplified descriptions with an analogy or two thrown in for good measure.

Colorless ADD/DROP

Colorless ADD/DROP enables any wavelength, regardless of color or frequency, to be connected to any ADD/DROP port at a node location. In the old days, each specific ADD/DROP port was "hard coded" to a specific color, meaning the wavelength of the transponder had to be tuned to exactly match that specific port.

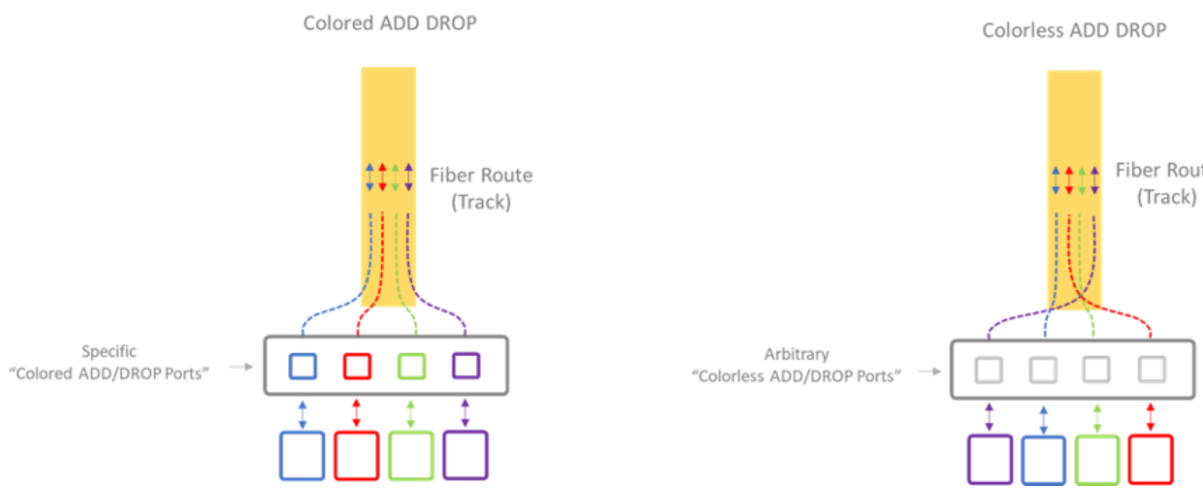

Figure 1: Colorless ADD/DROP

Using a train station analogy, a "blue train" wanting to access the track (fiber route) could only access the track by entering through a specific "blue platform" (or blue port) of the train station (node). However, with colorless ADD/DROP, each physical ADD/DROP port is software tunable to match the color and frequency of the incoming wavelength. Thus, the platforms at the station are now color independent. The train comes into the station, and the ROADM adjusts the platform (port) configuration to match the train's color. This solution simplifies network planning and eliminates the need for technicians to physically reconfigure switches—resulting in time savings and lower operational costs.

Directionless ADD/DROP

Originally the ADD/DROP structure (see image on next page) was "directioned," which meant that any traffic (trains) that were added or dropped off at a train station had to come from a specific route (track). Thus, trains coming in and going out of a station were strictly limited to specific tracks (for instance, only east to west). This was mainly attributed to the first-generation architectural approach of "broadcast and select," where the transmission from various nodes were combined and sent (or broadcast) to all receivers. These would then use tunable filters to select their particular wavelength. It's tough to use the train analogy here, so think of a radio that receives signals broadcasted from all radio stations but then is tuned to listen to only one station at a time. This technology lent itself well to various initial applications of ROADM such as "ADM on a blade" and provided a good balance between node cost and function.

With the significant increase in router density and packet transport over DWDM (dense wave division multiplexing), a more flexible "any to any" topology was required to match more modern traffic flows. Unlike the "one to many" approach of broadcast and select, directionless ADD/DROP enabled by a "route and select" architecture implemented with cutting-edge ROADM wavelength selector switch technology solves the limitations.

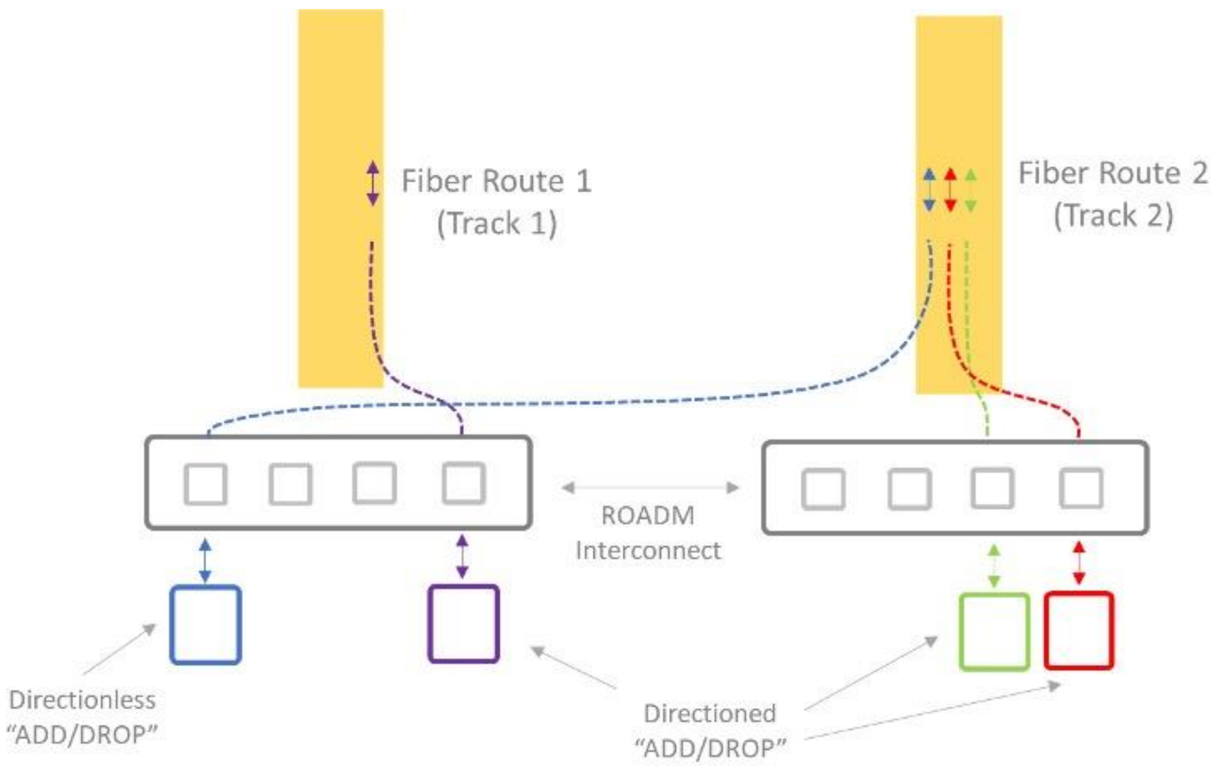

Figure 2: Directionless ADD/DROP

Going back to the train analogy, a two-direction or two-degree system meant trains coming from the east had only one choice going west to leave the station. Multi-degree technology increased the switching capability (typically up to eight routes) to enable meshed networks. Thus, trains could now be routed to additional tracks going in different directions to different train stations. However, these systems still had limits to their flexibility. Trains passing through the stations without stopping benefitted from this multi-degree switching, but trains that stopped (for example in add/drop) still required manual intervention.

Directionless ADD/DROP allows for any train (traffic) to access any of the tracks (fiber routes) at the station (node). This traffic flow is irrespective of which ADD/DROP patch panel location it is connected to. Directionless ROADMs enable automatic reconfiguration of the direction for an added or dropped wavelength. This solution provides a further increase in the flexibility of route design and implementation.

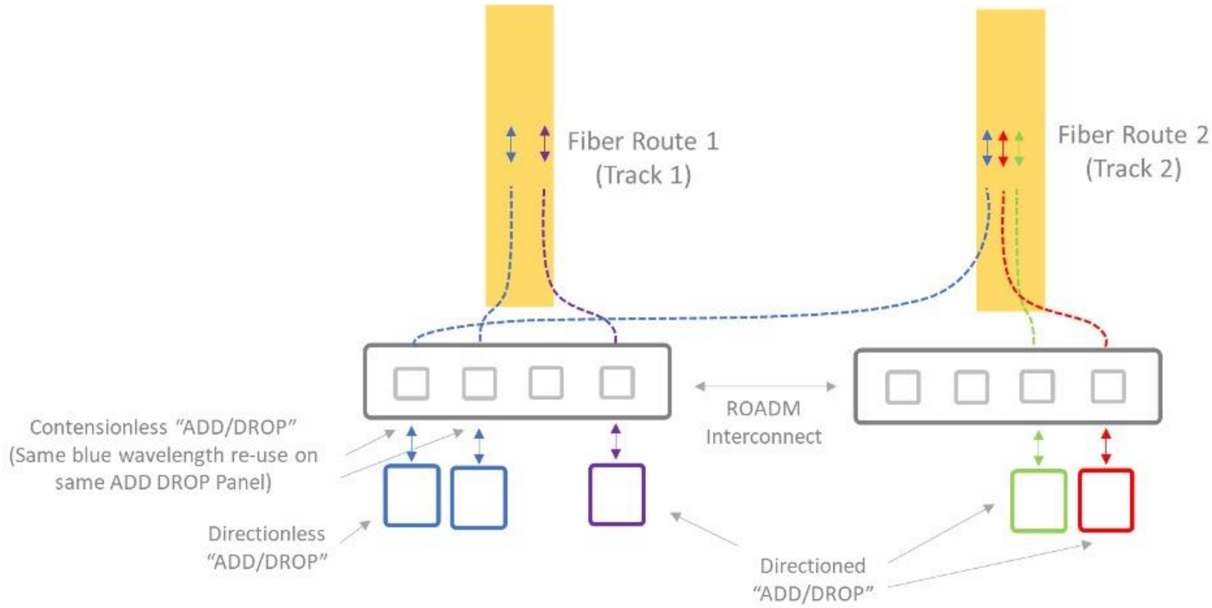

Figure 3: Contentionless ADD/DROP

Contentionless ADD/DROP

Contentionless ADD/DROP (see image, above) refers to the ability to manage two trains of the same color arriving at the same station at the same time. The ROADM can transmit and receive two signals with the same wavelength on the same ADD/DROP panel. Thus, contentionless ADD/DROP keeps the two "blue" trains separated and then routes them in two different directions without interference or blocking.

As illustrated, the add/drop tuning and route steering and switching can be done remotely via software, which provides the ultimate in dynamic design and planning flexibility.

Flexible grid

Flexible grid enables different-sized trains to operate side by side on the same fiber route. We're going to break our train track as a fiber analogy a little for this one. Instead, assume that multiple tracks are carried over the same fiber. Originally, each of these tracks and their trains had the same standard width of 50GHz (fixed grid). In a flex grid system, "fatter" and "wider" trains that can carry more load (increased data rate) can operate side by side with the standard 50GHz trains and tracks. Additional capacity is also increased by reducing the gap between side-by-side tracks. Putting more tracks in this free space without buying more land means better spectral efficiency and more usable bandwidth over the same fiber pair.

The flexibility to broaden this "passband" beyond the standard 50 GHz (88/96 Ch) and 100 GHz (40/44 Ch) allows us to take advantage of the high-speed, high-performance coherent transceivers such as 400, 600, 800 and future 1.2 Tbit/s. Moving to flex grid and larger load carrying trains allows the ability to carry multiple smaller independent trains such as 100 Gig and 400 Gig. Flex grid also allows for the frequency passband of each channel to be variable and adjustable remotely via software. Taking advantage of coherent transceivers and the spectral efficiency they offer leads to an increase in overall fiber route capacity while simultaneously lowering power consumption, equipment footprint and the critical cost per bit metric.

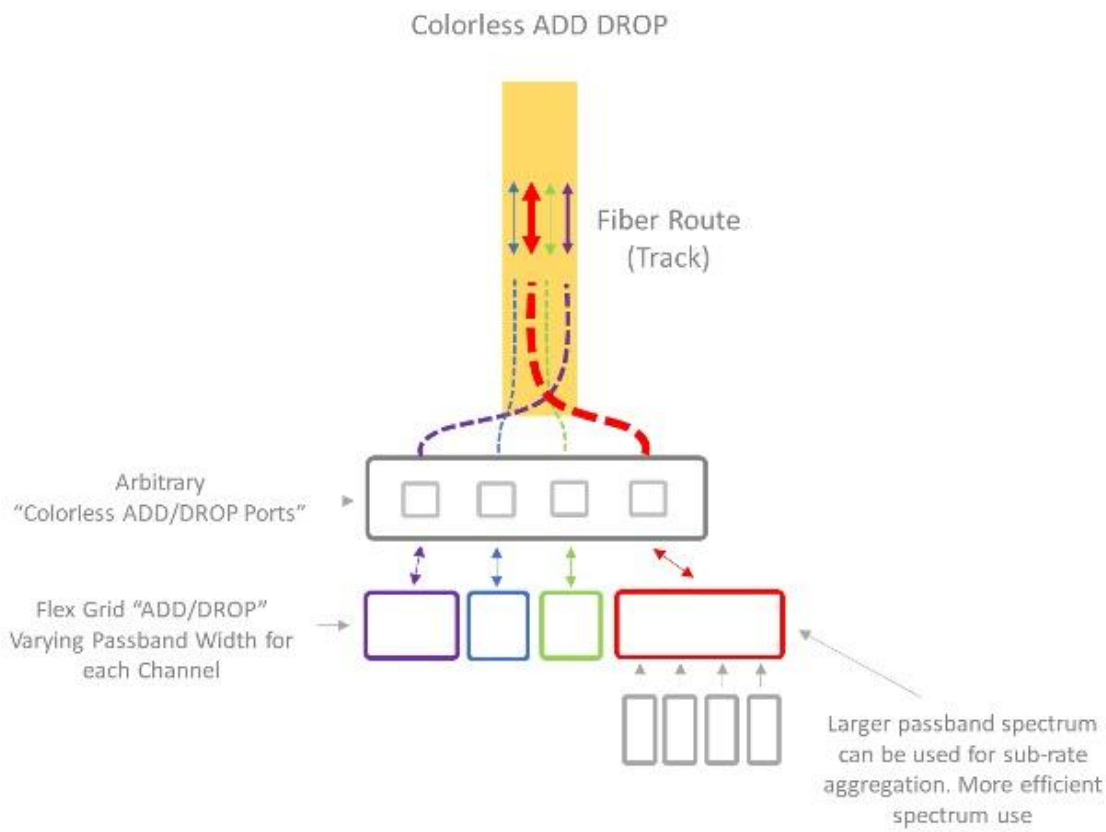

Figure 4: Flexible grid

Controlling and managing signals at the optical level provides an operationally optimized network by simplifying provisioning, reducing installation intervals, eliminating excess network elements, and increasing service reliability. One of the keys is to integrate these newer state-of-the-art upgrades alongside the existing network. Windstream is one such company to fully embrace these technologies with a nationwide network upgrade that incorporates Ciena's coherent optical technologies.

The ROADMs that Windstream is deploying will integrate well with the existing flex grid network and increase the overall capacity (including 400 GbE wavelength services) using both C and L bands. As noted above, CDCF provides extreme network capacity through efficient use of the existing fiber plant. Beyond the network flexibility and capacity, Windstream is also deploying Layer 0 analytics to monitor and manage services at the photonic level. Advances such as automatic link calibration and automatic fiber characterization help to combine engineering innovation with daily operational benefits.

The future continues to drive towards a one-size-doesn't-fit-all approach, and the new platform discussed here enables network providers to customize scalable solutions for their end users. Choosing the right partner who continually invests in advanced network technologies helps ensure that their customers are also ready for the future. At Windstream, we marry a passion for state-of-the-art technology with practical, customer focused engineering.