WHITE PAPER

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# FLEXING NEXT GENERATION OPTICAL MUSCLES

*A Perspective on Flexi-rate Innovation and True 400G*

From high-capacity data center connectivity to LTE-enabled mobility, the foundation of our modern communications infrastructure continues to be built upon optical networking innovation. This innovation is driven not only by the exponential growth in traffic and resulting demand for increased fiber optic transmission speeds, but also by demand for an entirely new level of optical layer flexibility to accommodate the dynamic characteristics of today's bandwidth-intensive cloud-centric services and applications. The advent of coherent technology and advanced modulation techniques have paved the way for the integration of flexible rate transponders into next generation optical networking systems that deliver the optimal transmission reach, performance, and agility based on real-time service requirements. This white paper explores the technology trends in the evolution of high-speed optical transmission including versatile and programmable 400G.

## FLEXI-RATE MODULATION: GOING BEYOND 100G

While coherent 100G has offered a successful and uncontested solution in terrestrial and submarine networks since its introduction, the evolution beyond 100G to date has not been quite so clear with a variety of proposed interfaces trying to address 100G+.

100G connectivity in core networks began with the 4QAM (4-ary quadrature amplitude modulation) scheme, where binary electrical signals are converted to a format with four constellation points, which is transmitted in two orthogonal polarizations. The applied coherent detection technology is capable of detecting arbitrary multi-level schemes, which can be used to transmit more bits per time slot. With increasing market demand for higher rate transmissions, concepts were borrowed from an age-old wireless communications playbook and turned toward more flexible modulation formats to increase capacity throughput, similar to a WiFi modem in every household.

## FLEXI-RATE OPTICAL INTERFACES

Next generation optical line interfaces will use a variety of modulation schemes to achieve a smooth trade-off between demand for connectivity distance and channel capacity. Extending the existing feature set of 4QAM for terrestrial networks or 2QAM for submarine transmissions, future modems will contain 8QAM and 16QAM to more optimally address metro, regional, and nationwide networks. The reach of 8QAM is roughly 50% of 4QAM, whereas 16QAM clocks in at nearly 25% of 4QAM. Combined with new and improved forward error correction (FEC), the appeal of such modulation schemes is undeniable in nationwide networks.

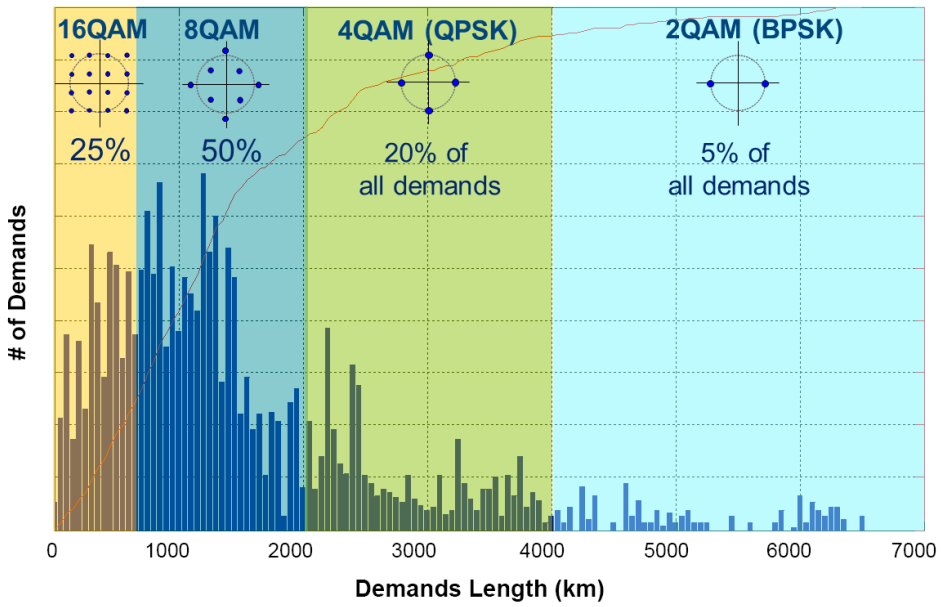


*Figure 1: Example of a flexi-rate interface with multiple modulation schemes on a cumulative distribution of demands in core networks with Raman amplification**

*Absolute distances of each scheme depend on fiber and amplifier type, span losses, channel counts, network type, end of life margins, and error correction limits.

Figure 1 shows the demand reach distribution in a variety of long-haul and ultra-long haul networks. The majority of the links are covered by 8QAM, the undisputed workhorse, while it decreases the interface costs per bit by 33% vs. 4QAM. In fact, advances in digital signal processing (DSP) improve the reach of 8QAM to the level of first generation 100G 4QAM solutions, giving network operators an effective tool to increase fiber capacity by 50% for most of the demands.

## TERABIT OPTICAL TRANSMISSION – FROM COHERENT 100G TO 1T AND BEYOND

Recent advances in DWDM transmission technologies have brought a new level of flexibility, efficiency, and scalability to optical networks. These advances give service providers and data center operators the tools to more easily provision and manage end-to-end high-speed transmission capacity, from flexi-rate-enabled coherent 100G/200G/400G to terabit-level super-channels and beyond. Key technology building blocks in next-generation optical transmission include:

**Flexi-rate modulation**
Software-programmable flexi-rate technology enables network operators to dynamically switch between modulation formats depending on the physical infrastructure and application requirements (e.g., metro core, regional, LH, and ULH), and thereby transmit higher bit rates, including super-channel bit rates, while achieving the optimal balance between data throughput, transmission reach, and spectral efficiency.

**Flexi-grid**
The flexible assignment of optical bandwidth to channels enabled by flexi-grid technology leads to higher bit rate transmission by maximizing flexibility in channel spacing. Flexi-grid also introduces the concept of virtualization of physical layer resources. With flexi-grid, operators can dynamically adapt the wavelength grid to the needs of multi-haul transport applications, as well as increase spectral efficiency and thus increase the overall capacity of the system.

**Super-channels**
Super-channels refer to the combination of multiple coherent optical sub-carriers to achieve a unified channel of higher data rate transmission through multiplexing the constituent channels. High bit rate super-channels, which can be provisioned and routed across end-to-end optical networks as single entities, increase spectral efficiencies and provide a means of boosting line side transmission rates to terabit levels.

Used individually or in combination, these building-block technologies are paving the way for terabit scale optical networks with an unprecedented level of flexibility and efficiency.

## FLEXI-RATE AND FLEXI-GRID

Understanding the relationship between flexible modulation capabilities and flexi-grid technologies is important to achieving the true benefits of next generation optical networking systems which employ both techniques to enhance network scalability, flexibility, and efficiency. Flexi-grid technology, which has been around for some time, has been viewed as a requirement but often without a clear benefit. While the industry has lately seen a variety of announcements related to 400G, 1T, or 2T demonstrations, these implementations have been nothing more than a bundling of independent client and line interfaces into a spectral container typically referred to as a "super-channel". However, a joint design of flexi-rate and flexi-grid technology can unfold crucial benefits that go beyond the claim of a line side capacity demonstration.

> True flexi-rate functionality with software-programmable 4QAM (QPSK), 8QAM, and 16QAM flexibility, in combination with flexi-grid, enables the simplified provisioning of dynamic reach- and/or capacity-optimized super-channels.

Figure 2 illustrates distinct flexi-grid use cases in a meshed network. In the first scenario, flexi-grid is used to increase the spectral efficiency of the fiber by spacing the different wavelengths closer together. As a result, the spectral efficiency can be increased by 33%, delaying a potential deployment of a new overlay network by 1-2 years depending on the capacity growth. However, operators would likely want to see a cost savings earlier than years down the road. In a second use case, flexi-grid is used to form a super-channel with identical spectral efficiency but higher reach, which is enabled by a better coding scheme that utilizes more spectrum. Thus, operators can achieve significant beginning of life (BOL) cost savings using flexi-grid to omit regenerators in network designs.

It is important to understand that claims about flexi-grid capabilities do not necessarily result in the same benefits for network operators. Flexi-grid benefits are determined by the type of scenario – from enabling a simple point-to-point transmission of bundled carriers to extending capabilities in meshed

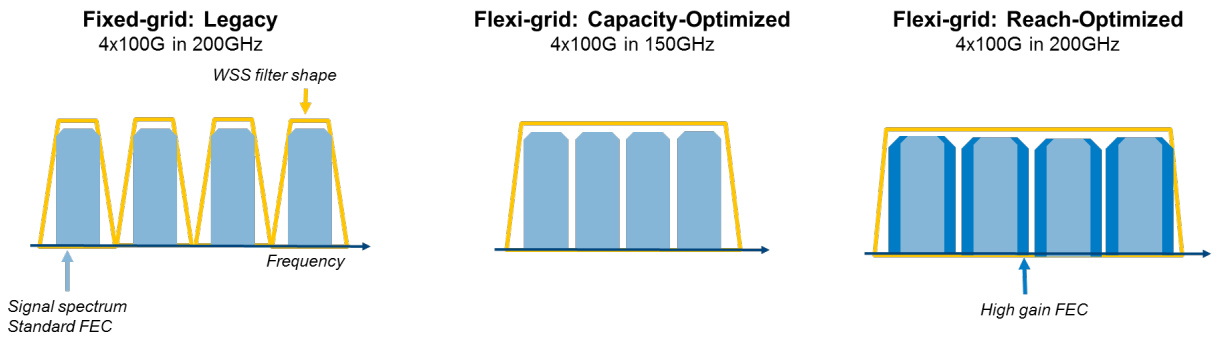


*Figure 2: Example of flexi-grid and super-channel use cases*

| MODULATION | C-BAND FIBER CAPACITY |
|---|---|
| 2QAM (BPSK) | <6.4Tb/s |
| 4QAM (QPSK) | <12.8Tb/s |
| 8QAM | <19.2Tb/s |
| 16QAM | <25.6Tb/s |
| 64QAM | <38.4Tb/s |

The capacity per fiber can be significantly increased using a combination of higher order modulation, advanced amplifiers schemes, or C+L band transmission. L-band interface designs enable a growing data center interconnect demand in point-to-point links.

networks with independent routing of super-channels that have a varying number of sub-carriers. Managing the complexity of super-channels in meshed networks, while providing customers with a solution that is scalable and operationally simple, is the key challenge in the evolution of optical backbone networks. How do we simply evolve and grow meshed networks in light of almost limitless possibilities of flexi-rate and flexi-grid technologies? The answer will differentiate a simple technology adapter from a true solution provider.

### BENEFITS OF FLEXI-RATE INTERFACES

**Cost-optimized coverage** from intra-city DCI connections to ultra-long haul demands
**Single sparing blade** for all modulation schemes - one part number with full functionality
**Dynamic margin allocation** starting with the highest spectral efficiency BOL
**Restoration of high-priority traffic** using higher reach modulation schemes

## ABOUT CORIANT CLOUDWAVE™ OPTICS

Coriant CloudWave™ Optics is a versatile suite of software-programmable photonic layer capabilities that bring a new level of flexibility, efficiency, and scalability to next-generation optical transmission networks. A key enabler of the Coriant Dynamic Optical Cloud™ Solution, Coriant CloudWave™ Optics features best-in-class photonics, software programmable line side modulation, tunable spectral allocation, and channel frequency flexibility. These carrier-grade capabilities significantly enhance service flexibility and network scalability in metro, regional, LH, ULH, and Data Center Interconnect (DCI) transport applications.

## ABOUT CORIANT

Coriant delivers innovative, dynamic networking solutions for a fast-changing business world. The Coriant portfolio of SDN-enabled, edge-to-core transport solutions enables network operators to reduce operational complexity, improve utilization of multi-layer network resources, and create new revenue opportunities. Coriant serves leading network operators around the world, including mobile and fixed line service providers, content providers, data center operators, cable MSOs, large enterprises, government agencies, financial institutions, and utility companies. With a distinguished heritage of technology innovation and service excellence, forged by over 35 years of experience and expertise in Tier 1 carrier networks, Coriant is helping its global customers maximize the value of their network infrastructure as demand for bandwidth explodes and the communications needs of businesses and consumers continue to evolve. Learn more at www.coriant.com.