Society of Cable Telecommunications Engineers

Rocky Mountain Chapter

TheSpectrum

Newsletter of the Rocky Mountain Chapter
http://www.scte-rockymountain.org/
January / February 2013

New Members on the Board

New members and fresh ideas are what make our chapter one of the best in the country. If you know colleagues or those who might benefit by being a member of the Rocky Mountain Chapter, please encourage them to register on our website or contact one of our current members.

This Issue's featured articles:

Ron Hranac: What is OFDM?

Jorge Salinger: DOCSIS 3.1: Why, What and When

Upcoming Seminars

Date	Location	Subject	Speaker
February 7th 2013	Comcast on Iliff	Working in an All-Digital World	Ron Hranac

8:30 AM to 9 AM – on-site registration and check in

9:00 AM to noon – seminar presentation

REGISTER AT: http://www.scte.org/devams/cgi-bin/eventsdll.dll/EventInfo?sessionaltcd=CHAP_RMTN_020713

FREE for SCTE members – $10 for non-members.

"Understanding Real-World MER": Measuring MER isn't quite as straightforward as one might think. A series of lab and field tests in which multiple instruments were used to measure MER under carefully controlled conditions yielded some surprising results. Guidelines will be provided to achieve more consistent MER measurement results, as well as ways to maximize MER in an operating cable network.

"The nuts and bolts of BER": What is BER, and just what do those numbers on QAM analyzers and other instruments mean? What types of impairments can affect BER, and what can be done to improve BER performance?

“Another Look at Signal leakage: The Need to Monitor at Low and High Frequencies”: When your aeronautical band leakage detector shows a tight plant, is it really? During the past couple of years numerous cases of signal leakage-related interference to LTE services have occurred. Is there any correlation between leakage field strengths at low and high frequencies? How can one see what is happening at higher frequencies?

“Digital Proofs or Not?”: The FCC for several years has in §76.640 required that digital signals in cable networks with upper frequency limits of 750 MHz or higher must comply with technical parameters in SCTE-40. Despite being on the books since about 2005, many cable operators are unaware of this requirement. This presentation covers the applicable technical parameters, and provides some tips on how to measure them.

Visit our SCTE Rocky Mountain chapter website for further information at:

http://www.scte-rockymountain.org

Mark your calendars and get ready for Symposium 2013!

The Rocky Mountain Chapter is planning for an even bigger and better symposium this year:

ANNUAL CABLE-TEC SYMPOSIUM and GOLF OUTING

June19th and 20th, 2013

Inverness Hotel and Golf Club

200 Inverness Drive West

Englewood, CO 80112

The Rocky Mountain SCTE Symposium has sold out for the last 12 years. We want to thank all of our vendors and members for your past participation in our events. Very soon you will see additional e-mails and correspondence regarding registrations and participation with the Golf and Symposium events.

Once again the Symposium Planning Team's goal is to provide an environment benefiting both our membership and vendor community. We are continuing to build upon our successes and provide a better Symposium each year for all participants. We plan to increase space allowing for additional vendors and offer technical presentations on a variety of topics, including more that are IP focused.

We continue to encourage all exhibit participants to consider showing state of the art live technical demonstrations of their products. Technical demonstrations of technologies will enable participants the ability to truly observe the latest vendor products and what they can provide for today's cable systems.

Technical Forum

By Ron Hranac, Technical Leader, Cisco Systems

Ron Hranac is technical leader at Cisco Systems and senior technology editor for *Communications Technology* magazine. Contact him at rhranac@aol.com. The following article originally appeared in the November 2012 issue of *Communications Technology*. Reprinted with permission of the author.

What is OFDM?

What An unusual collaboration of authors produced what is likely the longest NCTA paper ever at The Cable Show 2012, held in Boston in May 2012. The paper, comprising some 185 pages, was written and presented by industry competitors John Chapman of Cisco, Mike

Emmendorfer of Arris, and Rob Howald of Motorola, plus Shaul Shulman of Intel. What topic could possibly bring this diverse group of technologists together? The paper's title, "Mission is Possible: An Evolutionary Approach to Gigabit-Class DOCSIS" tells it all. The authors describe what could serve as the foundation for a future generation of Data Over Cable Service Interface Specification (DOCSIS) technology, supporting data rates as high as 5 to 10 gigabits per second (Gbps) in the downstream and 1 to 2 Gbps in the upstream.

The paper discusses various possible new forward and return frequency splits as well as upper frequency limits that go beyond today's 1002 MHz. New physical layer (PHY) technology would have to play a major part in achieving the previously mentioned lofty data rates. The authors propose something called orthogonal frequency division multiplexing (OFDM) in the downstream, and its upstream counterpart orthogonal frequency division multiple access (OFDMA). Helping to make modulation orders as dense as 4096-QAM (quadrature amplitude modulation) work reliably is a more sophisticated forward error correction (FEC) known as low density parity check (LDPC). Quick side note: The concept of LDPC was introduced by Robert Gallager in his 1960 Ph.D. thesis, but because of encoder and decoder complexity wasn't practical to implement until relatively recently.

A closer look:

What the heck is OFDM? Grab a cup of coffee and follow along as I attempt to provide a 30,000 foot explanation. Cable networks have for decades used frequency division multiplexing (FDM) to allow the transmission of several RF signals through the same length of coaxial cable at the same time. Each RF signal is on a separate frequency, or more specifically, assigned to its own channel slot. National Television System Committee (NTSC) analog TV signals each occupy six megahertz of bandwidth, and each six megahertz-wide chunk of spectrum is a channel. For instance, what we call channel 2 occupies 54-60 MHz. Within each channel used for NTSC analog TV transmission, one will find an amplitude modulated (more specifically, vestigial sideband amplitude modulation or VSB-AM) visual carrier located 1.25 MHz above the lower channel edge, and a frequency modulated aural carrier 4.5 MHz above the visual carrier. A color subcarrier is located in between the visual and aural carriers, approximately 3.58 MHz above the visual carrier.

When the cable industry made the jump to digital transmission several years ago, the modulation of choice was QAM. Each downstream QAM signal – which is really a double-sideband, suppressed-carrier analog RF signal – occupies the same six megahertz of bandwidth as an analog TV signal. The current method of QAM transmission is known as single carrier QAM (SC-QAM). The latter is true even when DOCSIS 3.0 channel bonding is used. Each channel slot carries only one modulated carrier – a QAM signal – hence the SC-QAM moniker. The entire data payload transmitted in the channel modulates just that one QAM signal.

Now imagine transmitting a large number of individual very narrow bandwidth QAM signals – hundreds or even thousands – within a given channel. A six-megahertz-wide channel could, for example, contain up to 480 narrow QAM signals that are spaced only 12.5 kilohertz apart. Each of these narrow QAM signals, called a subcarrier, subchannel, or tone (I'll use subcarrier in the remainder of this article), carries a small percentage of the total payload at a very low data rate. The aggregate of all of the subcarriers' data rates comprises the total data payload. This variation of FDM is known as OFDM.

For improved spectral efficiency, the subcarriers actually overlap one another. This sounds counterintuitive, because one would be inclined to think that if signals overlap each other, interference will occur. With OFDM, the subcarriers are mathematically orthogonal to – that is, distinguishable from – one another, which takes care of the interference concern. "Orthogonal" in this case means the subcarriers are independent such that there is no interaction between them despite the overlap in frequency. The concept is analogous to having zero inter-symbol interference (ISI) in the time domain.

Orthogonality is achieved by spacing the subcarriers at the reciprocal of the symbol period (T), also called symbol duration time. This spacing results in the *sinc* (sin x/x) frequency response curves of the subcarriers lining up so that the peak of one subcarrier's response curve falls on the first nulls of the lower and upper adjacent subcarriers' response curves. Orthogonal subcarriers each have exactly an integer number of cycles in the interval T.

With OFDM, the concept of a six-megahertz-wide channel is no longer necessary. The previously mentioned NCTA paper includes an example of a downstream OFDM channel's bandwidth being as wide as 192 megahertz, supporting some 15,200 subcarriers spaced 12.5 kilohertz apart. Along with the subcarriers are pilot tones for synchronization and other purposes. There are guard bands at each end of the 192 megahertz-wide channel, resulting in a useful bandwidth of 190 megahertz. The useful symbol duration time is 80 microseconds (µs), the reciprocal of which is the previously noted subcarrier spacing: 1/0.000080 second = 12,500 hertz. The total symbol duration time is 84.13 µs, which includes what are called guard interval samples and symbol shaping samples. Assuming 4096-QAM on each subcarrier, the 192 megahertz-wide channel supports 2.11 Gbps without FEC. Other example channel bandwidths discussed in the NCTA paper are 96 megahertz and 48 megahertz. All of these particular OFDM channel bandwidths are multiples of six and eight megahertz, which allows easier coexistence with today's North American and European channel plans. If the spectrum doesn't have enough room for a full OFDM channel, some of the subcarriers can be nulled, which effectively turns them off.

OFDM can be used for multiple access – say, as OFDMA in the upstream – by assigning different subcarriers to different users. OFDM also can be used in combination with other multiple access schemes such as time division multiple access (TDMA). In this case, the full channel would be assigned to one user at a time, and the multiple access achieved via time division. When combined with TDMA, OFDM can deliver a very high peak data rate, which may be desirable for some applications.

Pros:

Advantages of OFDM include the ability to adapt to degraded channel conditions such as severe micro-reflections, without the need for complex adaptive equalization algorithms. One reason for the latter is that a very narrow bandwidth subcarrier typically experiences what is known as flat fading when micro-reflections affect channel response. This is in contrast to a SC-QAM signal that occupies the full channel bandwidth, and is susceptible to amplitude ripple (standing waves) across that full bandwidth. Each OFDM subcarrier "sees" just a tiny portion of the ripple, which for the most part affects only the amplitude of the narrow subcarrier. Compensating for what amounts to little more than an amplitude variation among subcarriers simplifies the fix.

Likewise, the composite OFDM signal is more robust than SC-QAM in the presence of interference. For example, a narrowband ingressor such as a pager transmitter's signal affects only a few subcarriers rather than taking out the full channel. Depending on the severity of the interference, FEC may be able to deal with it. Alternatively, the OFDM transmitter can simply disable a few subcarriers to avoid narrowband interference on problem frequencies.

Inter-symbol interference is generally less of a problem with OFDM because of the low data rate per subcarrier. As discussed earlier, the overlapping nature of OFDM's subcarrier transmission provides high spectral efficiency. If information about the channel's condition is sent back to the transmitter by the receiver, then adaptive modulation, FEC, and power allocation can be applied to all subcarriers, blocks of subcarriers, or even individual subcarriers. In other words, some subcarriers in the channel can use higher orders of modulation than other subcarriers, some subcarriers can have more aggressive FEC, and the power of individual subcarriers can be varied – all on an as-conditions-warrant basis.

Cons:

OFDM does have a few disadvantages: It is susceptible to frequency and clock errors, although the pilot carriers that accompany the subcarriers help to mitigate this by providing the receiver a means of synchronization. OFDM has a high peak-to-average power ratio (PAPR), but a spectrum full of SC-QAM signals does, too. While PAPR-reduction techniques are available for OFDM and OFDMA, they probably won't be necessary in a typical cable network. Some of OFDM's high spectral efficiency is reduced by the use of cyclic prefixes, which help to maintain subcarrier orthogonality.

Why bother?

You may be wondering why one would even consider a new PHY for a possible future version of DOCSIS. After all, SC-QAM works well, and channel bonding can be used to significantly increase data throughput. The good news is that OFDM isn't some new-fangled technology without a proven history. It is used in Wi-Fi networks, worldwide interoperability for microwave access (WiMAX), long term evolution (LTE), digital audio broadcasting (DAB), ultra wideband (UWB), and Europe's digital video broadcasting (DVB). A variation of ODFM also is used in asymmetric digital subscriber line (ADSL) and very high-speed digital subscriber line (VDSL).

The previously discussed advantages bring a lot of signal transmission flexibility to the table. When OFDM is combined with more powerful FEC such as LDPC, higher orders of modulation can be used – within the limits of the channel conditions, of course. Toss in new frequency splits and upper frequency limits, and all of this could help cable networks of the future support far higher data rates than are possible today with SC-QAM.

DOCSIS 3.1: Why, what and when.

By Jorge Salinger

Jorge Salinger is the Vice President of Access Architecture at Comcast and frequent contributor to Broadband Library (www.broadbandlibrary.com). The following article also appears in the recent issue.

Many of you may have heard about it, but might be wondering why do MSOs need it, what are the new features that are included in it, and when will it be coming. Here are brief answers to these key questions.

First, what is the motivation for a new version of DOCSIS? In a nutshell, the answer is to scale DOCSIS more efficiently, both from the cost and operations perspectives.

For quite some time MSOs, and all Internet service providers for that matter, have witnessed consistent growth in both the number of users and the amount of use per user of the Internet. This growth has amounted to 40-60% for the downstream and 10-20% for the upstream year-over-year for the last 15 years.

Of course, this is not news. So, what has changed?

While for the first 10 years or more it was possible to offer Internet services and support its growth with just one DOCSIS channel, services today require many more channels. This is because one DOCSIS channel provides almost 40 Mbps, which was well above the data rate of the services offered. However, the year-over-year growth drove service speeds well above the initial levels, to 20, 50 and even higher Mbps tiers today, which can't be supported by the single channel. MSOs then went to multiple DOCSIS channels, now reaching eight channels and soon requiring well beyond that.

To that end, the three key goals and features of DOCSIS 3.1 are:

1. Much more efficient use of spectrum, with a 50% improvement in capacity, resulting from: a. the use of more efficient forward error correction (i.e., replacing the older and less efficient Reed-Solomon approach for the more modern and far more efficient Low Density Parity Check, and b. addition of the higher-order modulations 1024 and 4096 QAM downstream and 256 and 1024 QAM upstream. These new modulation schemes provide 2 and 4 bits/hertz/second improvement in both upstream and downstream, while the use of the new forward error correction approach provides approximately 5 dB better RF performance. The end result is that MSOs will be able to transport 1 Gbps of DOCSIS capacity in about 120 MHz of spectrum while doing the same with the current DOCSIS approach using single-carrier QAM requires about 180 MHz of spectrum.
2. Cost reduction, mainly by leveraging technologies commonly used in other transmission media, such as the inclusion of Orthogonal Frequency Division Multiplexing, which is used extensively in wireless and wireline transmission media. Specifically, the addition of OFDM for the downstream and OFDMA for the upstream should enable MSOs to reduce costs while "packing" more bits in the HFC network more efficiently since these technologies likely result in a larger supplier ecosystem, increasing innovation and fueling competition.
3. Enable a simple and orderly transition strategy, both with respect to compatibility with previous generation CMTS and CM equipment while supporting an expanded spectrum capacity in the HFC network. Specifically, DOCSIS 3.1 cable modems will operate with DOCSIS 2.0 and 3.0 CMTS/CCAP equipment, enabling deployment of DOCSIS 3.1 CPE as soon as available. Similarly, DOCSIS 3.1 CCAPs will support DOCSIS 2.0 and 3.0 CPE allowing MSOs to upgrade headend equipment without having to change any of the existing CPE. And, both DOCSIS 3.1 CM and CMTS equipment will support the currently required

upstream and downstream spectrum, plus an expansion of the upstream to 85 MHz and beyond, and of the downstream up to 1.2 GHz.

Finally, when will DOCSIS 3.1 become available? Pretty quickly! In fact, DOCSIS 3.1 will become the fastest concept-to-product evolution of DOCSIS ever, with cable modems likely becoming available in 2014 and CCAP equipment as early as 2015.

As these technologies make their way from the drawing board to products I will explore them in greater detail in this column. In the meantime, feel free to reach out to me with any questions or comments at jorge_salinger@cable.comcast.com

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Supporting Associate Board Members 2012

Definition: Somebody who supports the functions of the local chapter by participating in meetings provides input that helps drive board decisions, vol and generally those who make an impact through their involvement. *Associate Board Members do not have the ability to vote.*

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