Originally appeared in the **August 2010** issue of *Communications Technology*.

TOTAL POWER AND CHANNEL BONDING: A FOLLOW-UP LESSON

By RON HRANAC

My April 2010 column provided an overview of the concept of total power and how it applies to the world of DOCSIS 3.0 channel bonding. In particular, I looked at the impact on upstream per-channel maximum RF levels as the number of transmitted channels is increased beyond one.

But what happens when a cable modem is not transmitting at its maximum RF output power? It would be an understatement to suggest that things get a little interesting. Indeed, if you thought understanding total power causes confusion, grab yourself a strong cup of coffee and dig into the DOCSIS 3.0 Physical Layer Specification. If that’s a bit much, read on.

To help decipher the goings-on in DOCSIS 3.0 upstream transmission, I turned to two industry friends and colleagues — Broadcom’s Roger Fish and Cisco’s De Fu Li — both of whom contributed to the following: When a 3.0 cable modem performs initial ranging, it uses a single upstream channel. If that modem ranges at its maximum RF output power, Pmax, then the per-channel level for time division multiple access (TDMA) channels will follow the Pmax – 10*log10(N) relationship discussed in April (I’m leaving synchronous code division multiple access out of this—that’s a topic for another day).

As the number of transmitted upstream channels increases, the per-channel maximum power decreases to maintain the same approximate total power that existed when just one channel was transmitted. (A quick note: DOCSIS 3.0 sets per-channel power for three-channel operation the same as four-channel operation.)

When the modem initially ranges, it might do so at a level that corresponds to Pmax for the single channel case — say, +57 dBmV for 64-QAM. In other words, that modem is transmitting at the maximum level! If three more channels were to be added to that modem’s transmit channel set, the Pmax for the original channel would be reduced to +51dBmV.

For DOCSIS 3.0 modems operating in multiple transmit channel mode, the cable modem termination system (CMTS) must establish during registration a dynamic range window (DRW) which defines a 12 dB range of permissible transmit levels for each of the channels. The top of the DRW cannot be higher than the maximum allowable level for the channel so, prior to registration, the CMTS would have to adjust the original channel’s transmit level to +51 dBmV or lower. If the transmit level had not been reduced prior to registration, the modem would reject registration and reinitialize the media access control (MAC).

If the modem initially ranges at a level that is less than Pmax for, say, a four-channel case, there’s a good chance that the RF power level will not be changed during registration. Whatever the upstream per-channel transmit level is, each DOCSIS 3.0 modem encodes its transmit level information — also called its target power — in the source service access point (SSAP) field of the ranging request (RNG-REQ) messages. That way, the CMTS always knows what level the cable modem is using for each transmitted channel. Before getting too far along, this is a good time to introduce what the DOCSIS 3.0 spec calls constellation gain (Gconst) and Phi, where Phi = Pmax – Gconst. Let’s look at constellation gain first.

The DOCSIS Spec

The DOCSIS 3.0 spec states that supported upstream constellations are defined on a common integer grid (which further defines each QAM symbol with 5-bit values on each I and Q axis), and that relative symbol amplitudes must be maintained across all constellations. There is some variation in average constellation energy among different constellation types, and that difference expressed in decibels relative to 64-QAM's average constellation energy is called "constellation gain."

"What happens when a cable modem doesn't transmit at maximum RF output power? Things get more than a little interesting."
Thus, DOCSIS upstream 64-QAM is the constellation against which other constellations like quadrature phase shift keying (QPSK) or 16-QAM are compared when discussing Gconst. Constellation gain is -1.18 dB for QPSK0, +2.34 dB for QPSK1 (yes, DOCSIS supports two flavors of QPSK), -0.21 dB for 8-QAM and 16-QAM, 0 dB for 32-QAM and 64-QAM, and +0.05 dB for 128-QAM.

All of this means that if a modem is using a constellation other than 32-QAM or 64-QAM, the actual transmit power will be slightly different than the target power reported to the CMTS. For example, if a modem transmits 64-QAM at +45 dBmV, it will report to the CMTS +45 dBmV as its target power. If this same modem were using 16-QAM, the actual transmit power would be +45 dBmV + (-0.21 dB) = +44.79 dBmV; the target power reported to the CMTS would remain +45 dBmV.

DOCSIS 3.0 includes the concept of the previously mentioned DRW. The CMTS sets the top of the 12 dB DRW during the modem registration process, and it must ensure that all modems' upstream transmit levels fall within the DRW. Additionally, for noise and spurious performance, the CMTS must ensure that at least one of the transmitted channels is within 3 dB of the top of the window! The CMTS can adjust the DRW with the ranging response (RNG-RSP) message.

Using Phi

The DRW is defined in terms of Phi and is specified as some number of decibels relative to Phi, which establishes the top of the window. In the case of four 64-QAM channels, Phi is +51 dBmV per channel. If the dynamic range value sent to a given modem during registration was 6, then all of the modem's transmit levels would have to be in the range of +33 to +45 dBmV.

If one of the channels was QPSK, the Phi for that channel would be +56.18 dBmV (in the four-channel case), and the top of the DRW for that channel — using the previous example — would be +56.18 dBmV – 6 = +50.18 dBmV. So while there is a single DRW value sent to the modem, the allowable transmit levels are determined by Phifor each channel.

One more point of interest: If a channel's profile is changed from, say, QPSK to 64-QAM via an upstream channel descriptor (UCD) change, the cable modem's reported power on the channel will be changed immediately by the difference in Phi for the QPSK profile to the 64-QAM profile. If a modem was transmitting at +50.18 dBmV on a QPSK channel and then the profile was changed to 64-QAM, the modem would report its transmit level as +45 dBmV and still be exactly at the top of the dynamic range window, again based on the previous example.

We know that when a modem is transmitting a single channel at Pmax the per-channel power will have to be decreased as more channels are added. But what happens when a modem's single channel power for 64-QAM is, say, +45 dBmV, and then that modem is switched to four-channel mode?

Because +45 dBmV is lower than Phifor all the channels in the group of four, the CMTS will keep the original channel at +45 dBmV and will add three more at +45 dBmV each for a total power of +51 dBmV. The modem will start the first RNG-REQ of the newly added channels at the power level as commanded in the multipart registration response transmit channel configuration type/length/value (REG-RSP-MP TCC TLV) MAC message. Typically, that power level is same as the reference channel transmit power level. Subsequent periodic ranging on each channel will be adjusted independently as long as the transmit power remains within the DRW.

Whew!

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