TECHNOLOGY

# Dynamic high connectivity mesh networks with flexible grid ROADMs and 400G+ coherent transceivers

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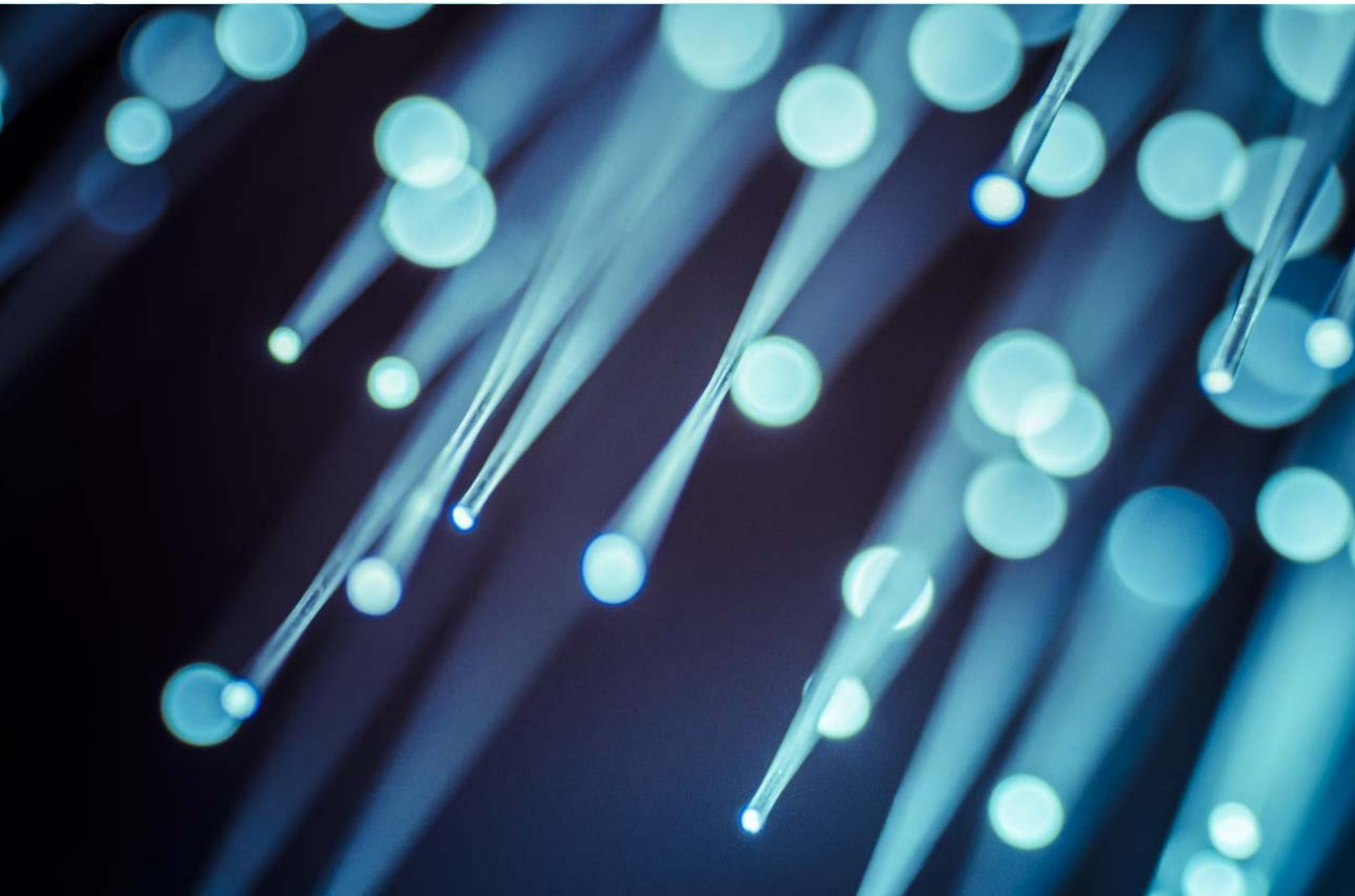

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# Introduction

Optical networks are evolving to support the insatiable appetite for information driven by the digital transformation of enterprise networks utilizing the cloud, video streaming, and mobile. Several data-rich apps are coming online now: 5G upgrades with millions of users demanding high-definition content and video anywhere and anytime, distribution of 4K video and 8K VR to consumers, and IoT with the promise of billions of devices communicating with remote equipment 24/7.

To keep pace with increasing demand while reducing the cost per bit, operators have traditionally moved to higher data rate transceivers. 400G+ coherent transceivers began initial deployment in 2018, and we expect scale deployments to begin in 2019. The transition from 100/200G to 400G is not as easy as the transition from 10G to 100G or 100G to 200G, because at 400G the carrier spectrum is not compatible with 50 GHz fixed grid fiber infrastructure, including ROADMs.

Dynamic WDM networks hold the promise of helping operators increase connectivity, roll out and change services quickly, and optimize spectrum use. An additional benefit is the ability to defer the need to deploy or light new fiber as demand increases using ROADM mesh architectures. This report looks at how CDC-ROADMs incorporating flexible grid WSS and 400G+ multi-rate coherent transceivers will be used to transition from manual, fixed grid, statically provisioned networks to autonomous control, flexible grid, and dynamically provisioned functionality. The cost-effectiveness of practical networks deploying these functionalities and technologies is still an open question.

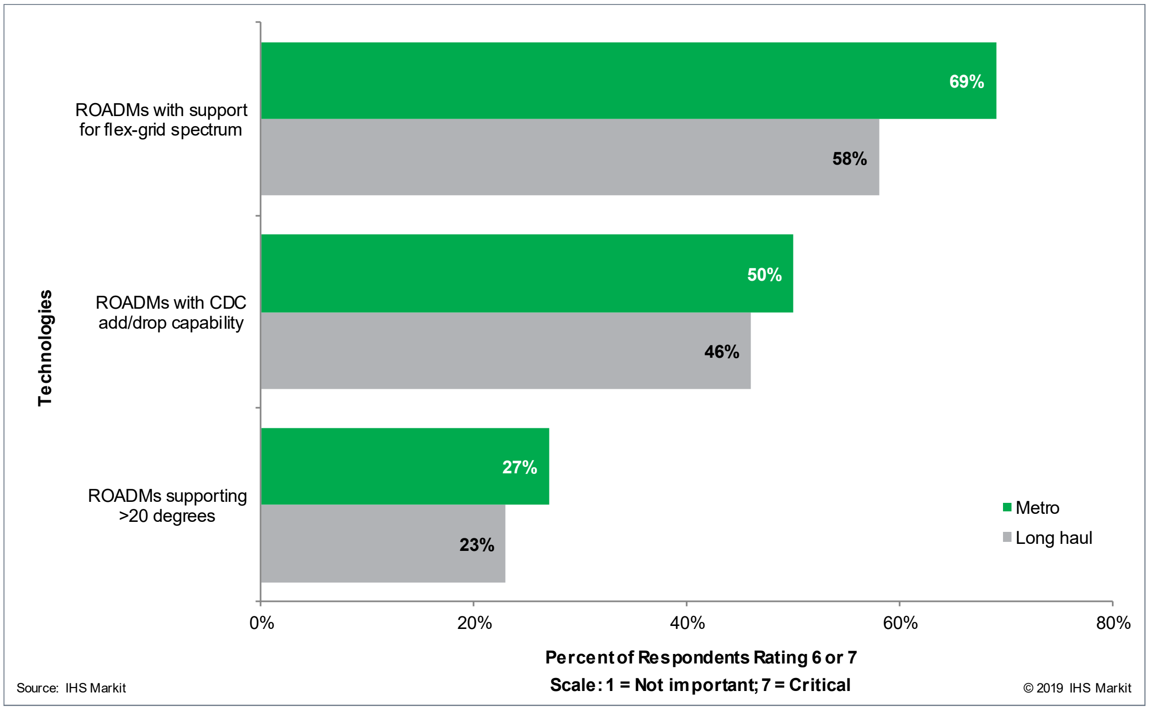
# Technologies most important to service providers

In Q4 2018, IHS Markit conducted a service provider survey to understand the top technical priorities for WDM networks. For metro and long-haul applications, the top two priorities associated with ROADM systems were as follows:

1. **Increased capacity per carrier through higher symbol rates and higher order modulation**
2. **ROADMs with flexible grid support**

The survey captured the top 3 priorities for ROADM technology, which are shown in Exhibit 1.

**Exhibit 1: Key technical priorities in metro and long-haul networks**



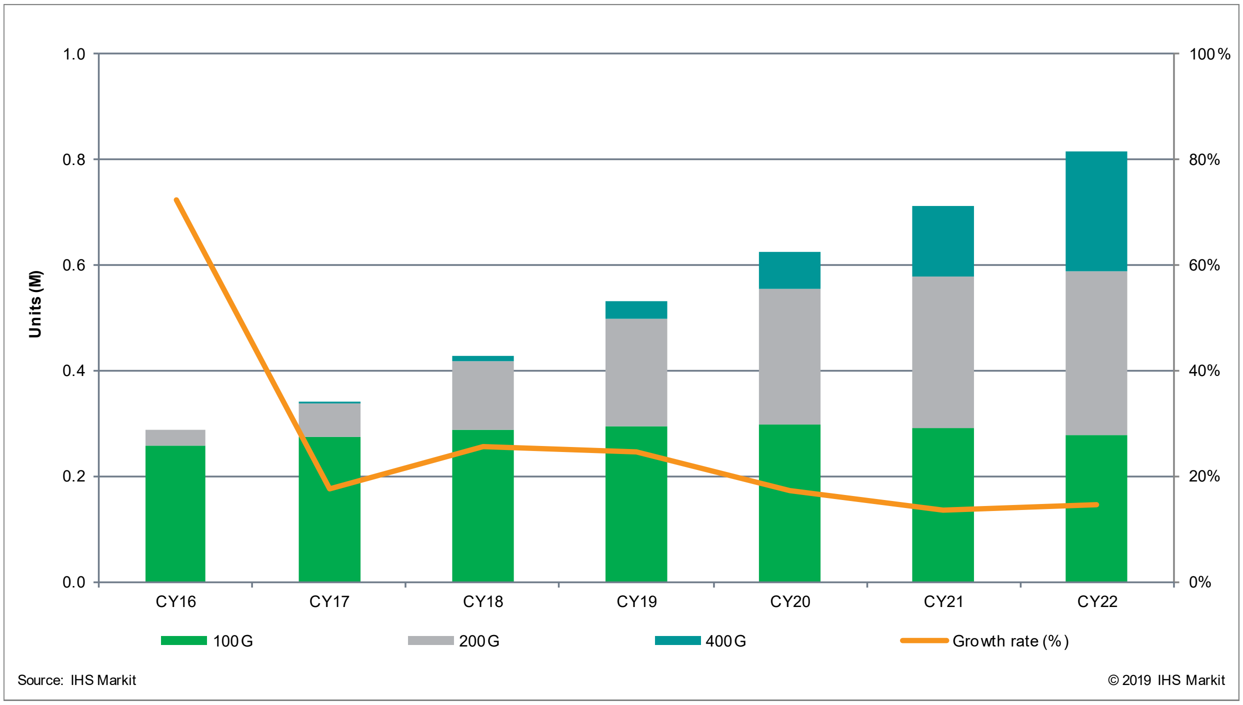

Source: *IHS Markit Optical Network Strategies Service Provider Survey - 2018*

No surprise on number 1, since it is required to support increased capacity per channel in these networks. CDC ROADMs were the second highest priority, as service providers are transitioning these networks from manually controlled, statically provisioned to autonomous control, dynamically provisioned adaptive mesh networks.

# Data-rich applications drive network growth

Telecom transceiver deployment can be used as a proxy for data center interconnect, metro and long-haul optical network growth. IHS Markit tracks the use of these transceivers for trend analysis and to forecast future use. During the coherent era, annual growth rates have been between 30% and 40% CAGR, with some year-to-year variation. Our conservative forecast model projects future growth rates between 25% and 35% from 2019 to 2022, with approximately 170Pb/s in new capacity deployed in 2022. Over this same period, we forecast the CAGR of 400G+ transceivers to be greater than 100%. Exhibit 2 shows the historical and forecasted transmission capacity from 2011 to 2022 broken down by transceiver data rates. In fact, by 2022, IHS Markit forecasts over 50% of the new capacity deployed will use 400G+ transceivers as networks adopt higher data rates to increase capacity and reduce cost.

**Exhibit 2: Transmission capacity growth forecasts**




*Source: IHS Markit Telecom Optics and Components Market tracker October 22, 2018*

# 400G and beyond multi-rate coherent transceivers

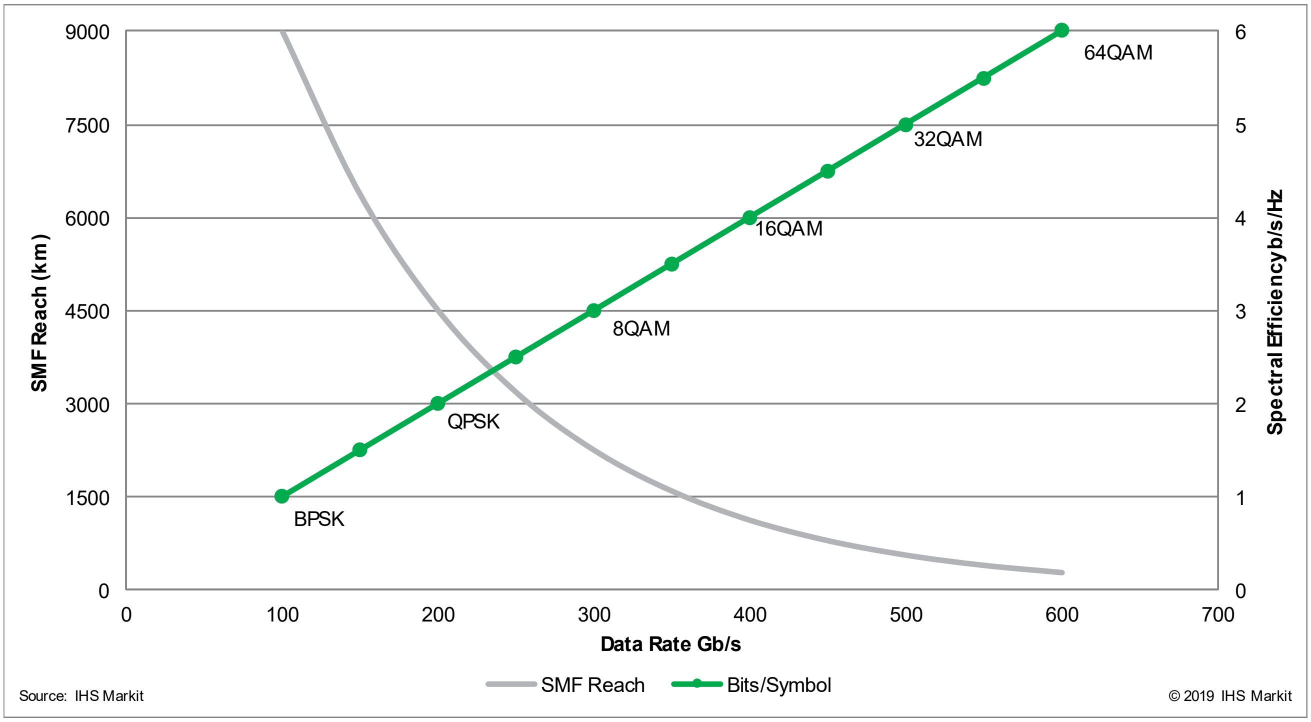
Transitioning from 100/200G to 400G+ coherent transceivers is enabled in two ways: 1) higher order modulation formats to increase the spectral efficiency; 2) increasing the baud or symbol rate of the carrier using higher speed electronics and optics. Each of these has advantages and disadvantages that depend on the requirements of the application and network. They use tunable lasers compatible with flexible grid and some support hybrid modulation, which can be used to optimize capacity and reach. Beyond 400/600G we expect 800G to use even higher data rates, which will require even wider channels.

Higher order modulation has the advantage of using fiber spectrum more efficiently, but it comes at a cost. Higher order modulation formats are more susceptible to noise, resulting in shorter fiber reach.

Moving from 8QAM to 16QAM results in two times the carrier capacity, but the reach is reduced by a factor of four. On the other hand, increasing the symbol rate from 35 to 70 Gbaud, and using the same modulation format, doubles the data rate while achieving fiber spans of ~90% the reach of the lower symbol rate when using optimized DSP algorithms and appropriate signal levels.

Using higher order modulation does not change the spectral width of the channel wavelength, so it is able to increase the spectral efficiency and work with both fixed 50 GHz and flexible grid WDM networks. However, the tradeoff is in OSNR, which limits the applications to shorter reaches.

**Exhibit 3: Fiber reach vs. spectral efficiency**




| | Higher Order Modulation | Higher Symbol Rate |
|---|---|---|
| Increased Spectral Efficiency | √ | Limited |
| Reach with 2x Capacity | ~25% | ~90% |
| Cost per bit | √ | √ |
| Fixed 50 GHz Grid | √ | Limited |
| Fixed 50 GHz Grid ROADM Mesh | √ | X |
| Flex Grid | √ | √ |
| Flex Grid ROADM Mesh | √ | √ |

Source: IHS Markit



Higher symbol rates up to 70 Gbaud are needed for noise-limited spans, and 400G+ carriers require grid widths in the range of75 GHz. They are not compatible with commonly deployed 50 GHz grids. They work with fixed 100 GHz grids, but this wastes approximately 25% of the fiber spectrum. To increase symbol rates above 70 Gbaud will require further investment in higher-speed electronics and optics.

## Next-generation ROADMs

The challenge for network operators when deploying new equipment is to do so in a flexible manner that supports legacy and future data rates by having the ability to provision both narrow and wider spectrum. The previous generation ROADMs are based on fixed 50 GHz grids, which do not support 400G+. CDC-ROADMs in these networks are based on MxN multicast switches (MCS), which use a lossy broadcast and select architecture. Moving to direct and select architecture, next generation ROADMs that replace the MCS with MxN WSS technology offer reduced loss and are compatible with flexible grid.

Flexible grid WSS technology is compatible with networks running legacy 10G and 100G while supporting wider channels needed for 400G and beyond. It also supports super-channels to a granularity of 12.5 GHz, which allows spectrum allocation to be more precisely matched to the channel's required width, thereby using fiber spectrum more efficiently. For leased bandwidth business, the ability to dynamically allocate spectrum in slices as narrow as 12.5 GHz will allow services to be customized in finer detail.

CDCF-ROADMs based on this technology provide the following key benefits:

- Supports flexible grids and 400G+ transceivers with increased signal levels
- Reduces channel count with support for wider channels and/or super-channels
- Minimizes or eliminates amplification at ROADM nodes, reducing cost and power dissipation
- Improves filtering to reduce noise and improve link performance
- Increases flexibility by providing traffic grooming in the photonic layer

## Capacity squeeze

Spectrally efficient coherent technology is rapidly approaching the Shannon limit for information content per channel, making the amplified fiber spectrum increasingly valuable as network operators seek to load each fiber with as much data as possible before deploying or lighting additional fibers. Multi-rate operation on flexible grids presents additional challenges to manage. Dynamically variable channel widths create opportunities for differentiated solutions to dynamically manage and optimize spectrum use.

A complimentary approach is to increase the amount of useful fiber spectrum by expanding C band and using L band. To accomplish this, the amplified spectrum needs to be increased, which will require investment in amplifiers. These amplifiers should also reduce noise to extend the reach for higher order modulations and accommodate increased signal levels used with higher symbol rate modulation.

Next-generation fiber infrastructure needs to both expand and use spectrum as efficiently as possible, reducing requirements for new fiber to meet bandwidth demand. Next-generation flexible grid-based CDCF ROADMs will play an important role improving the use and management of fiber spectrum in future WDM networks.

## The role of SDN and network automation

Service velocity, cost, flexibility, and capacity are key differentiators for optical networks as the industry transitions from static, fixed grid to dynamic, flexible grid architectures, and service providers have an opportunity to differentiate services and increase connectivity using these new tools afforded by flexible grid ROADMs and multi-rate transceivers. Effective use of these tools creates additional complexity in network management as modulation formats, symbol rates, and routes need to be carefully selected, monitored, and controlled to achieve desired reach, spectral efficiency, noise characteristics, latency, and other parameters. We believe managing this complexity will be a key driver for the adoption of adaptive control and optical network automation supported by SDN control and orchestration.

It is insightful to compare WDM networks with radio networks in cellular applications. Radio networks employ variable modulation formats and data rates, which are dynamically controlled to optimize link parameters such as quality of service, reach, spectrum, latency, and other parameters using adaptive technologies. 400G+ multi-rate coherent transceivers offer similar flexibility, and we expect increased use of adaptive technologies. Automated control of flexible grid CDC-ROADMs will be used to manage, add, drop, and groom traffic in telecom and web-scale applications.

## Bottom line

The transition from fixed grid statically provisioned to adaptive flexible grid networks with dynamic connectivity will drive further investment in fiber infrastructure, including flexible grid CDCF-ROADMs. If the business case proves viable, we expect strong demand for MxN WSS modules and flexible grid ROADMs in 2019 and beyond. IHS Markit forecasts that 50% of the 170 Pb/s of new capacity will use 400G+ transceivers by 2022. Initial deployments are expected on high capacity routes where service providers and network operators will have the opportunity to evaluate the performance and cost effectiveness of these solutions.

NEMs and service providers are developing network automation and monitoring and control solutions, which are needed to manage increased network complexity. The pace of network transition and the density of ROADM nodes will depend on answers provided from the initial deployments and the effectiveness of the first generation of adaptive network software solutions.

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## To Learn More

Join us for "**Next-gen ROADM networks for 400G and beyond**"
a free webinar presented by IHS Markit, Fujitsu, Huawei, and Lumentum:

**LIVE:** February 21, 2019
8:00 AM PT, 11:00 AM ET, 15:00 UTC

**REPLAY:** Watch on-demand any time

Both the live event and replay can be accessed at: https://bit.ly/2tn2Wfq

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