Go Small to Go Big with 400 Gig Line Side Pluggables

By:

We're living in an era of data explosion. Data center IP traffic is estimated to grow to 20.6 zettabytes by the end of 2021. As the demand for bandwidth continues to grow, operators must augment their network capacity, which in turn requires more space, power, and capital.

To help offset the cost increases from this growth, data center customers and operators have leveraged the benefits of smaller size and lower power utilization from small form factor pluggables to efficiently grow their campus networks. The expanded application of ZR and ZR+ technology to provide high-density pluggable coherent optics has increased data speeds while decreasing size.

A leap forward

A decade ago, a five-by-seven-inch equipment card that plugged into a large equipment chassis that used to take up five to ten rack units supported 40G. Today 400G can be achieved on a plugin that is 3.5 inches long and less than an inch wide in a single rack unit (1.75-inch-high) "pizza box." Small form-factor pluggables (SFP) that plug into these ultra-compact "pizza boxes" have been used for several years now. The latest increase in capacity performance from quad small form-factor pluggable dual density (QSFP_DD) modules provides the smallest form factor with the highest port density per rack. More importantly, the power consumption of these coherent pluggables ranges from 80 to 90 percent efficiency gains when compared with traditional deployments. Moreover, the coherent pluggables are expected to yield an overall cost reduction calculated from 50 to 75 percent.

The coherent pluggables are a direct result of a multi-generation aggressive challenge to achieve as much vertical integration as possible. Driving more silicon into these products reduces the packaging and increases the level of optical and DWDM integration. The 3D stacking of silicon allows a single optical-electrical component that has DSP, the photonic integrated circuit, and drivers all in a single

device. The pluggables showcase the latest in 7 nm manufacturing technology in addition to tight silicon photonics vertical integration. Integrating as many sub-sections as possible (DSP, TIA, modulator, SERDES, framer, and so on) into a single chip results in a smaller and more power-efficient coherent transceiver capable of being fitted in a CFP2 package with little to no performance trade-offs relative to its larger SLED-based counterparts. But does this integration and miniaturization have a detrimental impact on performance?

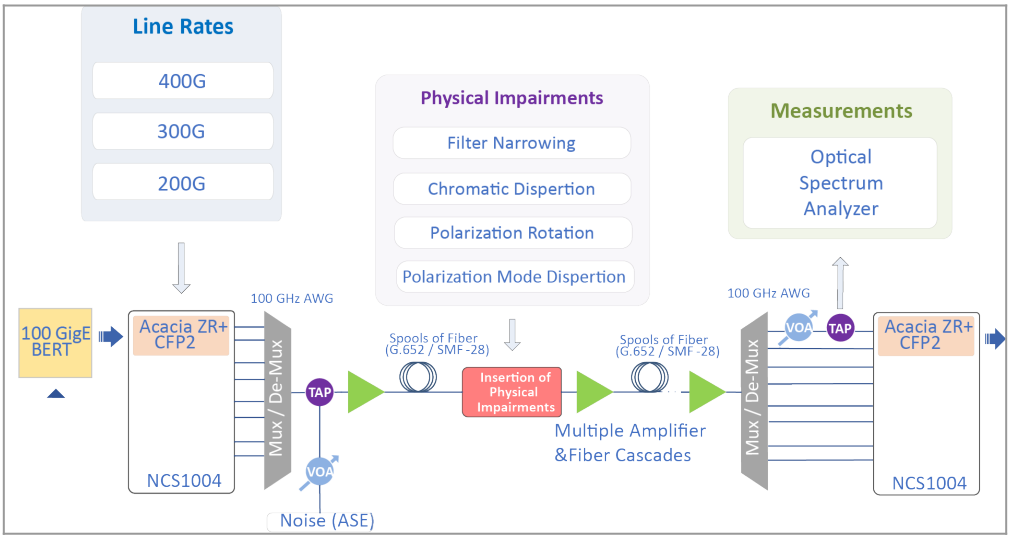

Figure 1: The CFP2 characterization and testing methodology
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Long-haul network operators confront some of the same challenges that data center operators face, and applying these coherent pluggables to long-haul network applications could help alleviate similar space, heat, power, and cost challenges. But does this technology, which has been so beneficial for campus deployments, also work over long distances? Spoiler alert: yes. Windstream conducted trials to prove the validity of expanding the use of 400G line side pluggable technology for long-distance network applications.

The field trials

The standard of “ZR+” that was used for the field trials was OpenROADM. This standard represents a superset of all other interoperable standards, allowing for the highest flexibility but also providing instant power-level compatibility with the rest of Windstream’s ROADM-based network. For 400G line side settings, the OpenROADM standard calls for a 16 QAM modulation scheme with a symbol rate of 63 GBaud and uses the OFEC standard for soft decision forward error correction, which is set to a coding gain of 15 percent. This lower coding gain also provides a side benefit of delivering a lower latency relative to the 20 to 25+ percent FEC coding gains commonplace in the industry today.

The Windstream technology R&D team also concentrated on the digital signal processor (DSP) of the CFP2 module, homing in on its true capability to cope with physical layer impairments such as noise, CD, PMD, filter narrowing and non-linear effects. The team performed full coherent transceiver characterization, subjecting the 400G ZR+ transceiver to the same rigorous tests used for the higher performance SLED-based transceivers.

The testing and characterization were performed on Acacia’s pre-general availability CFP2 module plugged into Cisco NCS 1004s, and the results were very encouraging. The team was excited to move this out of the lab environment to truly test pre-GA performance with its size and power efficiency. In the field, we could confirm if our core understanding and testing of these modules would translate to

successful transmission and validate if Windstream's disaggregation strategy truly supports multi-vendor, multi-technology interoperation. We tested performance with variables from a real-world environment, including various vintages of fiber types, uneven span distances and coexistence with various other types and generations of coherent transceivers.

Field validation

The first field trial attempt did not generate the successful results we were looking for. This was attributed to a higher percentage of the fiber spans being NZ-DSF fiber type than was originally expected. As we were approaching the upper limit for noise tolerance, the additional sectors of NZ-DSF fiber introduced higher-than-expected overall span non-linear impairments, which manifest as additional noise. The combined ASE noise and noise due to non-linearities was just enough to close down any window of operation. This exercise, although disappointing, provided us with good real-world data, which we then used to sharpen up our networking modelling and make some additional adjustments to both the CFP2 and Cisco's NCS1004 host platform.

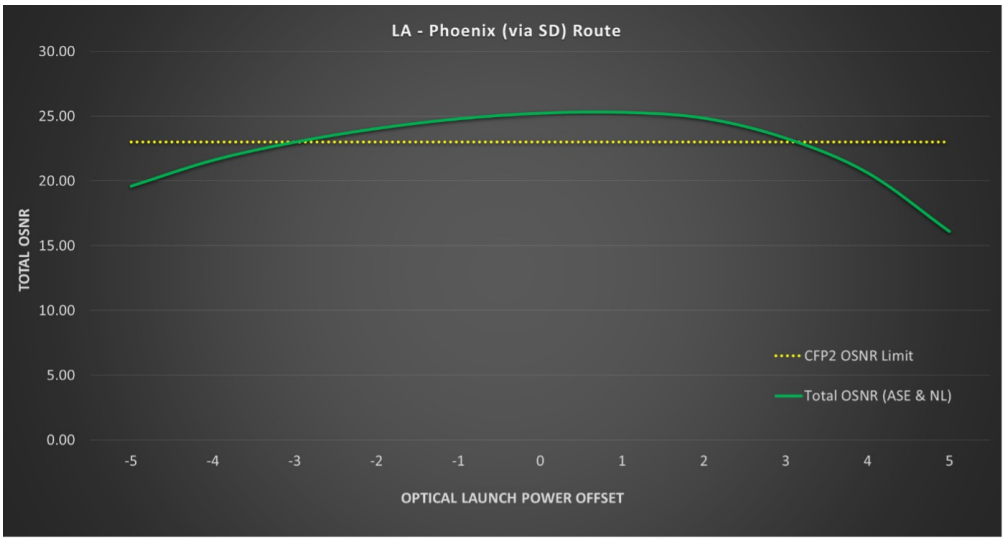

Figure 2: Testing results, second trial
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The second field trial was an overwhelming success. Windstream Wholesale set an industry-leading benchmark of 400G using Acacia's 400G ZR+ Coherent Pluggables over a live long-haul network. The successful trial deployed 400 gigabits per second single-wavelength transmission over 1,027 kilometers across Windstream's fiber network between Phoenix and Los Angeles. Additionally, Windstream set another industry record by looping back the signal to achieve 300G transmission over 2,054 kilometers using the Acacia pluggables. The test results showed that there was enough additional margin for actual production use. In other words, 400G line side pluggable technology was viable for long-haul network applications.

Figure 2 illustrates the testing results of the successful second field trial. It can be seen that the window for operation (area above CFP2 limit line) is large enough to meet the production network's operation margin.

Jimmy Yu, vice president of Dell'Oro Group's Optical Transport research concurred. "Windstream's live network trial demonstrates the real performance of 400G pluggable outside of a controlled environment. This is a significant development in the industry, paving the way for network operators to operationalize the benefits of pluggable optics in the network." Onboarding low-power, high-density pluggable coherent optics into long-haul network platforms will offer a viable alternative to traditional

chassis/sled-based modules. At a fraction of the size, along with a drastic reduction in power consumption when compared to the current networking opto-electronics, these small 400G line side pluggables will significantly expand deployment models from current-day edge to future metro-regional and long-haul applications

Bill Gartner, senior vice president of optics and optical at Cisco commented that, “Windstream is one of the first network providers to leverage the full capability of 400G pluggable optics in data center interconnect to metro and long-haul applications. With the emergence of 400G pluggable DWDM optics, we will be able to simplify network design and operations.”

Acacia partnered with Windstream for the 400 ZR+ trials because, according to Tom Williams, VP at Acacia, its leadership “could see a strong technical collaboration between the two companies and that close working relationship would allow everyone involved to push the upper limits, achieve an important industry milestone efficiently and in a quick timeframe. This level of collaboration and efficiency is something unique that we haven’t been able to do with anybody else… Windstream allowed us to do something that is really record-breaking in a timeframe that was impressive… This is the kind of thing we want with all our customer engagements. It’s important for the carriers to know directly what the technology is capable of but also, we need to foster relationships with carriers to provide valuable feedback into our future development efforts, so we know what carriers really need and we have that direct feedback.

“The thing that stood out to me is just the level of transparency with the engineering team at Windstream. It felt like a lean but focused team that can adapt and react quickly to issues. This mindset and ability helped to move things forward and get difficult things done. I don’t think a lot of organizations are set up to do that. The team was able to move quickly, to make sound, technical decisions and say, ‘yes we’re going to do this, and let’s go execute on it.’”

What’s next?

Windstream’s ICON (Intelligent Converged Optical Network) architectural strategy is to leverage the advantages of a disaggregated network architecture with multi-vendor open line system scalability and alien wave support. This disaggregation strategy allows us to ride the technology curve, so we don’t have to overbuild line systems every time there’s a stair-step advance in technology. Being able to use independent components in a multilayer architecture was foundational to incorporating the Acacia Coherent Pluggable modules (quickly and easily) into the production network.

According to a recent forecast by Dell'Oro Group, demand for 400G pluggable modules will materialize by late 2021. The company forecasts that the cumulative optical transport market revenue will be nearly $85 billion for the years that include 2021 through 2025. While 100 Gbps coherent wavelengths contributed most of the revenue before, Dell’Oro analysts forecast the largest contributor will be 200 Gbps in the near-term period, and then 400 Gbps in the outer forecast period. In all, 200+ Gbps wavelength shipments are forecasted to grow at a five-year CAGR of 30 percent.

Windstream continues as an early adopter of coherent optical technologies to drive efficient growth and scale of our network and services for our customers. The pluggables allow for different types of deployments that weren’t possible with previous generations of optical technologies. We expect to begin deploying ZR+ coherent pluggable modules in the second half of 2021, a technology that has applicability in as many as 80 percent of our existing links. We also see how 400 Gbps pluggable coherent optics technology will converge with Layer 3 routing as a natural use case for the technology as well as future 800G deployments.

The optical performance results of the trial mark a milestone in optical networking by demonstrating that high-speed optical transmissions, such as 400G and 300G, can be deployed over long distance, high-performance fiber networks using compact pluggable modules.

It’s remarkable that something so small can make such a big impact with efficiencies in power, space, and overall cost.