



# TECHNICAL COLUMNS

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## ADVANCED PHY

By RON HRANAC

In the latter part of 2002, I penned two columns discussing the then-new Data Over Cable Service Interface Specification (DOCSIS) 2.0, its support for greater per-channel upstream data throughput, two new multiple access technologies-advanced time division multiple access (A-TDMA) and synchronous code division multiple access (S-CDMA)-and something called advanced PHY. (See the October and November 2002 issues of Communications Technology: [www.ct-magazine.com/archives/ct/1002/1002\\_broadband.html](http://www.ct-magazine.com/archives/ct/1002/1002_broadband.html) and [www.ct-magazine.com/archives/ct/1102/1102\\_broadband.html](http://www.ct-magazine.com/archives/ct/1102/1102_broadband.html).)

### 2.0 changes

DOCSIS 2.0 added 64-QAM (quadrature amplitude modulation) to the upstream-plus 8-QAM and 32-QAM-and optionally supports 128-QAM trellis coded modulation (TCM) encoded modulations for S-CDMA channels. DOCSIS 2.0 increased the maximum upstream raw data rate to 30.72 Mbps, using 64-QAM or 128-QAM TCM digitally modulated signals. This tripling of the maximum per-channel throughput available in DOCSIS 1.0 and 1.1 requires more robust upstream data transmission. Otherwise, it's going to be pretty challenging to make a high order modulation like 64-QAM work reliably in the often hostile upstream RF environment.

Advanced PHY, or advanced physical layer, is a suite of cable modem termination system (CMTS) and cable modem upstream performance enhancements that enables higher orders of modulation and increased throughput. The advanced PHY umbrella includes better adaptive equalization, burst acquisition, and forward error correction (FEC) compared to DOCSIS 1.0 and 1.1. Also included are programmable byte interleaving and ingress cancellation. As well, the upstream burst receiver silicon used in today's CMTSs incorporates a digital receiver, allowing lower implementation margin.

### Implementation margin

What the heck is implementation margin, you ask?

Let's say the theoretical carrier-to-noise ratio (C/N) to achieve  $1.0 \times 10^{-6}$  bit error rate (BER) with a given type of upstream data signal is 21 dB. In practice, a CMTS with an analog upstream receiver comprising a tuner-local oscillator, mixer, various filters and gain stages-and first generation burst receiver silicon might actually need, say, 25 dB C/N to get  $1.0 \times 10^{-6}$  BER. In this example, the implementation margin is 4 dB. That is, the upstream data signal's real-world C/N performance needs to be 4 dB better than theory.

The upstream technology used in the current crop of CMTSs is based on digital burst receivers, which digitize the entire upstream spectrum before processing. This allows much of the analog tuner circuitry to be eliminated, reducing implementation margin to perhaps within 0.5 dB of theory, depending on CMTS design. Continuing the previous example, with only 0.5 dB of implementation margin, the required C/N to get  $1.0 \times 10^{-6}$  BER is 21.5 dB. That's 3.5 dB of additional C/N headroom compared to a CMTS with 4 dB of implementation margin!



Ingress cancellation is a nifty advanced PHY technology that digitally removes in-channel ingress. It won't do anything about out-of-channel ingress, but if a carrier pops up in the middle of the upstream data signal, ingress cancellation can remove the interfering carrier without causing packet loss. In fact, ingress cancellation works its magic such that it can remove one or more carriers that are higher in amplitude than the data signal! Ingress cancellation eventually will break if the in-channel ingress gets too high, of course, but I've seen it work when the ingress was several decibels greater than the data signal's average power.

### Improved FEC

What about advanced PHY's improved FEC? DOCSIS 1.0 and 1.1 provide for the correction of up to 10 errored bytes per Reed Solomon block ( $T = 10$ ) with no interleaving, while DOCSIS 2.0's advanced PHY allows correction of up to 16 bytes per Reed Solomon block ( $T = 16$ ) with programmable interleaving. These enhancements help some with certain types of impulse noise and other gremlins.

Carrier and timing lock, power estimates, equalizer training, and constellation phase lock are all done simultaneously using advanced PHY's improved burst acquisition. This allows shorter preambles and reduces implementation loss.

DOCSIS 2.0's adaptive equalization supports a symbol ( $T$ )-spaced adaptive equalizer with 24 taps. This accommodates operation in the presence of more severe microreflections, in-channel frequency response nasties (amplitude ripple and tilt) and group delay. Here, too, impairments can be so severe that even 24-tap adaptive equalization isn't enough. But data transmission robustness is much better compared to the 8-tap adaptive equalization in DOCSIS 1.1 modems and no adaptive equalization in most DOCSIS 1.0 modems.

Some of the advanced PHY features benefit existing DOCSIS 1.0 and 1.1 modems, since the performance improvements—ingress cancellation, for example—take place in the CMTS and are modem agnostic. That means it's not necessary to replace all of the older modems with brand new DOCSIS 2.0 versions to reap some of the benefits of advanced PHY, although 2.0 modems clearly will give the biggest bang for the buck.

### It works

Advanced PHY-equipped CMTSs have been available for the past couple of years, and the technology has clearly proven itself. When combined with a DOCSIS-compliant network, advanced PHY really will let you do 64-QAM in the upstream coax plant. Interestingly, in many cases where advanced PHY technology has been deployed, it hasn't been to take advantage of DOCSIS 2.0's increased upstream data throughput. Rather, it's used to improve existing upstream data transmission reliability and maybe even make the move from quadrature phase shift keying (QPSK) to 16-QAM a little easier to manage.

That's OK, but advanced PHY shouldn't be an excuse for not keeping the reverse path clean. Some operators have told me that advanced PHY lets them get away with less upstream maintenance. I shudder when I hear that. Yikes!

Remember, DOCSIS 2.0's assumed upstream RF channel transmission characteristics are largely the same as those for DOCSIS 1.0 and 1.1. You still need to maintain 25 dB or better carrier-to-junk and meet or exceed the other assumed upstream RF parameters. This is especially true for voice over Internet protocol (VoIP) deployments, where advanced PHY can provide an extra measure of headroom and reliability in an already properly maintained network.

Does it work? One engineer told me about an eye-opening, but unintentional experience with advanced PHY. It seems that about the same time his company deployed an advanced PHY-equipped CMTS, they inadvertently switched their modems to 16-QAM. Things ran problem-free for six months, when someone finally discovered that the modems weren't transmitting QPSK, as had been assumed.

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