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Vendors align technologies to 40G strategies

by Stephen Hardy

The advent of 40-Gbit/sec pipes in carrier networks has finally arrived, with Verizon's announcement at OFC/NFOEC in March of a 40-Gbit/sec link between New York and Washington the most recent milestone. The March conference and exhibition also highlighted both the requirement for new modulation formats to support the jump in transmission rate and the variety of options available to equipment vendors to meet this need. The startups that have laid the groundwork for 40-Gbit/sec deployment appear headed toward a consensus on the formats that will underpin their second-generation offerings. Meanwhile, transponder suppliers have positioned themselves to offer alternatives to the line-card-sized products now in the field. And each of these moves is being made with an eye toward the leap to 100-Gbit/sec transmission.

When choosing how to modulate a signal, equipment suppliers and network architects must consider how to encode the signal and which part or parts of the wave they'll use to decode that signal at the receiver. For most of optical communication's history, the industry has chosen to keep things as simple (and therefore as inexpensive) as possible; that has meant using non-return-to-zero (NRZ) encoding and subsequently decoding using the signal's amplitude (a modulation format called "on-off keying" or OOK).

NRZ OOK works fine as long as the receiver can derive the signal's amplitude well enough to decode the 1s and 0s properly. However, the dispersion effects encountered when traveling down a fiber's core can severely distort the signal and thus make decoding more difficult; these effects, particularly chromatic dispersion and polarization-mode dispersion (PMD), become significantly more acute as bit rate and distance increase. Some carriers encountered such obstacles when they attempted to move from 2.5 to 10 Gbits/sec. Just about every carrier will face these problems at 40 Gbits/sec-not to mention 100 Gbits/sec in the future.

For this reason, engineers began to experiment with and then offer for deployment alternative modulation formats that either relied on return-to-zero (RZ, which makes it easier to pick out 1s and 0s from a degraded signal) encoding or began to incorporate phase information-and frequently both-to reliably receive voice, video, and data signals at 40 Gbits/sec.

Two paths converge

While a number of companies sought to develop and promote 40-Gbit/sec subsystems during the latter stages of the bubble era, only two have survived with their commitment intact: StrataLight Communications (www.stratalight.com) and Mintera Corp. (www.mintera.com). The two companies have pegged their fortunes on their ability to transmit 40-Gbit/sec wavelengths over networks architected to carry 10 Gbits/sec. And they've used modulation schemes other than NRZ OOK to do it.

They didn't use the same alternative, however. Mintera opted for carrier-suppressed RZ (CS-RZ), a format that features a reduction in the peak energy, which enables more optical power to be pumped into the fiber. According to Niall Robinson, vice president of product marketing at Mintera, the format does a good job of enabling the transmission of 40-Gbit/sec wavelengths at 100-GHz spacing for comparatively longer distances than other alternatives.

Robinson asserts that includes optical duobinary (see "Duobinary Modulation for Optical Systems," *Lightwave*, June 2006, page 11, for a description of how this format works). StrataLight opted to use a variant of this, called phase-shaped binary transport (PSBT), for its offerings. Not surprisingly, StrataLight vice president of sales and marketing Dave Sykes claims PSBT is the superior format at 100-GHz spacing, particularly when it comes to running a signal through a series of cascaded ROADMs. Sykes says the company's line cards can support a reach of 800 km. The company also has developed a PMD compensator to further enhance the benefits PSBT and other formats can provide.

Both companies claim several OEM customers and carrier deployments. Mintera doesn't list its customers, although it has promoted demonstrations with Ciena and claims to have products shipping to customers in North America and EMEA. It also has reported on field trials with Verizon and, previously, MCI. StrataLight lists Siemens and Ciena as "partners" on its web site and has reported field trials and experiments with AT&T and Sprint Nextel.

Robinson and Sykes report that carriers now want the ability to transmit 40-Gbit/sec wavelengths at 50-GHz spacing, too tight for either CS-RZ or PSBT to handle. Thus, each company needed a new modulation format. Despite starting from different points, the competing firms arrived at the same conclusion: variants of differential phase-shift keying (DPSK). As described by Robinson, a DPSK receiver contains a phase discriminator/demodulator that splits incoming light into two "arms," one of which has a longer path length. The longer path length creates a time delay, equal to a bit period, in comparison to the other arm. The receiver then recombines the two arms. If the phases of the arms match, you get a 1; if the two arms remain out of phase, you get a 0.

The problem with DPSK, however, is that the pulses are too wide to fit in a 50-GHz wavelength grid. To narrow the pulse, Mintera shortened the arm delay to less than a bit period, which enabled its new format, which it has dubbed "partial DPSK," to operate at 50-GHz spacing while maintaining the reach and performance OEMs and carriers expect.

Sykes says that StrataLight has decided not to reveal details of its version of DPSK. Although the company presented a paper at OFC/NFOEC ("DPSK Receiver Design-Optical Filtering Considerations," OThK1) that Sykes conceded would give one the impression that the company was doing something similar to Mintera, he asserts StrataLight's approach is different. The end result is more or less the same, however, in terms of performance, including a reach as great as 1,600 km without regeneration.

Both companies are sampling DPSK products; Mintera reported on a trial of the technology in concert with ECI Telecom and Capella Photonics at OFC/NFOEC ("Demonstration of 1000km 43Gb/s RZ-DPSK Transmission through a 50GHz Channel Spaced WSS," JWA92). DPSK can work with both NRZ and RZ encoding. Sykes touts NRZ as superior to RZ in terms of resistance to XBM crosstalk and second-order PMD; Robinson praises the RZ version for its "excellent OSNR performance," reach, and intrinsic tolerance to PMD and optical nonlinearities. He suggests that Mintera can offer both versions, depending upon customer requirements.

Competition coming

StrataLight and Mintera compete head-to-head in supplying line cards that can plug into existing 10-Gbit/sec DWDM equipment. While Sykes and Robinson don't appear to expect additional competition at the line card level, they are very much aware of the advent of 40-Gbit/sec transponders that would enable their current OEM customers to build line cards - themselves.

Several announcements at OFC/NFOEC outlined the competitive landscape. Kailight (whose acquisition by Optium was announced at the start of the show) announced the introduction of a variety of 40-Gbit/sec transponders, including devices based on NRZ (for 2-km applications) and DPSK, which join an existing product based on optical duobinary modulation. Optical duobinary technology, which several companies have used to anchor transponders for dispersion-challenged 10-Gbit/sec applications, now is part of Finisar's (www.finisar.com) arsenal thanks to its purchase of Kodeos. Civcom (www.civcom.com) also possesses optical duobinary capabilities.

Also at the show, Yokogawa (www.yokogawa.com) and Fujitsu (www.fujitsu.com) exhibited sample results, including a transponder, of their jointly developed technology based on another modulation format, differential quadrature phase-shift keying (DQPSK). DQPSK also is compatible with 50-GHz spacing and is touted for its tolerance to PMD. (For a brief primer on DQPSK, see "Research Indicates Next Steps for 40 Gbits/sec," *Lightwave*, December 2006, page 13.) Researchers at NTT reported on a DQPSK field trial using technology that "will be employed in a commercial 43-Gbit/sec 40-wavelength DWDM system being developed to deploy in NTT's terrestrial network by 2007/Q1," according to the paper's authors ("Field Transmission by Using a Commercially-Ready 43 Gbit/s DWDM System Employing RZ-DQPSK Transponder in High PMD Installed Fiber," JThA45).

Robinson and Sykes acknowledge that DQPSK represents the leading alternative to modified DPSK for 50-GHz applications. However, they believe that DQPSK's potential performance advantages will be more than offset by a predicted higher price tag.

"The problem with DQPSK is that it's very complicated and it's very expensive," says Robinson. "You double up an awful lot of the components on the transmit path and you double up an awful lot of components on the receive path. We estimate that DQPSK is somewhere in the region of 1.6× more expensive than just a straightforward NRZ transmitter-compared to, say, PDPSK, which is 1.1× an NRZ transmitter."

Sykes believes DQPSK could prove even more expensive versus a standard NRZ OOK transceiver. "DPSK, as it turns out, is probably the preferred technology for Tier 1s in the US because of that additional reach that you get and the ability to still work over 50-GHz filters," he asserts.

One source at a systems OEM lends credence to Sykes's opinion. "For the best performance over long-haul links without a lot of optical filtering, the DPSK technology looks to have the advantage, just because it provides an OSNR benefit over the other technologies," offers Paul Morkel, director of carrier WDM business management, ADVA Optical Networking (www.advaoptical.com). "Where that is not such a major factor but you're looking to go through multiple ROADMs or OADM filters in the metro region, the spectral efficiency of the DPSK format is not ideal. That's where optical duobinary looks to have a benefit."

As for DQPSK, "I think the cost is a challenge," he says. "If you look at a DQPSK receiver in particular, there are several lithium niobate Mach-Zehnder components. It's four high-speed detectors, generally. And I think it's going to be a challenge to approach optical duobinary from a cost perspective-even if you might be able to approach it from a performance perspective."

The question of 100G

Every company in the high-speed arena has set its sights on 100 Gbits/sec-even though a lot of standards work remains to be completed before developers of transmission equipment have an idea of what kind of signals they'll need to transmit. That hasn't stopped vendors involved in the space from speculating that a new generation of modulation formats may be necessary.

Several potential 100G modulation options were the subject of papers at OFC/NFOEC. These schemes included various versions of quadrature amplitude modulation, orthogonal frequency-division multiplexing, and even variants to DPSK with exotic names like "8-ary

DPSK." Most 100G-capable technologies remain in the experimental stage, but at least one-coherent detection-was highlighted on the show floor at OFC/NFOEC by Discovery Semiconductor (www.chipsat.com) in the form of its Kitty Hawk rack-mounted coherent receiver system.

Coherent receivers are able to extract signal information from more phases of a communication signal than standard detectors, said personnel at the Discovery Semiconductor booth. This capability matches well with phase-based modulation formats. (For more on coherent receiver technology, see "Coherent Receivers Enable Next-Generation Transport," *Lightwave*, January 2006, page 1.)

The company currently positions the Kitty Hawk receiver system as a 10-Gbit/sec instrumentation platform. However, Abhay Joshi, president of Discovery Semiconductor, revealed that his company plans to repackage the technology into a format that could be deployed more easily within networks.

Meanwhile, several companies are looking at coherent receiver technology for 100-Gbit/sec transmission. In a post-deadline paper at OFC/NFOEC, researchers at CoreOptics (www.coreoptics.com), Siemens Networks/PSE (www.siemens.com), and the University of Eindhoven reported that they had combined coherent technology with DQPSK to transmit 10 wavelengths spaced at 50 GHz over 2,375 km at 111 Gbits/sec.

"When you get to 100G, I think in general the industry believes that you can't just do a serial implementation like we're doing with DPSK and duobinary. You're going to have to do something more where your baud rate is less than your bit rate," says Sykes. "Coherent detection might be also of some benefit as far as getting your OSNR up and doing something in the digital domain versus the optical domain."

While 100G remains a hot topic of conversation, the 40-Gbit/sec players firmly believe their current offerings will achieve market traction. "There are a lot of people talking that they're going to skip 40 gig and go to 100 gig. I think that's just talk, honestly," Sykes concludes. "If they could skip 40 gig and go to 100 gig, they will-and so would everybody. But if their traffic demands that they deploy 40 gig, they will. So I think what you'll see is that some of the people who are saying that they're going to skip 40 gig will actually do [40-gig] deployments later this year because of just the raw bandwidth growth out there."

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Author(s) :   Stephen Hardy