APPLICATION NOTE

# Groove (GX) Series 600G Generation Coherent

*Minimize cost per bit, power, and footprint; transport 400 GbE; and maximize fiber capacity*

Multiple coherent technology evolutions have driven down cost per bit, power consumption, and footprint while increasing spectral efficiency and fiber capacity. The first evolution was from 40 Gb/s to 100 Gb/s, followed by the transition from hard-decision forward error correction (FEC) to soft-decision FEC. Then came a 200G generation with flexible rate interfaces enabled by higher-order modulation, followed by a 400G generation with higher baud rates and additional modulations that enabled the first 400 Gb/s wavelengths. More recently, a 600G generation has emerged with even higher baud rates, enabling both 600 Gb/s wavelengths and significant improvements in terms of cost per bit, transport for 400 GbE services, power consumption, fiber capacity, and footprint. This technology in the form of the CHM2T sled for the Groove (GX) G30 is now shipping at volume, ready for immediate testing, integration, and deployment.

## REDUCE YOUR COST PER BIT WITH HIGHER BAUD RATES AND SUPERIOR CAPACITY-REACH

The primary driver for cost per bit is how much bandwidth you can get out of an interface for a given reach requirement. More bandwidth equals fewer interfaces equals lower cost per bit. Higher baud rates enable higher-bandwidth wavelengths with a minimal reduction in reach. 600G generation coherent increases the baud rate to up to 72 Gbaud, compared to between 45 and 64 Gbaud with 400G generation and around 30 Gbaud with earlier generations. This has enabled Infinera's GX G30 CHM2T sled to demonstrate 600 Gb/s at 250 km, while 600 Gb/s distances of up to 150+ km, 400 Gb/s distances of up to 2,000+ km, 300 Gb/s distances of up to 4,000+ km, and 200 Gb/s distances of up to 7,500+ km can also be achieved with the additional margin typically required for real network deployments. This compares with published 400G generation claims of 200 to 300 km for 400 Gb/s, 700 to 1,500 km for 300 Gb/s, and 2,500 to 4,000 km for 200 Gb/s, as shown in Table 1. The bars in Figure 1 compare the interface capacities of the 56 Gbaud version of 400G generation and 600G generation over a wide range of distances, with the approximate 600G cost per bit savings represented by the curve and ranging from 27% to 40%. For a typical network, cost per bit savings of around 33% can be achieved, with even higher savings available compared to the 45 Gbaud version of 400G generation coherent.

| | 600G Generation (Infinera GX G30 CHM2T) | 400G Generation (Published Data) | |
|---|---|---|---|
| **Max Baud Rate** | 72 Gbaud | 56 Gbaud | 45 Gbaud |
| **400 Gb/s** | 2,000+ km | 300 km (15%) | 200 km (10%) |
| **300 Gb/s** | 4,000+ km | 1,500 km (37.5%) | 700 km (17.5%) |
| **200 Gb/s** | 7,500+ km | 4,000 km (53.3%) | 2,500 km (33.3%) |

*Table 1: Reach: 600G generation vs. 400G generation*

## BENEFITS OF GX 600G GENERATION COHERENT

- **Reduce** cost per bit by 33% or more by boosting wavelength capacity-reach with baud rates of up to 72 Gbaud
- **Transport** 400 GbE client services cost-effectively over a wide range of distances
- **Cut** power consumption by more than 50% with a dual-wavelength 16-nm DSP enabling 0.2 W per Gb/s
- **Maximize** fiber capacity with high-order modulation that enables up to 38.4 Tb/s per fiber pair
- **Minimize** footprint with up to 2.4 Tb/s coherent capacity in 1RU, 1056 x 100 GbE in a rack, and options to mix a 600G generation muxponder with OLS or 10G aggregation in the same 1RU GX G30
- **Deploy** 600G generation technology in 300-mm-deep racks with the GX G25

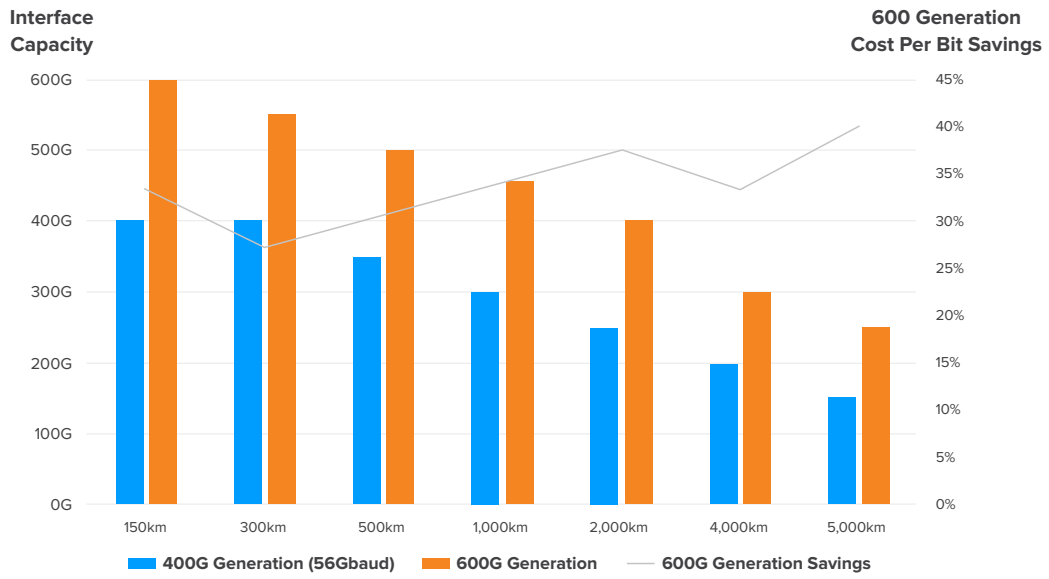


*Figure 1: Cost per bit savings: 600G generation vs. 56 Gbaud version of 400G generation*

## DELIVER COST-EFFECTIVE TRANSPORT FOR 400 GBE SERVICES

Compact pluggable form factors such as QSFP-DD are making 400 GbE an attractive option for routers, with network operators seeing increasing demand for 400 GbE transport both as an “internal” service interconnecting their own routers and as an “external” service for wholesale and enterprise customers. Transporting 400 GbE over a single wavelength is far more cost-effective than multi-wavelength solutions such as 400 GbE over two 200 Gb/s wavelengths. The CHM2T can transport 400 GbE over a single wavelength at distances of over 2,000 km. Its tuneable baud rate also enables the CHM2T to deliver 400 GbE services over a single 400 Gb/s wavelength in 50 GHz fixed grid point-to-point DWDM infrastructure leveraging PM-64QAM modulation and a 42 Gbaud baud rate. For longer reach requirements, the CHM2T can also leverage its dual-wavelength DSP to deliver 400 GbE over two 200 Gb/s wavelengths at distances up to 7,500+ km, as shown in Figure 2.

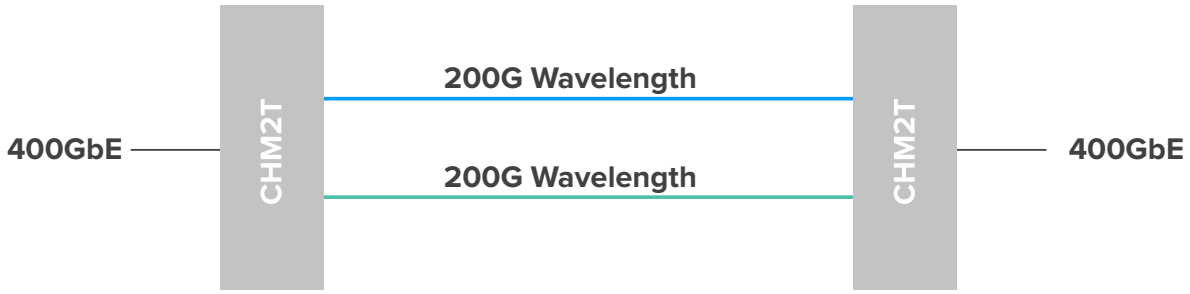


*Figure 2: 400 GbE to 7,500+ km leveraging dual-wavelength DSP*

And for shorter distances, its dual-wavelength DSP enables the CHM2T to transport three 400 GbE services over two 600 Gb/s wavelengths, as shown in Figure 3, providing a 33% cost savings compared to using a 400 Gb/s wavelength for each 400 GbE.

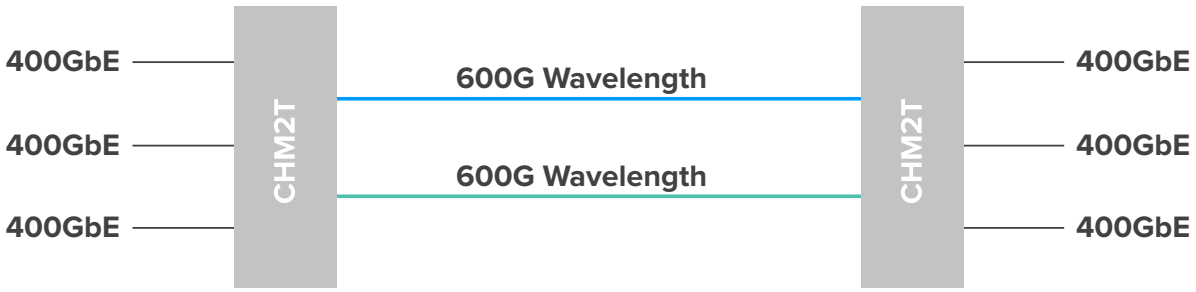


*Figure 3: 3 x 400 GbE over 2 x 600G wavelengths – 33% cost savings*

## REDUCE POWER CONSUMPTION BY MORE THAN 50 PERCENT

Power consumption is a big deal, both in terms of saving the planet and the energy bill component of operational costs. One factor that has a significant influence on coherent power consumption is the CMOS process node used for the coherent ASIC/DSP. The smaller the process node is, the lower the power consumption.

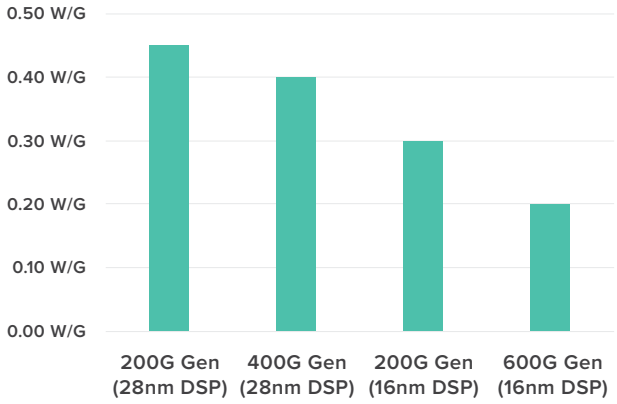


*Figure 4: Power consumption comparison*

As shown in Figure 4, the lowest power consumption for products based on 200G generation coherent with a 28-nm DSP is around 0.45 W per Gb/s. The lowest power consumption for products based on 400G generation coherent using a 28-nm DSP is 0.4 W per Gb/s, though minimum power consumption of 0.74 W per Gb/s was the best that could be achieved with other 400G generation products. Lower-power 200G generation coherent based on 16-nm DSPs, used in products such as the CHM1G sled for the GX G30 and the 400G flexponder for the Infinera XTM, emerged in 2017 and enabled less than 0.3 W per Gb/s. The GX G30 with 600G generation technology, also based on 16-nm ASIC/DSP technology, has even lower power consumption of around 0.20 W per Gb/s, enabling power consumption to be reduced by at least 50% compared to 28-nm DSP-based 200G and 400G.

## MAXIMIZE FIBER CAPACITY WITH HIGHER-ORDER AND HYBRID MODULATION

Increasing spectral efficiency can avoid the substantial costs and delays associated with acquiring and lighting additional fibers. 600 Gb/s technology leverages higher-order modulation to deliver up to 38.4 Tb/s per fiber pair with PM-64QAM or 32 Tb/s with PM-32QAM. Furthermore, hybrid modulation provides the ability to mix different QAM symbols in the time domain, enabling increased spectral efficiency over a wide range of reach requirements, as shown in Figure 5. For example, hybrid 32QAM/64QAM that alternates 32QAM symbols and 64QAM symbols delivers modulation with a capacity and spectral efficiency that is the average of the two individual modulations. As the input signal quality to the FEC block is the average of the lower- and higher-order modulation, the reach will get near to the average of the two individual modulations.

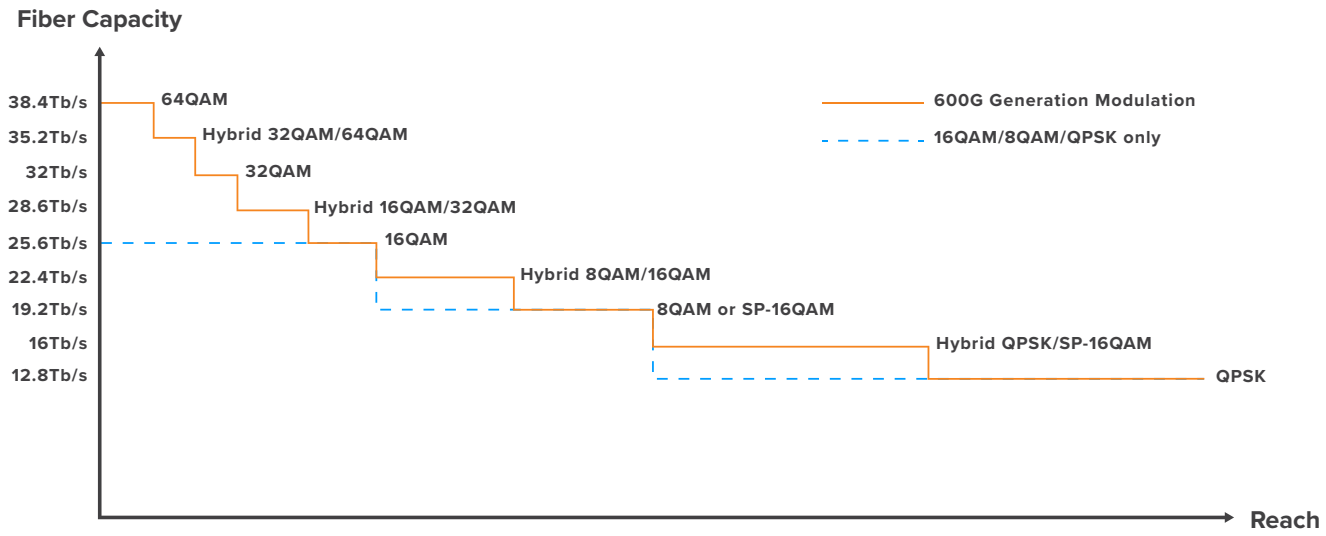


*Figure 5: Increased fiber capacity/spectral efficiency*

## INDUSTRY-LEADING 600G TECHNOLOGY WITH 72 GBAUD AND ADVANCED MODULATION

The 600G generation coherent technology in the CHM2T leverages a dual-wavelength 16-nm DSP and high-performance indium phosphide modulators to deliver two wavelengths from 100 Gb/s to 600 Gb/s in 50 Gb/s increments. It supports a tuneable baud rate from 28 to 72 Gbaud, with higher baud rates enabling maximum capacity-reach while lower baud rates enable more optimal use of available spectrum and provide support for scenarios including 50 GHz fixed grid point to-point and ROADM networks where the baud rate/ spectrum of the signal is constrained. Soft-decision FEC options include 27% with a 12.3 dB net coding gain for maximum reach, and a 15% overhead option for reduced spectrum.


*Figure 6: GX 600G technology*

In addition to the previously discussed PM-QPSK/8QAM/16QAM/32QAM/64QAM and time-domain hybrid modulation, the GX 600G technology supports geometric shaping, which optimizes the location of the constellation points for improved noise tolerance, as well as set partitioning for PM-QPSK and PM-16QAM, which provides high-performance alternatives to PM-BPSK and PM-8QAM respectively by only using a subset of the constellation points. Additional features include more robust non-differential encoding, high state-of-polarization rotation (i.e., lightning) tolerance, spectral shaping including WSS filtering mitigation, non-linear compensation, sub-50 millisecond line protection including coherent colorless add/drop, and comprehensive performance monitoring.

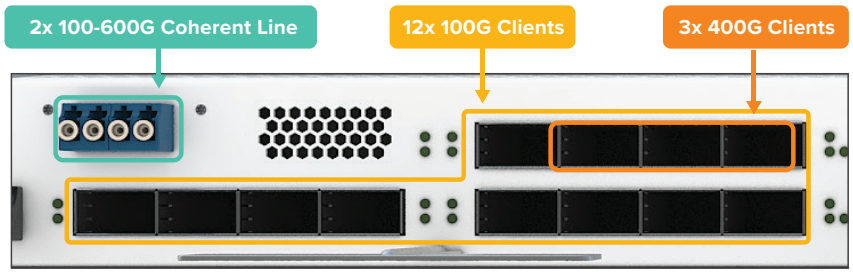


*Figure 7: The 600G generation CHM2T sled for the GX G30*

## MINIMIZE FOOTPRINT WITH THE COMPACT AND FLEXIBLE GX G30

600G generation coherent can also save valuable rack space. With two CHM2T sleds in the GX G30, as shown in Figure 8, it delivers 2.4 Tb/s of coherent line interfaces (4 x 600 Gb/s) and 2.4 Tb/s of client interface capacity (24 x 100 GbE/OTU4 QSFP28, 6 x 400 GbE QSFP-DD) in 1RU. In a 44RU rack, the GX G30 can deliver transport for over 1,056 x 100 GbE interfaces with 105.6 Tb/s of coherent interface capacity. The line interfaces can be used for both muxponder and 3R OEO regeneration functions. Wire-speed Layer 1 (ODU4) AES-256 encryption is also supported with no reduction in capacity.

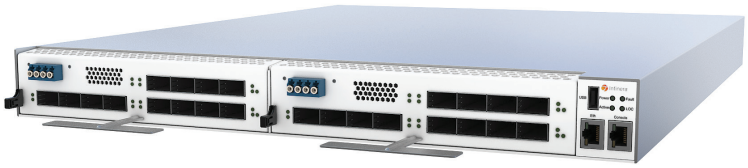

*Figure 8: GX G30 with two CHM2T sleds*

The GX G30 provides the option to put a single a CHM2T in one half of the 1RU G30 shelf and open line system functions, such as amplifiers, filters, OTDR, optical channel monitoring, optical protection switching, or even a ROADM, in the other half. Alternatively, the other half of the GX G30 can be used for a 10G aggregation sled with 20 x 10G SFP+ interfaces and two 100G QSFP28 interfaces, as shown in Figure 9.

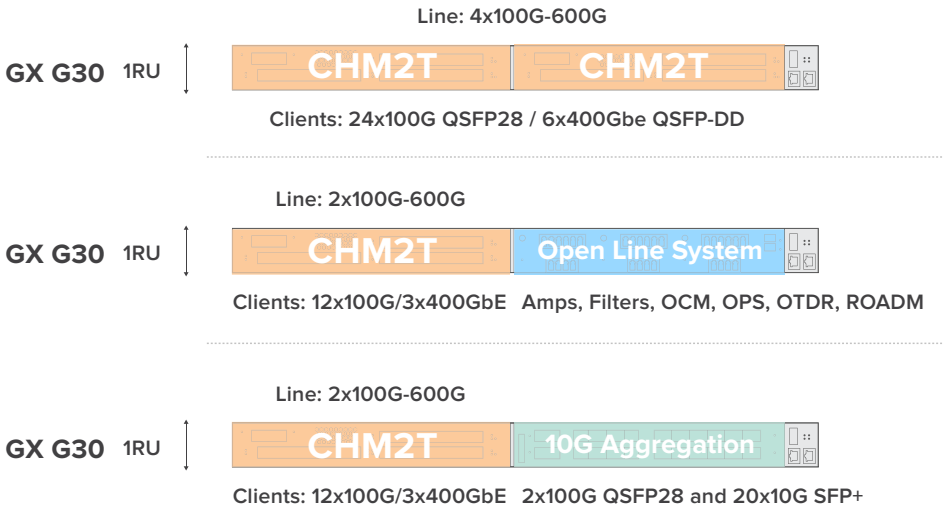


*Figure 9: GX G30 deployment examples*

## DEPLOY IN 300-MM-DEEP RACKS WITH GX G25

While the 1RU GX G30 was designed for 600-mm-deep racks, the GX G25 is an ETSI-compliant form factor with a height of 100 mm (4SU) that is optimized for deployment in 300-mm-deep racks. It provides the same functionality as a single CHM2T sled with 1.2 Tb/s of coherent line interfaces (2 x 100G-600G) and 1.2 Tb/s of client interface capacity (12 x 100 GbE/OTU4 QSFP28, 3 x 400 GbE QSFP-DD).

*Figure 10: GX G25 enables 600G in 300-mm-deep racks*

## READY FOR IMMEDIATE TESTING, INTEGRATION, AND DEPLOYMENT

Faced with strong traffic growth and pressure on revenues and margins, many network operators cannot wait and need to improve their network economics now. 600G generation coherent delivers significant economic benefits in terms of cost per bit, transport for 400 GbE services, power consumption, fiber capacity and footprint. Furthermore, the 600G generation CHM2T sled for the GX G30 has been shipping since 2019 and has been available at volume since the beginning of 2020, ready for immediate testing, integration, and deployment.



Infinera